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SEFI Annual Conference 2017

Angra do Heroísmo, Terceira, Azores, Portugal
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PREFACE

This book contains a selection of papers accepted for presentation and discussion at the 45th annual conference of the European Society for Engineering Education - SEFI (Société Européenne pour la Formation des Ingénieurs) with the theme "Education Excellence for Sustainable Development" (SEFI 2017).

SEFI is the largest organisation of higher engineering education institutions in Europe, and through its membership it connects over one million students and 160.000 academic staff members in 48 countries. The mission of SEFI is to contribute to the development and improvement of engineering education, to reinforce the position of engineering professionals in society, to improve the dialogue between all the actors of engineering education (policy makers, academic leaders and staff members, students, employers and related partners).

This conference had the support of the Dassault Systemes, MarhWorks, Granta Material Intelligence, National Instruments, Project Management Institute, and Quanser. We also thanks to Governo dos Açores and Câmara Municipal de Angra do Heroísmo.

It took place at Angra do Heroísmo, Terceira Island, Azores, Portugal, during September 19–21, 2017.

The Program Committee of SEFI 2017 was comprised of a multidisciplinary group of experts and those who are intimately concerned with engineering education. They have had the responsibility for evaluating, in a 'blind review' process, the papers received for each of the main themes proposed for the conference: (A) Sustainability and Engineering Education; (B) University-Business cooperation; (C) Engineering Skills; (D) Quality Assurance and Accreditation; (E) Continuing Engineering Education and Lifelong Learning; (F) Open and Online Engineering Education; (G) Ethics in Engineering Education; (H) Curriculum Development; (I) Attractiveness of Engineering Education, (J) Physics and Engineering Education; (K) Mathematics and Engineering Education; (L) Engineering Education Research; and (M) Gender and Diversity.

SEFI 2017 also included workshop sessions taking place in parallel with the conference ones. Workshop sessions covered themes such as: WA1 - Increasing interactivity in lectures; WA2 - Addressing Attrition: Changing Students' Futures: A Problem-Based Workshop; WA3 - Attractiveness of Engineering Profession in Europe; WA4 - The Online Learning HUB: a tool for teachers to develop and run online courses; WA5 - Demonstration of the Engineering

Education Research to Practice Cycle Using a Cyberlearning System for Environmental Education and Research; WA6 - Interdisciplinary Project Management in Engineering Education; WA7 - Closing the gap: Cooperation between secondary schools and Engineering institutions; WA8 - Employability of Engineering Graduates; WA9 - Teach as you preach: Professionalizing teaching assistants in engineering science within the 2020 context; WA10 - Future development of teaching & learning in Engineering Education; and WA11 - Publishing in an engineering education research journal.

SEFI received about 300 contributions from many countries from the 5 continents around the world. The papers accepted for presentation and discussion at the Conference are published by this book and will be submitted for indexing by ISI, Scopus, DBLP and/or Google Scholar, among others.

We acknowledge all that contributed to the staging of SEFI 2017 (authors, committees, workshop organizers, and sponsors). We also would like to thank ISEP (Instituto Superior de Engenharia do Porto). We deeply appreciate their involvement and support that was crucial for the success of SEFI 2017.

Terceira Island
September 2017

João Rocha
José Carlos Quadrado
Jorge Bernardino

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Welcome to SEFI 2017

SEFI – European Society for Engineering Education

SEFI is the largest network of higher education institutions (HEIs) and educators in Europe. Created in 1973, SEFI is an international non-profit organization aiming to support, promote, and improve European higher engineering education, enhancing the status of both engineering education and engineering in society.

SEFI is an international forum composed of higher engineering education institutions, academic staff and teachers, students, related associations and companies present in 48 countries. Through its membership and network, SEFI reaches approximately 160.000 academics and 100.000 students. SEFI represents 4 decades of passion, dedication and high expertise in engineering education through actions undertaken according to its values: engagement and responsibility, respect of diversity and different cultures, institutional inclusiveness, multidisciplinary and openness, transparency, sustainability, creativity and professionalism. SEFI formulates ideas and positions engineering education issues, influences engineering education in Europe, acts as a link between its members and European and worldwide bodies, contributes to the recruitment of good students whilst always promoting an international dimension in engineering curricula.

Our activities: Annual conference, ad hoc seminars/workshops organized by our working groups and task forces, specific events and actions for deans in engineering such as the SEFI European Engineering Deans Council (EEDC), scientific publications (incl. European Journal of Engineering Education), European projects, position papers, cooperation with other major European and international bodies such as the European Commission, the UNESCO, the Council of Europe or the OECD. The cooperation with partner and sister organisations in Europe and in the world, is also one of our proud priorities.

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Welcome to Azores

Mother nature has created a land full of wonders at Azores. Surrounded by the blue immensity of the Atlantic Ocean, there are nine islands, nine small and wonderful worlds, ready to be explored. The beaches of warm white sand, the volcanic lakes and landscapes are some of the attractions of these place.

Azores are a land full of nature beauty, as well the opportunities. In nowadays, the islands are recognised not only about their speechless scenario, also about the sustainability potentialities. Here the tourism and development are welcome, but in harmony with the environment. More secrets? In these islands, magic is still alive through the friendliness of the inhabitants, and by the delicious food.

Terceira is the second most inhabited island of Azores. Ask us some places to visit and we will give you a never-ending list. At the World Heritage town of *Angra de Heroísmo* you'll find a place immersed in its history and monuments. However, if you feel more passionate about nature there are plenty of options, starting with the vestiges of the volcanic activities, such as the *Algar do Carvão*: a deepen volcanic chimney. The *Furnas do Enxofre* deserves a visit too, among other spectacular places.

At Terceira you'll find history, fun, urbanity, thermal waters, friendly people, outstanding beaches and nature beauty. At the same time, there are whales and dolphins that can be spotted, to the delight of visitors. Be ready to taste a land of unique flavours. Be ready to explore a deep blue sea, to climb the mountains and to expand your horizons.

Welcome to Azores, and enjoy a taste of pure freedom!

Welcome message from *Instituto Superior de Engenharia do Porto*

On behalf of *Instituto Superior de Engenharia do Porto* (ISEP) I am very pleased to welcome you to the 45th annual conference of SEFI – the European Society for Engineering Education. We are proud to host the conference and bring all experts, innovators and educators of engineering education together at Azores.

ISEP is a trademark of engineering education and innovation. Since 1852, we have been pioneering the training and the specialisation of engineers with a strong creative and entrepreneurial mind-set. Our academic community combines ambitious and dynamic people, who believe in the potential of innovation and technology to promote a sustainable development. Over 6500 students and 500 faculty & staff motivated by the promise that engineering moves the world and create opportunities.

The students of ISEP benefit from an excellent learning environment, a prestigious institution and quality infrastructures. By exploring EUR-ACE and CDIO international best practices, we are creating opportunities for students to connect to the real-world and develop academic projects with companies and research groups. In 2017, ISEP has been awarded with more international accreditations. So, we have now 13 EUR-ACE labels and the on M.Sc. with ABET certification in Portugal. These numbers show up the excellence of the engineering education at ISEP.

In fact, ISEP has a strong strategy for the internationalisation, and that's why we have over 100 international partnerships that allow students to enjoy ERASMUS+ mobility. At the same level, ISEP has international agreements with South American and Asian higher education institutions, also double-degree agreements with Brazilian and Spanish institutions and is open to receive people from whole world. We believe in a strong and multicultural community working together for enhancing and explore now the future of the engineering.

"Education Excellence for Sustainability" was chosen as theme of the conference because this matter is very important for all of us, despite where we came from. Furthermore, this theme has a paramount relevance for the Azores islands, because these place is a worldwide reference on the successful sustainability development aligned with the wonderful landscape values.

I hope that during the conference ideas will be exchanged and developed and new models of co-operation created. I wish you all a very pleasant stay in Terceira.

João Rocha,
ISEP President

Keynote speakers and presentations

Dr. Dorte Rich Jørgensen

Principal Sustainability Engineer, Technical Authority Sustainability
Atkins

Dr Jørgensen provides strategic leadership within Atkins and the British construction industry as a sustainability expert and has 28 years' experience of successfully embedding sustainability into the built environment and infrastructure projects on a range of cutting edge and award-winning project such as London 2012 and Chiswick Park, and within large businesses.

Dorte is the former Atkins Infrastructure teams' sustainability manager for the London 2012 Olympic and Paralympic Park project and was sponsored by the institution for eminent engineers, Royal Academy of Engineering, as a Visiting Professor of Innovation at Heriot-Watt University in 2011-2015. Dorte is a founding industry director for the Royal Academy of Engineering's Centre for Excellence in Sustainable Building Design, a network bringing together Britain's leading Universities, creating a network of cross-collaboration between academia, industry and professional institutions. As a thought leader and business professional, Dorte is focussed on driving better collaboration between industry, academia, and industry bodies whilst influencing policy, codes and diversity in Britain at a national level. Dorte is a public speaker and author.

Delivery Excellence for Sustainability on Mega Projects

Delivering sustainability excellence on multi-billion dollar projects requires an on-going learning and growth environment.

The blueprint behind the delivery of major programmes such as London 2012 - the greenest games ever which saw 11,000 project staff at peak - will be presented, with a focus on the outcomes of infrastructure design. In addition, observations will be shared on the knowledge and skills engineering professionals need to enable a sustainable construction industry which is playing its part in addressing climate change and bringing hope for the future.

Dr. Gary Bertoline

Dean & Distinguished Professor of Computer Graphics and Computer & Information Techology
Purdue University

Dr. Gary R. Bertoline is the Dean of the Purdue Polytechnic Institute and a Distinguished Professor of Computer Graphics Technology and Computer & Information Technology at Purdue University. He earned his PhD at The Ohio State University and was on the faculty in the College of Engineering for 3 years before coming to Purdue University in 1990. Gary served as founding Department Head of Computer Graphics Technology then led the creation of the Rosen Center for Advanced Computing and the Envision Center for Perceptualization.

He co-founded the Indiana Next Generation Manufacturing Competitiveness Center (IN-MaC) as well as the Polytechnic Institute initiative at Purdue University. The Polytechnic initiative is a major effort to transform the college's curricula and learning experience for the students to better prepare graduate for life and work in the digital age. He has authored numerous papers in journals and trade publications on engineering and computer graphics, computer-aided design, and visualization research.

He has authored and co-authored seven text books in the areas of computer-aided design and engineering design graphics with one, Fundamentals 3D Solid Modeling and Graphics Communications currently in its 7th edition. Gary's research interests are in scientific visualization, interactive immersive environments, distributed and grid computing, workforce education and STEM education.

Transforming Engineering Technology Higher Education for the Digital Age

There is a long rich history to the development of higher education as it is practiced in most developed countries in the world. Engineering education has a shorter history but sharing the same roots as higher education in general. The original intent of engineering education was to prepare graduates that could become the leaders in the development of the Industrial Age.

Just as the Digital Age has become the catalyst for profound changes in society in general, it is also impacting higher education, specifically engineering education. With the world's knowledge easily and instantaneously accessed through hand-held devices like mobile phones, what might higher education look like in the Digital Age?

At Purdue University we are attempting to answer this question by transforming the learning experience of our students and transforming what it means to be a professor in higher education. This bold initiative is completing its third-year and the transformation of an entire college is beginning to take form.

Dr. Giovanni Azzone

Full Professor
Politecnico di Milano

Born in Milano, 24.11.1962, received his Master of Science, cum laude, in Management Engineering at Politecnico di Milano, in 1986. Since 1994 he is Full professor of Business Economics and Organization at Politecnico di Milano.

He served in many National and International university boards. Specifically, he was: Rector of Politecnico di Milano from 2010 to 2016; President of T.I.M.E. Network (2013-2015); President of Alliance 4 Tech (2016); Member of the Heads Board of Idea League (2016), Member of the Board of Ècole Centrale Paris (2012-14); Vice President of the National Committee for the Evaluation of State Universities (Comitato Nazionale per la Valutazione del Sistema Universitario) of the Ministero dell'Istruzione, Università e Ricerca (2004-2010); Academic Vice President of Unitech, a non-profit organization founded by 8 of the main European Engineering Universities (2002-2006).

He currently is Member of the Swiss Accreditation Council and of SIBAC-Seoul International Business Advisory Council, and Project coordinator for the National Program on Risk Prevention of the Italian Presidency "Casa Italia".

Educating for a changing world: New challenges for Engineering Schools

Over the last few years, many societal changes affected the context where Engineers and Engineering Schools live. A growing need for Environmental sustainability in processes and products, Digitalization of Economy and Society, Globalization, just to consider the most important emerging issues, are affecting the way engineers operate and the way they must be educated and trained.

The lecture will outline the consequences of these changes on the expected output of engineering Schools (i.e., competence and skills required) and their actual input (i.e., the competence and skills of new freshmen), deriving some consequences for the contents and process of engineering education.

Dr. Maria Knutson Wedel

Vice President of Education
Chalmers University

Maria Knutson Wedel is Vice President of education at Chalmers University of Technology and a professor in Engineering Materials (MSc in Engineering Physics, PhD in Physics). She is serving on audit committees for university evaluation for the Norwegian and Danish Agency for Quality Assurance in Education. She is a member of the board of the science centre Universeum and has been deputy director of the Gothenburg Centre for Environment and Sustainability, head of Chalmers mobility programme UNITECH, programme director of the Materials Masters programme and "faculty coach" in sustainable development.

Maria has published more than 60 papers in materials science and educational development and has contributed to the development of the international CDIO initiative. She co-authored the chapter Teaching and Learning in "Rethinking Engineering Education - The CDIO Approach" 2007. She was awarded Wallenberg scholarship 1998-99, Jacob Wallenberg Foundation prize for materials science 2007 and Chalmers pedagogical prize 2009.

The journey of integrating sustainable development in engineering education at Chalmers. Ups, downs, side tracks and vision

Engineering education develops continuously in many aspects and sustainability is one of them. From a focus on mere technology to include environmental effects related to technology, it has turned towards the integration of a contemporary complex definition of sustainability as being the relationship between the three pillars of economical, societal and ecological sustainability. As a part of facing the challenge of that complexity, many universities e.g. develop routes to integrate engineering ethics, to relate educational goals to the seventeen Sustainable Development Goals, or to educate engineering students to address global societal challenges that are multidisciplinary in its nature.

The story from Chalmers of leading and managing change regarding education for sustainable development (ESD) encompasses failed projects as well as working models. The talk will include both failures and models as valuable learning experiences. These hold several questions such as: What do students think about sustainable development courses and why? Why does a teacher not want to be taught? Is transformative learning necessary? What role can companies and society play in education for sustainable development? Chalmers current model to embed sustainable development will be presented including some examples which seem to work today, as well as challenges that are still to be overcome. Additionally, there will be a short reflection regarding the call for skills needed in a future digitized sustainable society.

1.

Sustainability and Engineering Education

Self-dependent students in transdisciplinary projects tend to higher interest in sustainability research

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ABSTRACT

The orientation program MINT^{grün} at Technische Universität Berlin (TU Berlin) offers two study semesters for open choices of teaching modules including a series of specially designed laboratories for research-based learning (RBL).
The online project laboratory in chemistry (OPLChem) offered in MINT^{grün} follows the concepts of RBL with a transdisciplinary approach and allows for a free choice of a project drafted by the students themselves. The concept of the OPLChem seems to motivate the students to follow their interests in sustainability research as during the last two years 16 of 23 student groups chose topics typically related to sustainability. Our students publish their results in the form of videos and blogs in the internet. In this way a growing pool of new blogs and online videos of various experiments was established for the public.

Conference Key Areas: Sustainability and Engineering Education, Open and Online Engineering Education, Attractiveness of Engineering Education

Keywords: research based learning, project laboratory, sustainability research

INTRODUCTION

Topics related to sustainability research motivate students in the initial stage of their studies. The orientation program MINT^{grün} offered as a two semester program at TU Berlin helps students to discover interests before entering a graduation course [1].

Especially during the initial phase of studies there is a lack of student centred learning environments in most STEM courses (German: MINT for Mathematics, Informatics, Nature Sciences and Technics). In contrast to this MINT^{grün} offers nine specially designed, interactive laboratories which cover topics such as robotics, construction, environmental research, mathematics, gender studies and chemistry. The suffix “grün” which means “green” indicates the link to sustainability and is intended to motivate the students´ interest in this area at the initial stage of their studies.

The students choose at least one laboratory where they have an interest to conduct their own project. The topics are often related to contemporary research topics in ecology, sustainability or social and intercultural debates and therefore of high societal interest. In the framework of MINT^{grün} we offered the Online Project Laboratory in Chemistry (OPLChem).

The OPLChem follows the concepts of research-based learning (RBL) with free choice of research topics and a transdisciplinary approach; the latter is a key component of sustainability science [2, 3]. It was reported in literature that free-choose learning and research promotes environmentally sustainable attitudes and behaviour [4].

In recent years students chose 16 out of 23 projects directly related to sustainability research such as the quantification of heavy metals in drinking water, in nutrition supplements, in food and soil; the production and decay of biodegradable plastics, electricity from bacteria, fuel cells, hydrogen from bacteria, photosynthesis research and alternatives for industrial fertilizers.

The concept of the OPLChem further motivates the students by giving them the opportunity to present their results to the public. The students produce online-videos and publish blogs in the internet.

The growing pool of online materials represents another aspect of sustainability as the experimental results are more persistently visible in comparison to the usually written paper protocols that vanish after correction by the supervisors. Videos turn out to be a suitable tool explaining important aspects of the theory, the configuration of complex experimental setups, the basic questions of interest and finally the videos offer a presentation tool for the students [5, 6].

In 2013 Professor Thomas Friedrich was awarded a Fellowship by the Joachim Herz Foundation for excellence in teaching, specifically for the whole teaching concept of the OPLChem. One year later, in 2014, Franz-Josef Schmitt was awarded a Fellowship by the Joachim Herz Foundation for excellence in teaching with regards to the targeted inversion of internships in chemistry, biotransformation and micro economy (IGT-educationTUB).

1. CONCEPT OF RESEARCH-BASED LEARNING AND MINT^{GRÜN}

MINT^{grün} students are school absolvents that just entered university typically aged 18 years or even younger [1,7]. RBL trains skills such as the ability to independently formulate questions and conceive research plans and to take responsibility for the outcome of projects [8]. The connection of orientation studies and RBL seems to be most promising in achieving successful identity, orientation and self-confidence among the students [9,7]. Interestingly it also activates students to choose topics related to sustainability [3]. RBL is additionally well suited for online support and new technologies as part of blended learning concepts [10,11].

2. THE ONLINE PROJECT LABORATORY IN CHEMISTRY (OPLCHEM)

The OPLChem follows the concept of RBL. Team RBL is a very effective way of promoting students' awareness of social, economic and environmental sustainability issues [12]. The introduction period of the OPLChem (see Fig. 1) mainly divides into i) the best practice examples introduced by students from former semesters (as part of their presentation) motivating the students research questions, ii) the investigation period for studying existing literature and collecting information and iii) the conception period combining ideas to an experimental concept, defining methods and considering the setup. Also the necessary materials are identified and organized. Usually the students define their topics within the first 2-3 weeks of the semester and come together in groups ranging from 2-4 participants. Then they conduct their research in the laboratory during the experimental period.

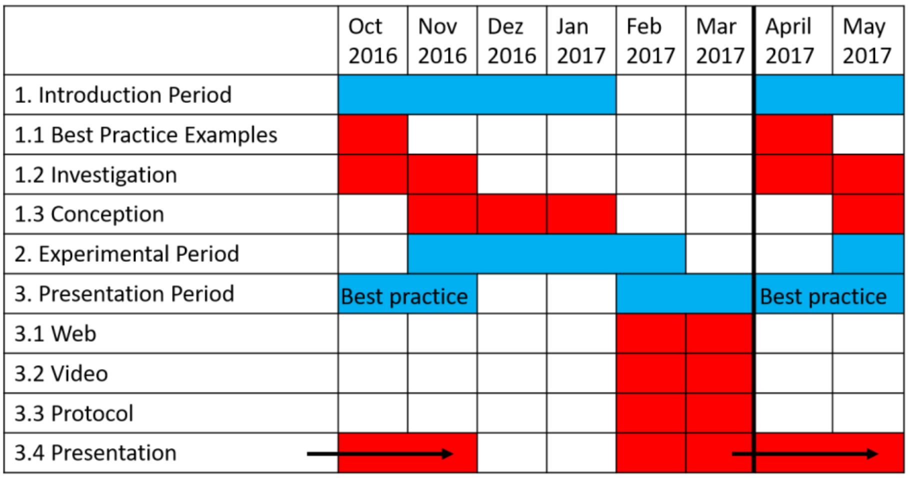

Fig. 1 Structure of the OPLChem in form of a gantt chart

At the end of the course the students have to present a written protocol and produce either a video or a blog where the conducted experiment and the results are described. Usually the video and blog are hosted at YouTube® or Wordpress®, respectively, and therefore public. Their presentations are impulse talks for the next group of students.

Fig. 1 presents the structure of OPLChem and the three overlapping periods which are marked in blue: 1) the introduction period, 2) the experimental period and 3) the presentation period. Marked in red one can see the segmentation of the introduction period and the presentation period. The semester change between March and April is indicated by a black vertical line.

3. RESULTS

During the last winter semester WS 2016/17 38 students participated in the OPLChem. The projects chosen by these students were: 1) oxygen production in photosynthesis, 2) light driven adaption of algae, 3) heavy metals in food supplements, 4) mercury in seafood, 5) gene analysis with polymerase chain reaction, 6) genetically modified organisms, 7) electricity produced by bacteria, 8) biopolymers, 9) generation and photocatalytic activity of nanoparticles, 10) optical properties of different nanoparticles and 11) function of ink erasers.

In recent years an average of about 50 % of all students who had undergone the OPLChem finished their projects with a presentation, written protocol and either video or online blog or both. All blogs as prepared by the students are collected in a metablog which is accessible via the URL http://oplchem.wordpress.com (Fig. 2)

Fig. 2 Metablog subsuming the students´ efforts in the OPLChem

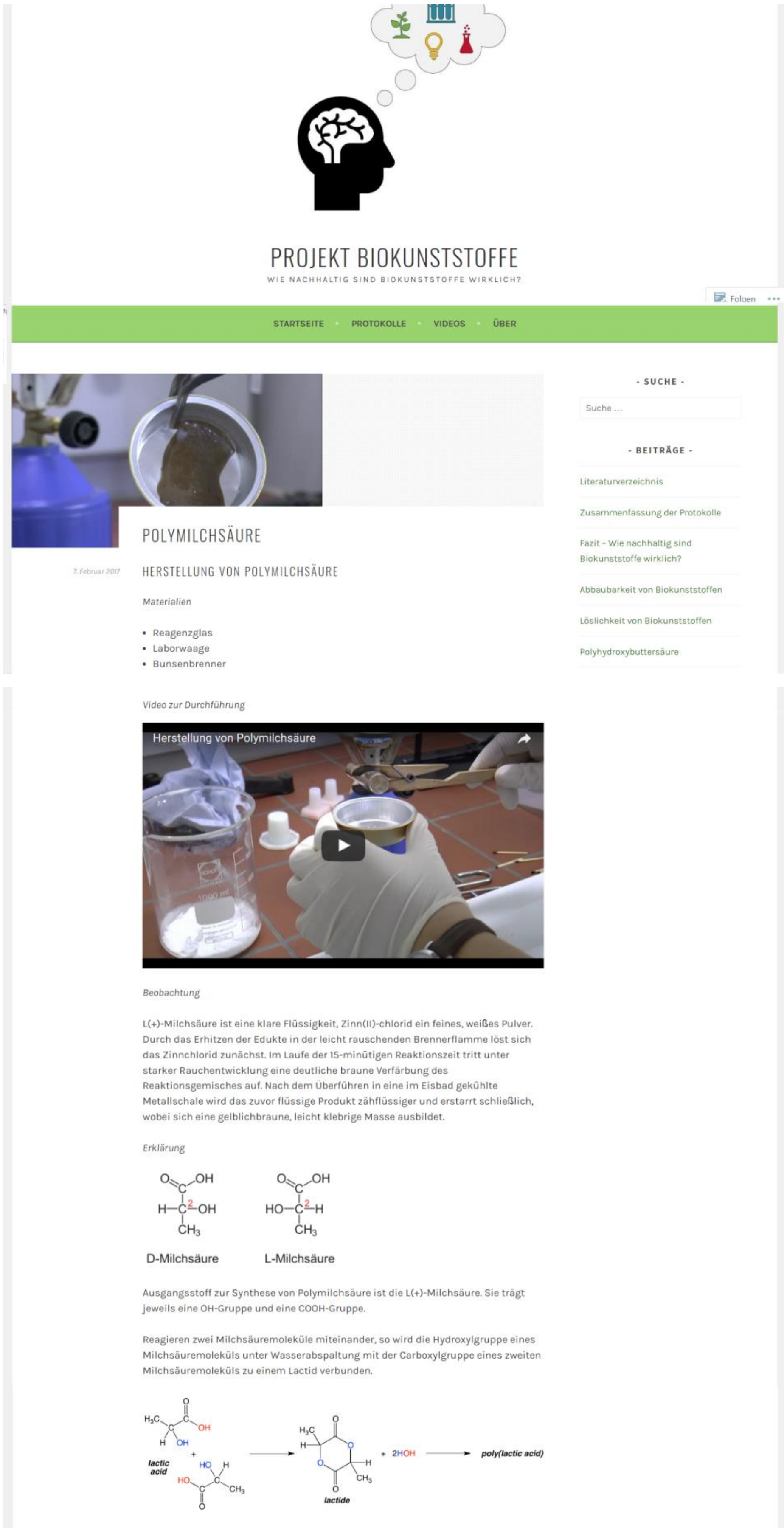

Fig. 3 Screenshot of the blog https://projektbiokunststoff.wordpress.com/

Fig. 3 presents the screenshot of a group that synthesized and investigated a number of various biopolymers such as polylactic acid, polyhydroxybutyrate, galalith or starch. They compared these polymers with industrial biopolymers such as technically produced polylactic acid and the synthetic polymer polyurethane. The degradation in contact to earth and water as well as the solubility in various different solvents was studied. The findings were subsumed in a protocol as well as presented on the blog. For the synthesis of most of the biopolymers a short video was produced and linked to the blog. The students´ presentation and discussion of their project can also be found on the blog.

4. DISCUSSION

The orientation study program MINT^{grün} is very successful regarding the number of participating students. The number of MINT^{grün} students rose from 77 in the first year, to 177 in the second year, to 325 in the third year and has stabilized at around 500 students since 2015. The proportion of women increased from 22% to 34% in the same time. In the winter semester 2015/16 21 students participated in the OPLChem. This number grew to the maximum capacity of 38 places in 2016/17: 28 students from Mint^{grün} and 10 students from Bachelor of Chemistry studied in the OPLChem during the winter semester 2016/17, of which 12 students were women (32 %). About 1/3 of the students from MINT^{grün} in the OPLChem announced an interest in continuing with Bachelor of Chemistry.

In general MINT^{grün} helped a lot of students to choose their future studies whereby most of the students who wanted to study announced that they are interested in STEM (up to 75%) [9].

We assume that for most of the students especially in the early stage of their studies there exists a strong attraction to topics of sustainability and the students appear to be highly motivated in getting engaged in such topics.

The concept of the OPLChem seems to motivate the students as they can follow their interests and have the opportunity to publish their projects in the form of videos and on a blog in the internet. Such online materials are transdisciplinary and sustainable as the students online published experimental results are more persistently visible in comparison to the usually written paper protocols that vanish after correction by the supervisors.

This approach also opened the laboratory for the public and turned out to be an interesting concept to support collaborations as for example with the office for urban development of the government of Berlin.

Interviews with the students showed that especially the groups who had experience with RBL during their school time were quick in finding project ideas or even wanted to proceed with their former school projects.

5. CONCLUSIONS

The main aim of the OPLChem is to introduce students to situations of real laboratory research and they should be motivated for hard working engagement to solve difficult issues in chemistry. This might sound as a contradiction to develop own interests however we believe that RBL can offer both, experience of reality and identification.

It turned out that this concept of RBL is highly appreciated by the students. Especially the flexibility in scheduling the time for the experiments was positively judged.

We believe that the concept of RBL in orientation studies together with transdisciplinarity for example by blended learning elements such as online videos and blogs is highly attractive and motivates sustainability research projects. RBL brings students into contact with the requirements of the subjects on the one hand and gives them freedom to follow own research questions on the other. It allows good students to explore their limits. RBL should ideally include elements which are typical for the subject such as the need to write elaborated and exact protocols as in studies of chemistry, so that the students in MINT^{grün} experience the study reality and get a good orientation from participating in OPLChem. But RBL should also allow for the freedom of a researcher to choose his questions, to design experiments and to schedule his time on his own.

ACKNOWLEDGEMENTS

The authors acknowledge support by TU Berlin in the framework of the student reform project “educationZEN in Praktika”. Special thanks belongs to the board of teaching and studying (LSK) and the board of the faculty (FKR II) who were both engaged in discussions and contributed with constructive criticism to the success of this project and finally decided on the funding in a positive way. The authors thank the Executive Board (President Prof. Christian Thomsen and the Vice President for education Prof. Hans-Ulrich Heiss) from TU Berlin for his support to MINT^{grün}.

Thomas Friedrich and Franz-Josef Schmitt especially thank Stifterverband der Deutschen Wissenschaft and Joachim Herz Stiftung for supporting the projects “Onlineprojektlabor Chemie im Alltag” and “IGT- educationTUB” and support by the ministery of education and research (BMBF) for financing the *WIMI^{plus}* project SynTUBio. Central institute of scientific cooperations (ZEWK) at TU Berlin is acknowledged for supervising *WIMI^{plus}*.

Christian Schröder and Zulehya Yenice Campbell acknowledge support by the ministery of education and research (BMBF) for funding the project MINT^{grün}.

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A guideline for planning and implementing an action-based and transnational course in higher engineering education:
A Case for Sustainable Value Creation

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ABSTRACT

This paper outlines a generic guideline for planning and implementing an action-based and transnational course in higher education for training the engineering competencies required in a future dynamic European workplace and economy. This guidance is intended for universities, research and teaching institutes, as well as for

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companies interested in establishing novel teaching concepts by closing the gap between know-how and experience. The guideline will provide suggestions and lessons learned for the realization of an efficient and effective implementation. Important development phases of the guideline are explained through a use case based on a master course, which has been jointly established in cooperation by four European universities. Learning objectives for this course aim at raising the awareness about sustainable value creation by focusing on the development of sustainable and technological innovations with entrepreneurial objectives.

Conference Key Areas: Sustainability and Engineering Education, Curriculum Development, Engineering Skills

Keywords: Guideline for Higher Education, Transnational Teaching and Learning, Sustainable Value Creation

INTRODUCTION

The future working environment of young engineers within the dynamic European society and economy will be coined by mobility, intercultural exchange, and virtual cross-border communication. Future engineers will be more and more required to work in international teams and be able to interact effectively and efficiently with colleagues, suppliers, and customers coming from different countries as well as cultural backgrounds. Moreover, modern digital engineering tools are driving this change in a very fast way. As a result, the training of mobility as well as of transnational and intercultural competencies has become a strong requirement for teaching and learning in higher education. To this aim, the paper outlines a guideline for planning and implementing an action-based and transnational course in higher education for training young engineers towards a future dynamic European workplace and economy. It aims to empower organizations to implement their own action-based and transnational activities by providing highly practical-oriented recommendations. This guidance is intended for universities, research and teaching institutes, as well as for companies interested in establishing novel teaching concepts in higher education. The action-based and transnational course addressed within this guideline consists of the following training and teaching phases involving a consortium of international learners and supervisors:

- A project working phase driven by a challenging engineering problem including:
  - International mobility phases for both students and teachers
  - Virtual cooperation and collaboration through digital tools
- E-learning lectures

The paper outlines the methodical background (1) and the state-of-the-art (2) for the action-based and transnational course. The guideline (3) addresses the activities: preparation, development, as well as implementation, evaluation, and follow-up. Important development phases of the guideline are explained on the basis of a use case patterned on the master course “European Engineering Team”. Learning objectives for this course aimed at raising the awareness about sustainable value creation by focusing on the development of sustainable and technological innovations with entrepreneurial objectives. The concept, first results, and outcomes of the course are described in [1] and at the project website (engineering-team.net/).

1 METHODICAL BACKGROUND

The framework for the action-based and transnational course in higher education follows the concept of Experiential Learning, based on the research results from David Kolb [2, 3]. Experiential Learning is based on a learning cycle of reflecting on the impacts of performed activities and subsequently deriving and implementing measures for improving these activities [3]. For combining the learning cycle with the search for solutions during the project work of the course, a specific logic was developed. This logic is an integration of the approaches presented in [3, 4, 5, 6, 7]; it supports the natural problem solving behaviour of humans and originally is inspired by the TOTE-Model [8]. *Fig. 1* shows the logic of the learning cycle applied during the project working phase. Moreover, specific elements have been developed for training different competencies of the learner. The structure of the relevant competencies is oriented on the competence profile for sustainable leadership [9] and consists of four main competencies: professional competence, methodical competence, social competence, and self-competence. *Table 1* points out the relevant course elements for training the four main competencies. For the improvement of the course, different evaluation activities with a subsequent development of improvement measures are carried out. The framework has been implemented and evaluated within the first and second cohort of the European Engineering Team.

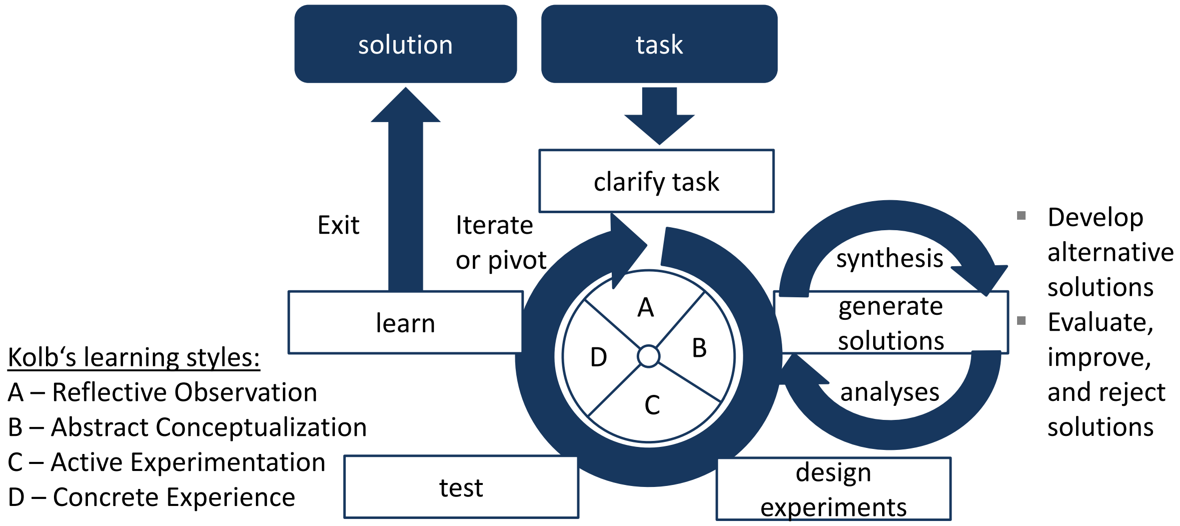

Fig. 1. Learning cycle for the project working phase (in accordance with [10])

Table 1. Course elements for training the competencies

Competencies		**Course Elements**
Professional and methodical competencies	▪ Depending on the involved engineering disciplines	▪ Project topic ▪ E-learning lectures ▪ Application of specific engineering methods and tools depending on the project topic ▪ Application of digital tools for communication
Social competencies	▪ Intercultural competencies ▪ Capacity for team work ▪ Communication capability ▪ Willingness to resolve conflicts ▪ Persuasive strength	▪ Intercultural team composition ▪ Project work in small teams and with work packages ▪ Periodic presentations of the work progress
Self-competencies	▪ Self-confidence and leadership ▪ Mobility and flexibility ▪ Engagement and reliability ▪ Target orientation and commitment	▪ Mobility phases ▪ Intercultural teamwork

2 STATE-OF-THE-ART

The state-of-the-art derives from approaches for action-based and transnational curricula in engineering education, considering both virtual and physical elements. The virtual-oriented approaches put an emphasis on online cooperation between the transnational partner organizations.

- Moore and May describe an interactive online course for engineering students based on a web-platform between the University of Virginia and the Dortmund University [11].
- Petrea and Velescu present an example of a mostly virtual-oriented approach with only one initial meeting for inter-university teaching of science students in a foreign language (French) [12].
- TRIP was a project aimed at using web services for distribution of large software engineering projects [13].
- Teaching students global software engineering skills using distributed Scrum in inter-university Canadian-Finnish teams was described in [14].

The physical-oriented approaches are essentially characterized by short-term, collaborative working phases, which take place with a co-located team and specific tasks and objectives.

- The BASE Transnational Training Course established by Fundação da Faculdade de Ciências da Universidade de Lisboa (FFCUL) and by the Ecologic Institute in Berlin provides a curriculum for the implementation of climate change adaptation projects using hands-on experiments and case studies for 16 learners [15].
- “Global Engineering Teams” managed by Global Education Team UG is an international and interdisciplinary project-oriented study course specifically for engineers [16].
- Jane presented a transnational course prepared by four European universities in the area of construction engineering and management [17]. All the activities were performed during physical meeting. The entire course lasts 28 academic weeks and students reside 9-10 full weeks at three different campuses, respectively.
- Mukerji presents further examples in [18].

The approach presented in this paper integrates both sets of practices and puts the focus on sustainability in entrepreneurial engineering.

3 GUIDELINE

The guideline is one of the final deliverables from an ERASMUS+ strategic partnership project. It captures lessons learned from our experiences as well as practical recommendations for any educational or training consortium interesting in replicating our engineering program. The guideline will be structured in the main activities: preparation (3.1) development (3.2), as well as implementation, evaluation, and follow-up (3.3). These activities are briefly outlined in this paper and are undergoing continuous improvements as we proceed with the ERASMUS+ project. Each activity covers different development phases (A-I) for the action-based and transnational course in higher engineering education. These phases address the development of different course elements.

3.1 Preparation

The definition of the course curriculum is the first relevant phase (A) for initiating the future action-based and transnational teaching and learning activity. This phase follows a fairly typical planning model including the development of the course elements A.1-A.5 It covers the definition of a vision and mission for the course (A.1), as well as an outline of the leaning outcomes (A.2) and learning contents (A.3). This includes a definition of specific competencies for the course as well as a generic description of the applied procedures, principles, methods, and tools. The learning outcomes and learning contents define specific teaching and learning activities against which a duration and workload needs to be subsequently determined (A.4). Lastly, the target group and pre-requisite knowledge of the participants (A.5) are elaborated. For the development of the course elements, it should be ensured that they can be realized by applying the learning cycle in *Fig. 1*.

Within the second phase (B), the necessary stakeholders have to be identified, selected, and first contacts have to be established (B.1). The main relevant stakeholders are the transnational teaching partners from different countries. The partners should be selected according to the different competencies required to realize the learning outcomes as well as the learning contents. Besides, it should be ensured that the curriculum can be adjusted to the individual academic calendars of the partners. Other relevant stakeholders are e.g. external experts or organizations who/which are required for supporting the course with know-how or materials. For establishing the cooperation with the stakeholders, it seems to be more promising to select stakeholders with already existing good contacts on all organizational levels, e.g. from chair, to department, and up to administrative level. All project partners should be involved as early as possible in the development of the course elements. This process was applied by the European Engineering Team, with an early assessment of the feasibility of the course concept and detailed schedule for each university's curriculum and academic calendar. Concurrent to the selection of the stakeholders, a funding for the mobility phases (B.2) and the required materials for the project working phase (B.3) need to be specified.

The alignment of the course schedule to the academic calendars of the partners as well as the establishment of a funding for the course has been experienced as especially critical for the development of the European Engineering Team.

3.2 Development of the course model

After the preparation, the detailed course model has to be elaborated. This covers as a first development phase, the definition of the educational contents (C). The concrete topic for the project working phase (C.1) has to be determined. Moreover, the duration, sequence and objectives of the mobility phases (C.2) have to be specified. Additionally, a set of topics for the supporting e-learning lectures (C.3) must be selected, addressing professional and methodological as well as transversal competencies for the students.

In a second phase (D), the roles and expectations on both teachers (D.1) and supervisors (D.2) have to be detailed. This includes to define "who teaches what and when" as well as the learning outcomes and outputs for the students.

A third phase addresses the development of a concept for the quality assurance of the curriculum (E). In this context, an evaluation plan (E.1) and specific evaluation criteria (E.2) must be defined.

Lastly, the communication between the different stakeholders has to be set (F). For this purpose, the communication infrastructure and required tools are selected, e.g. for web-conferences. A first schedule for the communication between the different stakeholders is specified, especially taking into account the virtual cooperation and collaboration phases (F.1-F.3). *Table 2* shows a detailed use case for the course elements of the development phases C-F based on the European Engineering Team (EET).

Table 2. Use case for the course elements for the development phases C-F

C Educational contents
C.1 Project working phase: The project topic for the EET is to find a solution for breaking the chain of infection by developing an autonomous disinfection vehicle for application in hospitals based on the Sustainable Development Goals of the United Nations. This covers the development of a prototype as well as the development of a suitable business model. A sub-group of 4-8 students will be working on one topic supervised by four teachers from the partner universities.
C.2 Mobility phases: Four mobility phases at each of the partner universities are planned, one at each partner university with a duration of five days: week 14, Milan – introductions, define and analyze the problem to be solved; week 19, Trondheim – refine the problem definition and candidate solutions; week 41, Berlin – active prototyping; week 2, Warsaw – final meeting and introduction of the solution to investors.
C.3 E-learning lectures: For assisting the project work of the students the following e-learning lectures have been defined: Sustainable Value Creation, Systems Thinking & Systems Engineering, Technology Management, Circular Economy, Development of sustainability-oriented Startups, Sustainable Supply Chain Management, Virtual and Augmented Reality, and Digital Factory. The partner universities are recording the screen-casts and are prepare an exercise for each topic.
D. Roles of and expectations on teachers and learners
D.1 Roles of and expectations on teachers: For the EET, two different roles are required to be taken by the teachers: lecturer for the e-learning contents and supervisor for the project work of the students. The teachers are expected to be PhD students, post docs, or professors. Moreover, the teachers must attend all mobility phases and must closely supervise a small sub group of up to five students according to their individual competencies.
D.2 Roles of and expectations on learners: The students (learners) are expected to take different roles according to the project, such as project managers, product developers, or business model developers. In terms of the learning outcomes, the following expectations have been determined: ability to critically assess the goodness of a solution and its ability to meet a real customer's need; ability to work together and at the same time work in smaller groups that are capable of effectively sharing information between themselves; demonstrate (virtual) communications techniques learned during the project; ability to structure plans that address interdependencies and pre-requisites between the groups; ability to use abstract methods such as digital simulation or drawing to support decision making and design; ability to critically assess the contributions of a proposed solution to sustainable development. As output during the course, the students need to produce different reports including a reflection on the progress of the project work as well as a description of the produced results. Furthermore, the students have to create presentations for each mobility phase.
E Concept for quality assurance
E.1 Evaluation plan: It is necessary to monitor the learning and teaching progress and outcomes. During the course, three course evaluations are carried out with the participating students based on an anonymous online questionnaire. At the end of the EET an evaluation and improvement workshop is carried out by the teachers. As part of the workshop, feedback and possible improvement measures will be discussed with the students during their last mobility phase.
E.2 Evaluation criteria: For monitoring qualitative evaluation criteria, the change in the intercultural, mobility, methodical, professional, and self- competence of each student are evaluated during the anonymous online questionnaires. Therefore, the students rate their competencies in terms of speaking/understanding/writing English, sustainability, dealing with valued rules/norms, and expectations of people from other cultures, startup development, etc.
F Communication between the stakeholders
F.1 Communication of teachers and leaners: The infrastructure for communication between teachers and learners is designed as an open-source web-based platform. Moreover, the teachers and students meet physically at the mobility phases and virtually during the project work on the basis of web-based conference calls.
F.2 Communication between students for the virtual cooperation and collaboration phases: The communication between the students is organized in a decentralized manner. The students themselves chose within their group, the relevant digital tools for organizing their work.
F.3 Communication between teachers: The communication between the teachers takes place during the mobility phases, as well as by using web-based conference calls.

3.3 Implementation, Evaluation, and Follow-Up

This final section of the guideline includes recommendations for project management, for implementing the educational contents, and for continuous evaluation. The implementation of the course model entails an effective transnational project management (G) of the curriculum. This requires the adherence to responsibilities and scheduled meetings as well as the usage of the digital, communication tools. Secondly, the educational contents have to be implemented (H). This activity comprises the acquisition of students (H.1) as well as the operational planning and execution of the mobility phases (H.2), the virtual cooperation and collaboration phases (H.3), and the e-learning lectures (H.4). After the course is implemented and performed, evaluation and follow-up actions (I) ensure the educational quality of the curriculum and identify possible criticalities and subsequent improvements.

4 SUMMARY AND ACKNOWLEDGMENTS

The paper addressed the definition of a guideline for planning and implementing an action-based and transnational course in higher education for training the engineering competencies required in a future dynamic European workplace and economy. The main activities highlighted were: preparation, development of the course model, as well as implementation, evaluation, and follow-up. Important development phases for the main activities were explained on the basis of a real implementation of a master course focusing on the development of sustainable and technological innovations with entrepreneurial objectives.

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Challenges for teaching sustainability and promoting diversity within a software engineering course

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ABSTRACT

This report covers the challenges of integrating sustainability into the curricula of an undergraduate module for software engineering students and ensuring an inclusive and research based learning environment. Making skills audits explicit to team members provided a mechanism to help identify topics students wanted to learn and skills they needed for their projects. These audits particularly identified females' interests in sustainability and a chance to collaborate more widely, which helped identify a suitable research project and industry partner. Ensuring that there were no lone females in any project team necessitated larger groups, requiring more detailed attention to team structure and communications but provided greater opportunities for students to develop knowledge in areas that they wished. Documenting skills and discussing the different views of stakeholders: potential users of the software product, team members, industry teams and research groups across the university, also provided an appreciation of the value of diversity. Integrating projects that cover the topics female students have identified has provided a path for increasing sustainability education within the curricula and provided opportunities to pursue their interests. Experience suggests larger agile research teams may provide a route to supporting women in engineering and developing their potential in leadership.

Conference Key Areas: Sustainability and Engineering Education, Gender and Diversity, Attractiveness of Engineering Education

Keywords: sustainability, software engineering, women in engineering, diversity

INTRODUCTION

There has been a continuing problem for years of under-representation of females in STEM subjects [1]. This paper outlines the challenges in addressing this issue while also trying to ensure sustainability is integral to the curricula of a technology management module and aligned to the humanitarian objectives of the university and UN Sustainability Development Goals (SDGs) [2]. Identifying student's interests and aspirations helped develop a suitable undergraduate research project, as well as create an improved understanding of each team member's goals. Detailed skills audits (see section 2.1) clarified students' interests; brought to the fore female students' interests in wider topics within their subject, particularly regarding sustainability and opportunities to collaborate, and male students' interests in developing a complete solution. Working in larger teams not only gave individuals a greater opportunity to work on topics they wanted to learn, but also facilitated a supportive environment and an understanding that diversity enhances teamwork and research.

1 BACKGROUND

Improving diversity in engineering enhances creating solutions that inherently meet the needs of the wider population, not just solutions based on a narrow range of perspectives [3]. Improving diversity also aids innovation, the economic success of organisations, addresses the engineering skills shortage and contributes to creating a fairer society [3], [4]. University College London (UCL), Faculty of Engineering Sciences is dedicated to promoting diversity and increasing the number of women within engineering careers. The Department of Computer Science, within this faculty, has gained recognition for initiatives to support women in engineering in achieving an Athena Swan Silver award [5].

This paper covers the technology management module for final year undergraduate computer science students for the academic year 2015/16. This module is now integrated into other engineering courses. It covers the experience of ensuring research-based projects, problem-based learning (PBL) [6] and curricula are in line with the recommendations of professional bodies and leading engineering education reviews [7], [8] and content is co-evolved with students. To avoid gender bias and sole females in project teams, larger sized groups were required. This created the need for more detailed attention to boundary communications [9], how the teams were split along architectural lines and a focus on industry team structures and their approaches to acknowledging each team member's contribution.

There is recognition that organisations need to attract what Eric Schmidt, chief executive of Alphabet, and the holding organization of Google terms "learning animals"; employees who want to embrace life-long learning, willingness to continually learn new technologies and processes [10]. The wider social and teamwork skills are often just as important, if not more so [6] if we are going to develop the necessary collaborative skills needed in research and business.

Highlighting problems from other cities around the world helped engage students from the diverse cultures within the class and helped them appreciate that the research is aimed at solving a global problem. The project was placed in context of the UN sustainable development goals and the sustainable initiatives of the university, UCL Grand Challenges [11].

Students during the previous academic year had delivered research projects in the form of apps to enhance bicycle hire provision [12]. This theme of sustainable living continued for projects for the year 2015/16. Each team were encouraged to develop a solution of their own choice that would suggest routes or areas with lower levels of air pollution for those walking or cycling in London. Students were given the option to suggest an alternative project, to facilitate a more sustainable future and improve health and were encouraged to seek feedback from the intended users of their app as well as from an appropriate industry partner.

2 CHALLENGES

2.1 Integrating sustainability into the curriculum

Understanding of what students wanted to learn was gathered via feedback, retrospectives and project reviews. An in-depth understanding of goals and aspirations helped all team members and tutors understand what each individual wanted to achieve, what they could contribute and what they wanted to learn and helped everyone appreciate each other's skills. Subjects identified from female students' feedback included: sustainability, opportunities to collaborate and an emphasis on the wider aspects of computing. Feedback from male students included technical interests, relating to building data-intensive applications and behaviour driven development (BDD). Integrating the needs of Education for Sustainable Development (ESD) within a crowded curriculum was a challenge. Sustainability is a contested concept. However, there is general agreement according to Hasse [13], that it covers social, environmental and economic concerns. In addition, Haase considers that the different perspectives and models may help students develop the necessary critical pedagogic experience to understand different stakeholders' viewpoints.

2.2 Integrating the interests of female students

Studies of female students show a higher percentage participation in health and medical technologies, design, and biotechnology [14]. As feedback and skills audits from this module, indicated that female students were interested in pollution and health, it was agreed that students would be encouraged to develop apps to reduce exposure to air pollution. For this course feedback from female students also indicated that opportunities to work collaboratively in projects aligned to industry and sustainability were important issues. So it would seem logical to assume that courses with a focus on projects that overlap these interests may enhance the participation of female students.

2.3 Ensuring females are supported by their peers

In discussing STEM self-concept, Simpkins et al., [15] have considered how one's belief in one's abilities, based on the perception of others, can affect pedagogic outcomes. Rachael Robnett [16], outlines evidence that gender bias is antecedent to self-concept [17]. Robnett further highlights evidence that bias often originates from male peers, and this is further exacerbated in fields where females are severely underrepresented. To this end, to ensure a reduction in gender bias and that there were no lone females, an issue of concern highlighted by Beddoes [18], the class was split into 6 teams, of either 13 or 14 students, ensuring at least two females in each team. Eccles and Wigfield [19] suggest that ensuring that females are supported via their peers and teachers can improve their self-concept and that ensuring support by mentors would enhance this further. Female students were therefore encouraged to select someone they considered supportive from another team, to help with retrospectives.

Where research goals are clarified and females have their peers' affirmation, the development of effective team building skills necessary for engineering projects is enhanced [20]. Also, aligning the goals to the values of peers and society, the perceived value of the research is likely to be raised. As the problems associated with air pollution are a societal concern, all teams considered that opportunities to create an app to reduce exposure were an opportunity to create something worthwhile, learn new skills, and engage with research initiatives across the university covering sustainable cities.

The lecturers were invited to have access to team online project areas, in contrast to making this a course requirement in previous years. This seemed to create more openness over project issues as well as approaches to resolve problems. As *Table 1* shows, the percentage of communications initiated by females were higher than would be expected from the percentage representation within their teams. (Tools selected by students included: Trello, Slack, Jira, GoogleHangouts and Microsoft Visual Team Studio.)

Table 1. The data shown for two project teams, tracking just one of their software communication tools, Trello, within project weeks 2 to 6. Teams A and B both consisted of 3 female and 11 male students. (Letters have been substituted for actual project names for anonymity.)

Project Team	Number of communications tracked	Number of female initiated communications	% female within project team	% female initiated communications
A	112	60	21	54
B	102	56	21	55

As in previous years, females were encouraged and supported in taking on leadership roles for projects, as advocated within WISE publications [21]. Female students considered the structures and being allowed to elicit support from their peers during retrospectives helped them to contribute and develop their project management skills.

"Being the first practical insight I had into the Agile Methodology, this project enabled me to grow from a management, teamwork and leadership perspective. Throughout the development process, I seriously improved my self-discipline, which was crucial in order to properly manage my team to success." (Female student)

Challenge 2.4 Initial concern regarding team size

The opportunity to work in a larger team than students had previously experienced during their studies created an initial concern for one team. Students mentioned that they had not experienced these large groups before, and were concerned that they would only have a limited time to get to know one another. With students asking for advice how to split teams and plan communications, team structure examples were outlined; covering "Inverse Conway's Manoeuvre" [22] ensuring the team structure reflects and supports the architecture of the app, and also boundary communications with sub-teams and their industry collaborators.

3. DISCUSSION

To ensure student-centred learning "flipped lectures" were adopted, providing key research papers the week before discussing these in class and considering how findings could be applied to their projects.

The Adair model was introduced as outlined by Braun and colleagues [23], with an explanation that this is often used in industry as a framework for skills audits: what skills individuals need to develop, what skills the team require, what skills are necessary for the project. Students were encouraged to view this not as a static document but as a tool to help identify the necessary skills throughout the project, as well as self-appraisal, sub-team and project appraisal at the end of the project.

From audits, class questions and project reviews, it was apparent that all students were keen to link these to the UCL Grand Challenges. Male students were particularly keen to build working apps, as one commented: “from beginning to end”. Not surprisingly, as this was a computing module, virtually all skills audit comments, including those from female students, covered their wish to improve their software development skills and machine learning techniques.

“As a member of the research team, I also got the chance to work on something that I have long planned to learn, R programming. Working together with … we implemented 3 models for NO2, PM2.5 and PM10 … but also learn more things about linear regressions and hypothesis testing.” (Female student)

Working prototype apps, reports, and videos were delivered within 9 weeks. All project teams elicited feedback from: industry partners, potential users and the class, to improve designs and digital accessibility of their prototypes. Apps are being currently developed further by organisations, such as the London Sustainability Exchange (LSx) [24] a not for profit community-based organisation, set-up to enhance the sustainability of London. All teams expressed positive views that they had the opportunity to produce something tangible to improve sustainability and provide an opportunity for those living in cities to lower their exposure to air pollution.

Rogojanu and Badea outline that ESD encapsulates an attitude to the environment and ethical aspects [25]. One team negotiated a slightly different focus for their project, based on estimating the pollution level residents may be exposed to for properties available for rental or sale. They developed an air pollution app to be incorporated within the website of the online property sales and rental organisation they were collaborating with. During prototype discussions in class, the team outlined the dilemmas faced, with uncertainty whether properties associated with high levels of pollutants will actually have air quality data shown on the property website. These discussions were invaluable in helping students appreciate the ethics associated with sustainable engineering solutions and the perspectives of different stakeholders.

The course integrated the technology with coverage of technology management with an emphasis on communication and design decisions. Detailed investigations of the data sets and the different viewpoints of the designs from potential users, industry partners and other researchers at UCL also provided a range of improvements. One team utilised traffic noise open data, as an effective proxy measure for air pollutants. Recording design decisions and alternatives also supported the ethos of the course considering opinions from all stakeholders.

4. CONCLUSIONS AND FURTHER WORK

It has been shown by EU sponsored surveys [26] that females are more concerned with air pollution than males. Carefully selecting related engineering projects may, therefore, help promote engagement and increase numbers from female students. Kolmos et al., [14] have indicated that female engagement may be further encouraged by interaction with female professional engineers in the workplace. It was noticeable that students had specific interests during this project, covering technical areas, sustainability or ethics. Female students showed a particular interest in sustainability topics, which were integrated throughout the course. Male students showed specific interests in application development, such as the node.js platform, and coding approaches that could be understood by both technical and business users. The nexus of interests, from both genders, aided collaboration with industry partners and ensured engagement with this research from all teams. This also provides further opportunities to track students' engagement, whatever their initial interests, and ensures that their progression and development of skills for each category of interest are met. This is particularly important if we are to further improve diversity and inclusion initiatives.

We need to consider how students learn in a more holistic way and consider students' methods of learning, including cognitive and affective [27]. The project structures allowed teams to work in an environment of psychological safety and the opportunity to ask for support during retrospectives increased openness and encouraged a higher level of participation, especially from female students. An inclusive environment was further fostered, by encouraging students to support their peers and join specific support groups at UCL [28].

Research papers often point to small team size covering agile software practices [29]. However, further understanding of optimal team size for education is an area of research that needs investigation, especially as there is a trend in technology organisations to adopt larger team sizes [30]. This also created a need for more detailed peer assessments to show the contributions of individuals and what the project would have been like without their support. The larger size of the project teams, compared to other courses in the department, allowed for specialism and ensured there were no "token" females in each group.

"By working on the project with the big team, it makes me realize how we can manage the project and team relationship effectively using sprint iterations." (Female student)

"Comparing with my previous teamwork and team lead experiences, I noticed a fair improvement of my time management and planning skills. This was mostly due to the fact that I learnt to rely on others, instead of taking care of every issue myself. Although I am a perfectionist through nature, the complexity of this project forced me to pass over responsibilities to the Point Persons [responsible for the task]." (Female student)

Teams were encouraged to develop detailed skills audits, which created the opportunity to identify the knowledge and skills individuals wanted to learn and share, and recognition that everyone has something valuable to contribute. Many students considered they had developed a better understanding of complex sustainability issues from consideration of the different viewpoints from potential users of their app, industry partners and other research groups within the university. Discussions regarding the interpretation of pollution and health data, software architecture decisions and approaches to software development and communications also helped them gain a better appreciation of the value of diversity, and that everyone brings valuable experiences and skills to a team.

"We all have different backgrounds, different personalities, different habits and different ways of working. I learnt to enjoy the differences in our cultures and respect one another." (Female student)

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Sustainability literacy and engineering

Experiences from a literacy test as a teaching and assessment tool in Nordic universities

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ABSTRACT

The role of engineering education is essential in global sustainability transformation, considering the impact technology has on the environment and societies. Many suggestions have been made on what competences universities should teach to educate game changers and how to improve sustainability literacy. Despite the growing number of studies in the field, research is scarce on how to assess what the students know about global sustainability challenges and how to embed sustainability literacy into curricula. This paper presents the first experiences on using a sustainability literacy test (the Sulitest) as a teaching tool. The test was developed in 2012, and it includes global and national questions on multifaceted sustainability challenges. Our results are based on national questions created for the Nordic countries and on the test results we got from 700 students in Finland, Sweden and Norway. The Sulitest seems to be useful as a teaching tool, but the national questions ought to be re-evaluated to achieve balance between different aspects of sustainability. The test has weaknesses regarding its use as a curricula development tool, but it can facilitate teachers in engineering education in drawing a comprehensive picture on the problems the future engineers are required to solve.

Conference Key Areas: Sustainability and Engineering Education, Curriculum Development, Engineering Skills
Keywords: Sustainability Learning, Literacy Test, Nordic universities

INTRODUCTION

Engineering education needs to adapt to the global sustainability transformation, which has been widely acknowledged [1]. Engineering associations in the west point to competences for solving 21th century challenges, and a number of scholars find engineering curricula in the midst of a paradigm change from “how to integrate sustainability into our discipline” to “how our discipline can contribute to sustainability” [2, 3]. Such scholars emphasise that engineers need holistic understanding on the environmental, societal and economic impacts of their profession, and advocate for generic and interdisciplinary skills. Moreover, engineering education should focus also on the values, behaviour and problem solving skills in order to solve wicked problems, in addition to the technical expertise and specific knowledge they acquire from their studies.

Many teachers worldwide have made efforts to tackle the challenge of combining sustainability transformation and engineering education. Contributions vary from individual methods, including online learning [4], games [5] and concept maps [6] to wider measures such as a dedicated program for sustainability engineering combining different engineering fields [7], multiple course-specific sustainability components integrated in chemical engineering curricula courses [8] and integrating sustainability into learning outcomes of courses or programs [9]. By way of illustration Segalas et al. [9] study three European technical universities' bachelor programs, and find none of the sustainability competences under investigation contained a learning outcome "world current situation", despite of the otherwise sustainability-oriented learning outcomes.

In fact, in the global research concerning sustainability in higher education, the question of key sustainability competences has raised debate over what and how, we should teach in order to empower the students to contribute to sustainability transition [see for example 10, 11]. Some of the most commonly agreed competences are systems thinking, integrative and holistic thinking, strategic and collaborative competences [12], whereas some of the most used teaching methods across disciplines include problem-based learning, case studies, group discussions and critical writing tasks [13].

However, knowledge on current global sustainability challenges, "the world current situation", is a fundamental precondition for learning on how to promote sustainability transition**.** According to UNESCO [14], education for sustainable development (ESD) should include several issues, including climate change, biodiversity, poverty and disaster reduction, sustainable consumptions and market adaptation. Moreover, engineering innovates solutions to sustainability challenges in one scale, but may produce sustainability challenges in another. Therefore, there is a need to define what should be included in this "basic knowledge set" of world's current situation.

One opening was made in 2012 in the form of an international, internet-based test containing different global challenges, and covering all the pillars of sustainability. This Sustainability Literacy Test (Sulitest) was created as the response to the goals set in the United Nation's (UN) Rio+20 world sustainability summit, and it's also closely aligned to the 17 Sustainable Development Goals of the UN Agenda 2030 for Sustainable Development. Sulitest development was guided by over 300 contributors and its panel of senior and regional advisors, including the UN, the UN Development Program (UNDP), the Globally Responsible Leadership Initiative (GRLI), the UN Educational, Scientific and Cultural Organization (UNESCO) and the International Association of Universities.

The test aims to facilitate higher education teachers to assess their students' knowledge and skills on sustainability and works as a means for testing participants' sustainability awareness. The Sulitest has already been adopted to hundreds of universities all over the world, and over 40000 students have taken the test by the end of 2016. However, scientific discussion is yet to be opened on its benefits and disadvantages as a teaching and assessment tool in higher education. In fact, research in general is very scarce concerning the use of tests as teaching or assessing tools in sustainability education.

This paper discusses the first experiences gained from the Sulitest in a Nordic project, which aimed to find new ways to evaluate student's sustainability literacy across disciplines. The paper examines features of the Sulitest and Nordic university students' sustainability literacy, and discusses the test as a tool for integrating sustainability into engineering education. Finally, the paper reflects on how making engineering and interdisciplinary study can contribute to sustainability, to paraphrase Mulder [3]. The results will benefit teachers in higher education interested in promoting sustainability literacy, regardless of discipline, to familiarize themselves with different aspects of the Sulitest.

1 NORDIC SULITEST PROJECT

1.1. Sustainability in Nordic higher education

The Nordic countries are renowned for their ambitious strategies for sustainable development, and they target at leading the way in ESD [15, 16]. For example, at the Norwegian University of Science and Technology (NTNU), interdisciplinary environmental oriented courses with different approaches and perspectives have been mandatory for the engineering students for more than 25 years and according to a recent overview from the NTNU Sustainability Programme, more than a 100 courses are connected to sustainability concepts [17]. However, recent research has on the other hand suggested that Nordic universities follow a global trend [18, 19] in emphasizing campus operations over sustainability education [20], and that sustainability is inefficiently integrated in the learning outcomes of Nordic universities' courses and programs [21]. Moreover, Boman and Andersson [22] found that only 1/3 of the courses in the University of Gothenburg, Sweden, include sustainability contents.

The factors affecting sustainability integration in higher education are multifaceted. In the research done in the Nordic countries, mainly focused on Swedish case examples, the role of good leadership, clear strategy, environmental management systems and collaboration have been highlighted to promote institutional sustainability [23-26]. However, major global challenges for teachers to integrate sustainability in their teaching seem to be overcrowded curricula, lack of resources or insufficient competences in sustainability [27-29]. Therefore, evaluation tools, such as the Sulitest, with which teachers could get an understanding of the students' sustainability competences, while students acquire sustainability knowledge and obtain generic competences, would be useful.

1.2. Description of the project

The Sulitest is designed to include a global set of questions (module) and a regional/local module. All researchers and teachers are free to suggest questions for the global question pool, after which they are validated by a Sulitest board and added to the test platform. However, in the case of the local questions, it is up to each country or region if the questions will be created or not. The Nordic universities took the challenge in 2015-2016 and created national modules for Finland, Sweden, Norway, Denmark and the Faroe Islands, utilizing the experiences acquired from the first pilot test in Finland during 2014-2015. Also additional 5 questions on Nordic-level sustainability challenges were included in each national module. The final number of questions in the new modules varied between 25 and 31, depending on the country.

The project included also the piloting of the new questions with each partnering universities' students. Four Nordic universities from Norway, Sweden and Finland piloted the Sulitest with their national modules during spring 2017. This paper is based on the results from those pilots. The piloting institutions chose themselves the matrix design of using the Sulitest: as an assessment tool for exploring sustainability literacy, as a teaching tool offering the students the opportunity to study the Sulitest questions with the references they include, or as a tool to introduce the students to the subject. Moreover, all the institutions were instructed to ask the students to fill in an optional background survey following the 50 Sulitest questions, which includes questions on age, gender, discipline and interest toward sustainability.

1.3 Description of the Sulitest architecture

One important feature of the test is the architecture of the questions: the questions should be designed so that there are equal amount of questions belonging to each Sulitest-theme. Preferably, the distribution should be even also in the 24 subjects classified under the 7 themes (see Table 1 for the themes and subjects). Moreover, to facilitate research purposes, the questions must be tagged with at least one sub-subject out of 42, which tells even more precisely what sustainability challenge is discussed in that question.

Table 1. The architecture of the Sulitest: themes and subjects.

Themes	**Subjects**
1. Sustainable humanity and ecosystems on planet Earth	1. Ecosystems: Biosphere, global and local ecosystems, interdependent and diverse community of life, life supporting cycles, system closed (materials) / open (energy), etc. 2. Humanity: Individual human needs, diversity, social fabric, cultures, local and global world, etc 3. Sustainability: Definition of Sustainability / Sustainable development 4. Ecological perspective : where are we at, and why sustainability is both an urgency and an opportunity 5. Social perspective : where are we at (demography, (in)equalities, gender equality, education, …), and sustainability being an urgency and an opportunity
2. Global and local human-constructed systems to answer people's needs	6. Local and global social structures and governance: paradigms; positive results negative impacts; laws; how organisations work; land use; gender equality; etc. 7. Within local and global social structures and governance, zooms on : Education, and Culture 8. Local and global economic systems: paradigms; positive results negative impacts; production, distribution, consumption of goods and services; life cycles; value chains; finances; etc. 9. Within local and global economic system, zooms on : Water, Energy, and Food
3. Transitions towards sustainability	10. How to start, reinforce, accelerate systems change 11. Initiatives towards sustainability … more from institution / int'l level (like UN MDGs, Global Compact, GIEC, GRI, ISO 26000, ESD, etc.) 12. Concepts, tools, frameworks … more from individual NGOs or smaller networks (like Cradle to Cradle, Natural Capitalism, The Natural Step, Ecological Footprint, etc.) 13. Examples and ideas we can learn from: case studies of successes or failures ; technological, strategic, or social innovations
4. We each have roles to play to create and maintain individual and systemic changes	14. How does one become aware of his own roles and impacts … whoever "one "is (individual, organisation, south, north, etc.) 15. How does one efficiently act to create both individual and system change … whoever "one "is (individual, organisation, south, north, etc.)
5. Personal Skills	16. Ability to reflect/self-evaluate alone and in a group; Ability to constantly renew energy; Ability to continuously to learn/develop; Creativity; Critical thinking 17. Capacity for empathy, compassion, solidarity; Futures-oriented and strategic thinking 18. Dealing with complexity and uncertainty; Practical problem-solving / management / planning skills
6. Working with others	19. Networking; Communication skills; building effective coalitions for systemic change 20. Catalysing / managing change; Inspire a shared vision; Enable/Motivating others to act/participate 21. Teamwork; Work in multi-cultural and interdisciplinary (diverse) settings; Participatory skills, decision-making; Conflict resolution skills/consensus building; Focus on process, dialogue, listening;
7.Think and act systemically	22. Ability to put in practice systems thinking concepts; identify and use leverage points 23. Ability to zoom in and out in time and details, and to keep the desired future and global perspective in mind 24. Ability to understand formal and informal structures, power dynamics, and interactions

This paper presents the first results of sustainability literacy levels of Nordic higher education students, and preliminary descriptions on the factors affecting the test results. Moreover, the aim is to initiate discussion on the Sulitest as a tool for sustainability education. For the tool is rather new, it's essential to explore the quality of the created national questions, and what causes may lie behind the questions revealing to be among the easiest or the most demanding ones.

The detailed research questions are:

1. What are the average scores of Finnish, Swedish and Norwegian students?
2. Which factors affect the scores of the Nordic students?
3. How equally the national questions are distributed to the different Sulitest themes?
4. Do the different modules of the Sulitest include questions that are on average very easy or very demanding (over 70% respond correctly / incorrectly)?
5. If there are clear differences in the degree of difficulty of certain questions, are there any common factors in the questions that may explain the trend?

2 RESEARCH FRAMEWORK AND METHODS

The motivation for this study was to explore the usability of the Sustainability Literacy Test (Sulitest) as a teaching and curricula-development tool. We succeeded in having test results from 3 technical and 2 other universities in Norway, Sweden and Finland, the amount of responses being finally 700 in total. The students represented multiple fields, including business, law, water and environmental engineering, sustainability, environmental sciences, environmental management and corporate governance.

The main purpose of the Nordic project's pilots was to gain experiences on how the test could be used in teaching, and to explore if there were too trivial or too demanding questions. Moreover, the project signalled the importance of sustainability issues to students, and that the topic is of great concern to higher education institutions. The most demanding and easiest questions were defined to be those, which <70% or >70% answered correctly, respectively, and were analysed with qualitative content analyses to find out the possible factors explaining the difficulty/easiness. The content analyses was conducted using open coding, based on which classifications for easy and difficult questions were created. The factors affecting the students' sustainability literacy were analysed quantitatively.

As the data was not collected with an empirical research setting, the backgrounds and amounts of students varied substantially between the piloting institutions. Therefore, the approach of this study is explorative, and the results on the students' literacy only suggestive. Moreover, the limited amount of background survey data allowed quantitative analyses for only some of the surveyed factors (only 220 students answered the survey).

3 RESULTS

3.1 Which factors affect Sulitest scores?

The total scores of the students from Finland and Norway were a bit above international reference scores (51% for international module). In all the countries, the international module seemed to be easier for the students compared to the national module. The total results for Sweden were significantly lower compared with both Finland ($p<0,001$, $F=19,193$, one-way Anova) and Norway ($p<0,21$, $F=19,193$). All the average scores are presented in Table 2.

Table 2. The averages of the Sulitest scores from Finland, Sweden and Norway. In counting the national module scores, the results from the students who indicated in the Sulitest background survey being of other nationality than Finnish, Swedish or Norwegian, were excluded.

Sulitest Module (n of questions responded)	Countries							
	Finland		Sweden		Norway		All countries	
	N respon-dents	% correct	N respon-dents	% correct	N respon-dents	% correct	N respon-dents	% correct
International (30)	199	57%	453	50%	48	60%	700	53%
National (20)	157	50%	440	44%	40	46%	637	47%
All questions (50)	199	53%	453	45%	48	52%	700	48%

The vast majority of all the respondents represented Master's degree students, except for Sweden, where 44% of the 106 students who responded the background survey, were bachelor students. However, there was no statistically significant differences between the scores of bachelor and master students, but instead, age seemed to have a positive correlation with the total test score (Fig. 1, r=0,22, p<0,001). Gender instead had no effect on the total scores.

The students responding the Sulitest represented mostly business, law and engineering fields, with only a few students representing other fields, such as arts, humanities and communications. However, since 82% of the 220 students who indicated their discipline in the background survey, represented business and law, the effect of discipline on the scores was not explored.

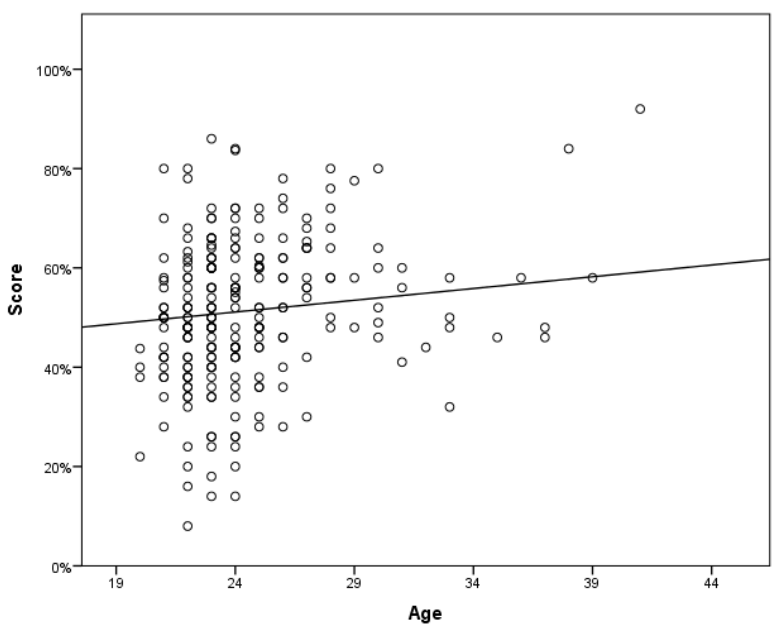

Figure 1. There was a positive correlation between age and total scores of the Sulitest (r=0,22, p<0,001), N = 256.

The nationality of the students seemed to have a minor, yet not significant, effect on the scores: the Nordic nationalities scored better in the national modules compared to the nationalities coming from outside of Nordic countries (international students), whereas the international students scored on average slightly better in the international module (Table 3). Moreover, minor difference was observed between different Nordic nationalities in answering two joint Nordic questions: The Finnish respondents scored better (49%) in a question concerning the eutrophication of the Baltic Sea compared to the Swedish (29%) and Norwegian (25%), whereas the Swedish had better level of knowledge (88%) on the Nordic ecolabel Swan's contents than the Finnish students (40%) (the Norwegians did not answer the Swan-question).

Table 3. The average results of international students compared to Nordic nationalities. The results include only the students who responded the background survey.

Sulitest module	Nordic students		International	
	N	% correct	N	% correct
International	200	55%	58	59%
Finnish	68	50%	37	44%
Swedish	113	45%	13	43%
Norwegian	19	53%	8	36%
All questions	200	50%	58	52%

However, when exploring the effects of sustainability involvement or interest, which were asked in the background survey, there was a statistically significant difference between those who indicated they keep up with the news about sustainability often (n=74, score=57%) compared to those keeping up about the news only rarely (n=128, score=48%), (F=19,863, p<0,001, one-way Anova).

3.2 Quality of the questions

The quality of the national questions varied. The Norwegian module included several questions that revealed to be very challenging, as well as the Swedish module, while the Finnish questions all seemed to be moderate in their level of difficulty (Fig. 3). In all the national modules, theme number 4 was underrepresented compared to the number of questions in other themes, and in Finnish and Swedish modules themes 1 and 2 were somewhat overrepresented (Table 4).

Table 4. The distribution of questions used in the pilots according to Sulitest themes.

Theme	Module				
	International	Finnish	Swedish	Norwegian	All
1. Sustainable humanity and ecosystems on planet Earth	9	4	9	8	30
2. Global and local human-constructed systems to answer people's needs	10	11	11	5	37
3. Transitions towards sustainability	9	8	8	6	31
4. We each have roles to play to create and maintain individual and systemic changes	2	2	2	2	8
5. Personal Skills			1	3	3
6. Working with others				3	3
7.Think and act systemically				3	4
All themes	**30**	**25**	**31**	**30**	**116**

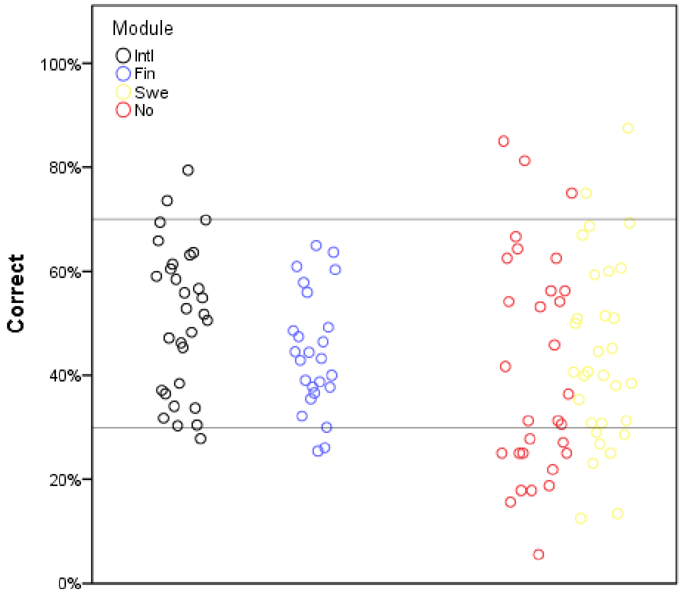

Figure 3. The difference in questions' difficulty in each module: In the Norwegian module, there are more difficult questions compared to the other modules.

Of all the 116 questions used in the pilot sessions, 25 revealed to be on average relatively difficult (<30% of respondents correct), and 9 relatively easy (>70% respondents correct). No explicit factors were found to explain why those particular questions were easy or difficult: they represented multiple subjects and themes. However, questions including statistics seemed to be challenging, specifically when the answering options were close to each other. The most difficult questions also required in many cases detailed knowledge on certain field, and the answering options were well designed making it hard to guess the expected answer. On the contrary, some of the easiest questions were designed in a way, which revealed the correct answer in the formulation of the question. In a few cases the correct answers were also quite evident, as the incorrect answering options were somewhat irrelevant considering the question formulation. (Table 5.).

Table 5. Factors affecting the difficulty of questions.

	Specific information on a field or actors	Statistics	Terminology	Correct answer can be guessed	General knowledge
Difficult questions	18	5	2		
Easy questions	1		1	4	3

4 DISCUSSION AND CONCLUSIONS

Having examined a cohort of 700 responses from students in Norway, Finland and Sweden, this section discusses the main findings. The results are examined against Mulder [3] on how engineering education may contribute to sustainability and how the results indicate interdisciplinary challenges.

Students indicating they follow the media on sustainability subjects seemed to score relatively high in the Sulitest. In addition, the easiest questions in the pilots revealed to include several subjects that are widely discussed in the Nordic public media, such as the effects of Chernobyl radiation, high global costs of climate change or the amount of electric cars in Norway. These results, added with the positive correlation of age and scores, suggest that sustainability literacy discussed in the Sulitest questions measures respondents' level of awareness, all-round education and personal interest, rather than the level a university has been teaching sustainability subjects. Thus, the Sulitest can be recommended only with caution as a tool to assess sustainability contents of curricula.

In addition, the questions used in the test vary from session to session due to the design of the Sulitest online platform: the system randomly selects a set of questions from a larger pool to a single test session. However, we found also the quality of the questions, as well as the representativeness of different Sulitest themes, varying substantially. The uneven distribution of questions concerning different themes may result in biases in students' scores: students having more experience from their studies concerning themes 1-2 might score higher than their peers studying a field that has emphasis on themes 3 or 4 (see Table 1 for the themes). This might make comparisons between different institutions or disciplines unreliable. We therefore suggest the national modules to be developed to a more balanced direction. Moreover, our findings suggest that the strength the Sulitest resides in its ability to evaluate progress from course to course, or within a course, rather than in comparing the scores between students, institutions or countries.

Thus, due to the imbalance of questions representing different themes, we recommend the test to be used by teachers as an introduction to sustainability, or as a teaching tool making good use of the references each question of the Sulitest includes. Segalas et al. [9], for example, called for a common definition on sustainability competences for engineering curricula to facilitate sustainability integration. Sulitest could, if properly developed, offer a framework for teaching world's current situation, reasons behind unsustainability, technological development and ability to act and solve problems. However, one needs to acknowledge that knowledge is not the only factor affecting the environmental performance of a person, but several factors contribute to it, such as country and culture, informal education, and personal motivation and attitudes [30]. To which degree students actually acquire sustainability knowledge and obtain generic competences in higher education was beyond the scope of this study, and invitations to study engineering pedagogy and the use of tests is most welcome.

For future development, we suggest re-evaluation of all the national modules to have appropriate and equal quality and balance between the themes. In addition, we recommend detailed analyses to be made on the students' test results before drawing conclusions on their literacy or making decisions on the curricula according to the test results. Moreover, an empirical study would be needed to investigate more thoroughly the factors having an effect on students' sustainability literacy, such as nationality, age or discipline. The fact that different Nordic nationalities gained varying results from a few questions on Nordic-level sustainability, is also interesting and raises a question if sustainability challenges or actions often considered Nordic, are after all more relevant to specific countries than to the whole region, and the subject could offer possibilities for future research with the Sulitest. Finally, it would be interesting to investigate teachers' motivation to use the test, for it contains many aspects beneficial for higher education.

To conclude, we consider the potential of the Sulitest substantial in teaching global sustainability challenges in universities. According to a short questionnaire by one piloting institution, the test revealed to be eye-opening for many students, presenting the considerable diversity of different fields, challenges, solutions, definitions, management practices and agreements relating to sustainability, added with references to the question sources. Therefore, despite its weaknesses as an assessment or curricula development tool, it can facilitate the teachers also in engineering education substantially in drawing a comprehensive picture on the problems the future engineers are required to solve, and on the interdisciplinary and interconnected nature of future working life.

ACKNOWLEDGEMENTS

We want to express our warmest gratitude to all partners in the Nordic project, and all the experts involved in creating the national modules. We additionally want to thank the Sulitest organization for the smooth collaboration and assistance in creating the national modules. This study wouldn't have been possible without the kind permission from the piloting universities to use the students' Sulitest results for analyses. The Nordic Sulitest project was funded by the Nordic Council of Ministers.

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How to integrate Sustainability and Entrepreneurship in the Ba/Ma-Curricula?

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ABSTRACT

The paper presents the design-process of new bachelor/master-curricula at the Technische Universität Berlin. Examples for the successful integration of sustainability and entrepreneurship in the curricula are presented. The master program “innovation management, entrepreneurship and sustainability” and the one year orientation study program “MINTgrün” were introduced in detail. With the instruments of our quality-management-system the behaviour as well as the competencies of our graduates has been assessed. The centre of entrepreneurship gives support for the start-up foundation and helps in the cultural change on the way to an entrepreneurial university.

Conference Key Areas: Curriculum Development, Attractiveness of Engineering Education, Sustainabilty and Engineering Education

Keywords: Entrepreneurship, Sustainability, Curriculum Design, Quality Management

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INTRODUCTION

The Technische Universität Berlin (TUB) offers 51 bachelor (Ba) and 73 master (Ma) study programs. 65 % of the fields of study of TUB are in engineering, 15 % in mathematics and natural sciences and 20 % in social sciences and humanities. Sustainability and Entrepreneurship are addressed in the mission statement of TUB. Both topics should be integrated in research and education as well. In the following we will show, how sustainability and entrepreneurship are integrated in our curricula. With the instruments of our quality-management-system (QMS) we have assessed, if students and graduates have been educated in the line of our mission statement.

1 DESIGN OF A NEW CURRICULUM

1.1 General design

The flexibility in the design of the curricula has been made possible by the Bologna-process. This process has led to the transformation of the one-cycle diploma curricula through the two-cycle Ba/Ma-system. The Bologna transformation of the curricula started at TUB in the year 2004/2005. Of specific significance was the paradigm change in the design-process, the so called shift from teaching to learning. Here, the workload as well as the competencies achieved by the students during the learning process has been taken into account in the design-process for a new Ba/Ma-curriculum. In the following, we describe the design-process and the structure of a Ba/Ma-curriculum at the TUB.

Altogether, the length of study of a consecutive Ba-/Ma-program does not exceed 5 years due to German law regulations. Thus, usually mainly three-year bachelor and two-year master are realized at TUB. Each year of study is organized in two semesters. A student should get 30 credit points in one semester according to the European Credit Transfer and Accumulation System (ECTS). The credit points are corresponding to the workload of the students. One credit point is equivalent to 30 hours of work. The resulting annual workload is 1,800 hours. If the students have finished the master they have achieved 300 credit points in the consecutive bachelor-master program. *Fig. 1* shows the schematic structure of a consecutive Ba/Ma-curriculum in engineering.

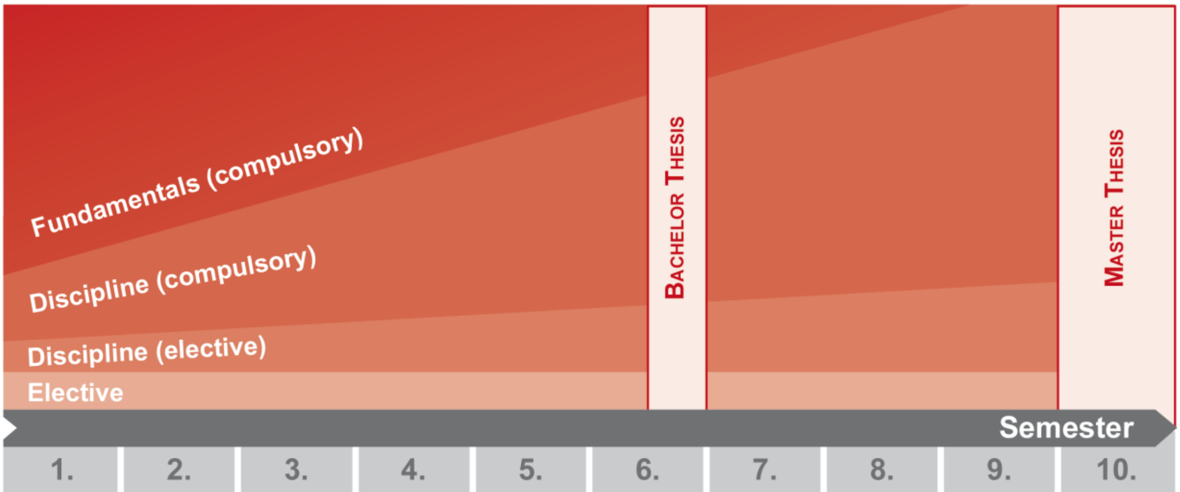

Fig. 1. Schematic Ba/Ma- curriculum in engineering at TUB.

The fundamentals (like mathematics, physics, mechanics and thermodynamics) dominate in the first semesters of the bachelor in engineering. Usually, they are compulsory. The new developed curricula of the bachelor programs include project work in the first semester courses on subjects of particular significance in the specific engineering discipline to increase the academic success. The curricula are constructed with modules. The workload of the modules is usually 6, 9 or 12 credit points. The compulsory part of the specific engineering discipline increases during the bachelor-semesters. An individual profiling of the students competencies is possible with the elective-compulsory part of the discipline and the free elective part of the curriculum. Both bachelor and master programs usually contain internships in industry (range between 6 and 12 credit points). They are part of the compulsory part of the specific engineering discipline. In the master programs the fundamental part is much smaller compared to the bachelor. The curriculum is dominated by the specific compulsory and the compulsory elective part. In the last semester the master thesis is elaborated. The formal design process of a curriculum is fixed in our QMS. However, the relevant content as well as the final curriculum is established in the faculty.

1.2 Entrepreneurial modules

Around 50% of the curricula of all Master degree programs require entrepreneurship courses as mandatory or semi-mandatory, for all other students these courses are elective. The courses are organized from offering basic knowledge and first contacts to entrepreneurs up to the development of business plans and proto-types. In detail, three of these modules are described in the following:

<u>Module venture campus (12 credit points):</u> The strategic aim of this course is sustainable support and economic exploitation of high- tech foundation potential of the students of the TUB. As a practically oriented course, venture campus is providing its students with all business and management skills required for the establishment of a start-up company. Within this course its participants are working closely together in interdisciplinary teams preparing business plans. Although the economic realization of the business plans of the participating teams is not required in reality it is highly acknowledged and around 30 start-ups were established out of this course in the last 10 years.

<u>Module entrepreneurship research (6 credit points):</u> In contrast to venture campus the entrepreneurship research course is theoretically oriented as it aims at giving students a state-of-the-art overview of all streams of research around the theme entrepreneurship. The course intends to shed light on different aspects from managing and aligning internal and external networks, all facets around founding enterprises, how to explore and develop markets, how to get and exploit creative ideas, the debate effectuation und causation, just to mention a few. The course studies both theoretical models and their empirical application, changing between micro and macro-economic perspectives with a strong methodological focus. This course may also be combined with venture campus resulting in a total of 18 credit points.

<u>Module innovation management and entrepreneurship (6 credit points):</u> This module is an integrative course on the basics of entrepreneurship and innovation management. The course focuses on the in-depth understanding of aspects as idea generation, technology-based entrepreneurship, marketing and markets, organization and project management, new product and process development, entrepreneurial finance and human resource development. The basic course is based on introductory lectures into the above mentioned topics. In addition, the students get lectures/presentations from entrepreneurs and visit entrepreneurial venues, companies, incubators, customers etc. In order to increase the practical relevance of the course lectures are complemented with team-work on case studies or small

entrepreneurial projects. The course is the basic course on entrepreneurship and innovation for students of European Institute of Innovation and Technology (EIT) master programs and is as all other courses above taught in English.

1.3 Sustainability modules

The number of modules with sustainability contents is significantly higher than those of the entrepreneurial modules. At least 30 modules with sustainability contents are identified so far. It is the plan for this year, to realize a sustainability certificate. This certificate will be given to Ba/Ma-students, which receive at least 18 credit points from modules with sustainability content.

“tu project” supports undergraduate students with a two-years funding for an own research project. These projects have been invented in the year 2012 and they are founded by the Federal Ministry of Education and Research [1]. According to the mission statement of the TUB the funded project should have a focus on sustainability and interdisciplinary teamwork. In order to start a tu project, two students have to write a project plan for a research topic. The project should run for two years and usually 15-20 students as participants should be involved. Usually, the student team is mixed in age and disciplines. According the specific workload, the participants receive credit points directly corresponding to their personal workload within the project. Up to now 34 tu projects have been realized. Topics range from “simulation game for technical environment protection” to “welfare accounting” and promise to yield new insights for the involved disciplines.

In the module “prototyping eco-innovation” aspects of sustainability and entrepreneurship have been combined.

2 EXAMPLES FOR NEW CURRICULA

2.1 Master innovation management, entrepreneurship and sustainability

Moreover, one master degree program (MSc) is specifically devoted to innovation management and entrepreneurship and is the most attractive one in Germany with more than 500 applicants for 35 places. It is the dual degree master`s program “innovation management and entrepreneurship” (IME) organized in cooperation with the University of Twente, the Warsaw School of Economics, the Higher School of Economics in Moscow, the St. Petersburg Polytechnical University and the Norwegian University of Science and Technology. Students are supposed to stay two semesters in Berlin and two semesters in one of the partner institutions. The compulsory area comprises 30 credit points. Modules are “entrepreneurship research”, “venture campus”, “innovation economics” and “strategic management”. In the compulsory elective part the students should select modules with a total of 30 credit points. 30 credit points are elective. It is strongly recommended, to elect courses in the fields of management, innovation management, entrepreneurship, business administration, economics and industrial engineering and management. The master`s thesis is usually completed in the fourth semester. It comprises 30 credit points. The last ranking 2015 based on the evaluation of human resource departments made by “Wirtschaftswoche” sees the entrepreneurship education at TUB among the top ranked business education in Germany. The eduniveral ranking 2015/16 ranked this master as the best in Germany and the number 42 worldwide. In the CHE Master Ranking 2014, the IME master is classified as Germany`s leading master program in 5 out of 14 categories. The IME is leading in “Study comfort”, “Practice focus”, Scientific focus”, “Support in international exchange” and in International orientation”. Recently, the curriculum was redesigned and a new sustainability track has been opened. In the winterterm 2017/2018 the new master “innovation management, entrepreneurship and sustainability” will start. The structure of entrepreneurship courses at TUB also served as blue-print for the educational programs at the EIT and was copied in many European universities.

2.2 Orientation study program MINTgrün

MINTgrün (English STEMgreen) is a one year orientation study program. It addresses high school graduates who are interested in natural sciences and engineering but don’t yet know what exactly to study. The superscript “grün” indicates the conceptual focus on ecological und social questions. The target of MINTgrün is to show them the several possibilities of a future in natural sciences, technology, engineering and mathematics. A special target group are young women, who miss aspects of sustainability in the regular engineering curricula. Mandatory courses are the “science window” and the “orientation course” as well as the “MINTgrün laboratories” (all 6 credit points). In the laboratories, real project work has to be done. Examples of the labs already have been published [2, 3]. In the mandatory elective part (42 credit points), the students can choose all modules within the university. Popular are modules like mathematics, physics and computer science (6 credit points). All received credit points are usually accepted if the students will change to another bachelor-degree program. MINTgrün started in 2012 with 77 students. The number of participants increases continuously up to 490 in the year 2016. Today, we have 38 % female students (average at TUB in engineering is 28 %, overall 33 %). The program enables approximately 82 % of the MINTgrün students to make an informed decision on their later field of study, 74 % of them stay in the field of STEM. 10 % see their future outside academic contexts. In the next 4 years we will investigate, if the success rate of former MINTgrün students is higher from those students, who choose their bachelor directly.

2.3 Master programs at the TUB- EUREF campus

At the TUB-European Energy Forum (EUREF) campus, three international MBA-degree-programs where actually offered since the year 2016: “energy management”, “european and international energy law” and “building sustainability – management methods for energy efficiency”. The new program “sustainability mobility management” will start in the winterterm 17/18. The energy transition of the society is in the focus in these master degree programs. The study location is on the site of the EUREF around the historical Gasometer in Berlin-Schöneberg. The campus is the setting of an innovative community including applied research, economic and policy consultancies mainly based on the philosophy of sustainability.

3 QUALITY MANAGEMENT

3.1 Process Management

The QMS of the TUB is designed close to the ISO-9001 norm. The relevant processes are available on the website of TUB. In order to evaluate the performance in teaching and learning several instruments are used in our QMS. However, there often is no simple way from check to act, but the results are helpful both for the internal discussion and marketing purposes.

3.2 Graduate studies and impact for the region

Continuous improvement of the curricula was performed by using the results of the quality management instruments. Especially our graduate surveys, which were performed in cooperation with Incher Kassel since 2009 in a nation-wide-project are very well accepted inside the university. The graduates of every year were polled with a detailed questionnaire 1.5 year after graduation. The response rate is usually around 35 % and the results are representative. Current investigations concern the TUB-graduates of the year 2014. Table 1 present some keyfacts for this graduation year.

Table 1: Keyfacts of the graduation survey for the TUB-graduates of the year 2014.

Keyfacts of the graduation cohort 2014	Bachelor degree	Master degree	Diplom degree	TUB overall average
Percentage of female gender	28	30	30	30
Avarage age at time of graduation (years)	25.3	28.1	30.4	27.4
Avarage grade at graduation	2.2	1.7	1.8	1.9
Avarage duration of study (Fachsemester, Median)	8.0	5.0	14.0	8.0
Avarage duration for job search (in months; Median)	2	3	4	3
Average income (pre-tax) per month in € (Median; Only full-time employees)	2,626	3,251	3,251	3,251
Overall satisfaction with TUB (Median 1=very satisfied / 5=very unsatisfied)	2.0	2.0	2.0	2.0
Overall job satisfaction (Median 1=very satisfied / 5=very unsatisfied)	2.0	2.0	2.0	2.0
Number of graduates (N)	**525**	**448**	**200**	**1173**

Both the overall satisfaction with the TUB, as well as job satisfaction at the first job is evaluated good (= 2.0) by bachelor and master graduates. However, the average salary per month in the first year is significantly lower for the bachelor graduates (€ 2,626) compared to the master graduates (€ 3,251). To explain the difference we like to remark that Ba-programs are viewed in the German public sector as leading to second-rank careers ("gehobener Dienst"), whereas Ma-programs lead to first-rank careers ("höherer Dienst"). In the last three graduation cohorts, the salary of the bachelor graduates has increased about € 750 whereas the Ma-value remains constant. This indicates the raising acceptance of bachelor graduates on the job market. In the last four graduation cohorts, the graduates received their first jobs outside university one to three months after graduation. Graduate studies also show the relevance of the graduates for the regional job market. These results are of great importance for the society and the regional government as well. *Fig. 2* shows, that more than 60 % of the TUB-graduates (graduation years 2011, 2012, 2013, 2014 and 2015) find their first job in Berlin. In computer science, nearly 80 %, except in 2015, remain to work in Berlin.

Berlin has become the first start-up city in Germany. 17 % of the German start-ups had their headquarters in Berlin in 2016. Berlin has also the highest foundation rate for start-ups in computer science. In order to strengthen the science in this area, a new centre (Einstein Centre for Digital Future) as a joint venture between Berlin universities and industry with the financial support of the government and the Einstein-foundation has been opened at the 3rd of April 2017 in Berlin. Here, up to 50 new professors in the field of computer science come to the universities and will increase the power of the in this area significantly. The overall funding is € 38.8 million for the next six years.

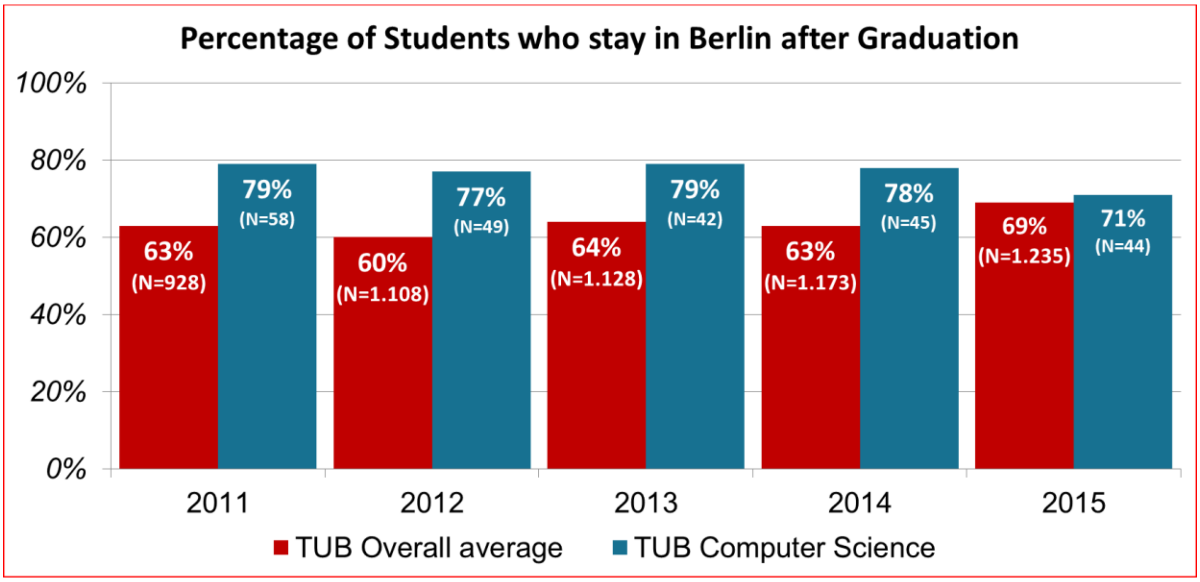

Fig. 2: Berlin as a working place for TUB graduates.

Another fact is remarkable in our graduate studies: 44 % of our graduates could imagine, that they will found their own company in the future. In computer science, the corresponding amount of 61 % is significantly higher. The detailed result for the different disciplines is shown in figure 3.

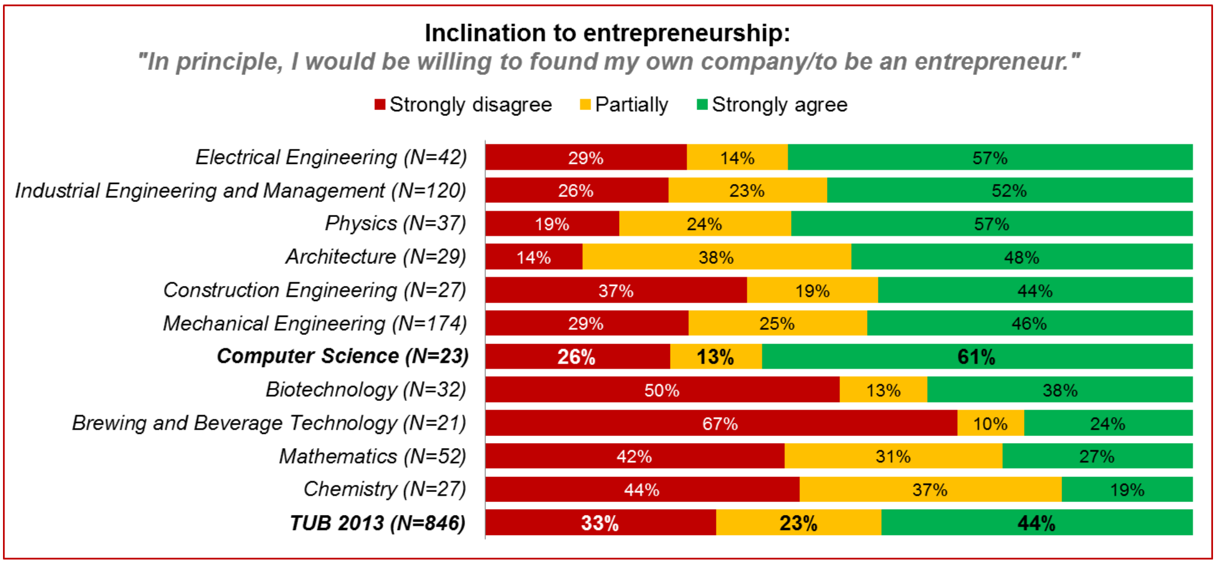

Fig. 3: Inclination to entrepreneurship of TUB-graduates (Graduation year 2013).

Recently, a new study shows the courses offered for the EIT effect entrepreneurial intentions and attitudes significantly positive in only five weeks [4]. It has been proved, that opinion leadership in entrepreneurial related topics positively influences changes in the pro-entrepreneurial intentions. Therefore, we address some of these topics (i. e. start-up science slam, talks by famous founders…) even in the opening ceremony for the new freshman students since 2015. However, we do not have panel studies or tracking which proves the careers of our graduates so far.

4 THE CENTRE FOR ENTREPRENEURSHIP

The TUB aims at profoundly embedding the subject of entrepreneurship in all areas of the university and to make use of the huge potential of commercializing inventions and research results. It´s not surprising that the university decided to do the next step and to concentrate its competencies in research, education and practical entrepreneurship support within the Centre for Entrepreneurship (CfE) which was established in April 2010. The advantage of this new integrated institution is its long-term orientation. Thus, the CfE is financed not only by third-party funding but has also stable financing from university-side. Before designing the TUB CfE programmed, its staff benchmarked successful counterparts at Stanford, the Massachusetts Institute of Technology, Danish Technical University and ETH Zurich. The activities of the CfE are organizationally divided into three main areas: research, education and practice (advice and support). Thereby, the research activities are located at the Chair of Entrepreneurship and Innovation Management. The Founder's Service is responsible for the practical entrepreneurship support of TUB entrepreneurs. The education activities, finally, are coordinated and executed by both the Chair of Entrepreneurship and Innovation Management and the Founder's Service and where described above. The success of the CfE has been measured recently. There are 25 high-tech start-ups per annum in average. More than 70 % of those who have received intensive coaching since 2007 are still in business. The CfE has a great economic impact for the city and beyond: In 2015, 758 spin-off companies run by Alumni of TUB employed up to 20.000 people. The overall turnover was 2.7 billion Euros. Some of the start-ups have direct connection to sustainability topics. On example is the start-up akvola which was founded in 2013. The idea is to make a sustainable sea water treatment. The company receive the ACES Green award and is described in [5]. The "Gründungsradar" an evaluation of academic entrepreneurship sees the TUB on position three out of all larger German universities.

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Student Comparative Self-Assessment based on Learning Outcomes

Evaluation of a Stand-Alone Course on Sustainability and Engineering.

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ABSTRACT

The on-going evaluation of a stand-alone on sustainability and responsibility at Technische Universität Berlin aims at a comprehensive triangulation of quantitative and qualitative data. This paper will present the core of the quantitative evaluation: A student comparative self-assessment. The students themselves rate their competences on a 6-point Likert scale. The items of this survey are based on the learning outcomes of the course. The assessment takes place either at the beginning (pre) and at the end (post) of the course or as a combined assessment looking back to the beginning of the course (then) and after completing the course (post). The pre-/then-/post-testing results show a significant gain of competences. The described process can easily be adapted which makes this paper relevant for anybody interested in evaluating a course on sustainability and engineering.

Conference Key Areas: Sustainability, Ethics or Engineering Education Research

Keywords: self-assessment, competences, sustainability, ethics, learning outcomes

INTRODUCTION

Education for Sustainable Development (ESD) aims at fostering a generation of active citizens equipped with the tools, knowledge, and experience they will require to induce sustainable changes in both professional and personal contexts [1]. ESD is unique in its quest to ensure graduates to not simply graduate with more knowledge, but newfound competences to embody the traits they value and the capability to act accordingly. In order to be effective within an outcome-based education, competences need to be implemented as learning outcomes. Next, these learning outcomes should be aligned with teaching/learning activities, assessment of students and course evaluation to ensure a coherent teaching/learning experience.

The Blue Engineering Course at Technische Universität Berlin (TUB) addresses the ecological and social responsibility of engineers. Its learning outcomes are based on the concept of Gestaltungskompetenz [1]. Therefore, the learning activities are organized in such a manner that students may acquire competences of an ESD. An effective evaluation of such a course is demanding due to the complex nature of ESD competences and the corresponding activities. This paper will provide a case study on how to describe learning outcomes for such a course and how to evaluate whether the students reach these learning outcomes through a student comparative self-assessment.

1 DESIGN AND CONDUCTION OF THE BLUE ENGINEERING COURSE

The Blue Engineering Course is organized in a highly interactive manner that takes the shift from teaching to learning [2] seriously. Roughly speaking, only one third of the course is conducted by the tutors while two thirds are conducted by the participants themselves. For a successful completion of this 6 ECTS course, the students have to fulfill four assignments: 1) to keep a learning journal [3] over the whole semester; 2) to conduct an existing teaching/learning unit of about 60 minutes length; 3) to develop and conduct a new demanding teaching/learning unit on a topic of their choosing [4]; 4)to document this teaching/learning unit in such a way as to enable others to conduct it.

The fourteen-week course has been first conducted during the winter-semester 2011/2012 with 24 students. From this semester onward, it has been offered every semester, which amounts to a total of 12 semesters and 564 students who participated in it. The number of participants was raised continuously and levels now over last six semesters at about 70 students per semesters. About 31% of the participants study mechanical engineering and about 22% study industrial engineering, where the course can be chosen as an option from a list of compulsory courses. The rest of the students take it as an elective from various study programmes crossing all faculties.

2 LEARNING OUTCOMES OF THE BLUE ENGINEERING COURSE

The description of the learning outcomes of the course follows a design down process, which means that the learning outcomes on the higher educational levels function as guidance on the lower levels [5]. State law as well as various regulations at TUB require that students will learn about responsibility as well as sustainability through various study programmes. Therefore, the described course can easily be integrated into the overall learning outcomes of said university.

For the course itself, two learning outcomes describe what the participants will have learned at the end of the course. These two learning outcomes on the general level of the course are then further ‘designed down’ to be used on lesson level as well as on exercise level. The learning outcomes on the various level have been developed in an open participatory process over the course of five years. The multi-disciplined core team consisted of the professor responsible for the course, two lectures charged with the further development of the course, 8 tutors and many members of the student group that has initially developed the course. Their work was regularly feedbacked by their peers and participants of the course.

2.1 Two Learning Outcomes on the General Level

The two general learning outcomes consider for the individual responsibility as well as the collective responsibility of (future) engineers [6]. Furthermore, the learning outcomes identifies engineers as relevant actors in the democratisation of society nature-relations [7] as well as the general power relations of society [8].

1) The prospective engineers analyze and evaluate the present reciprocal relations of technology, individuals, nature and society by taking different perspectives. Based on this analysis and evaluation, they are able to state their personal perspective and values of the reciprocal relations and act accordingly.

2) The prospective engineers cooperate with others to analyze and evaluate in a democratic process the present reciprocal relations of technology, individuals, nature and society. Based on their analysis and evaluation, they are able to work out a collective understanding with regard to their collective values and democratise the reciprocal relations.

2.2 Twelve Learning Outcomes on Course and Lesson Level

These two general learning outcomes are further design downed by adapting an existing framework of competences of ESD. The concept of Gestaltungskompetenz [1] was chosen over other concepts as it is the only concept that is placed within the broader framework of the set of OECD key competences. It comes with many good practice implementations as it is widely used within Germany where it was used to implement the UNESCO Decade of ESD [1] at the secondary school level. In addition, it is also picked up on an international level in higher education where a trend towards a harmonization of ESD competences is identified [9].

For the design down process, the 12 broadly recognized sub-competences of Gestaltungskompetenz of an ESD [1] have been reformulated as learning outcomes. Next, they were adapted to reflect the two general learning outcomes which let to a total of 12 specific learning outcomes for the Blue Engineering course. See Table 1. These learning outcomes are already specific enough to constructively align with the broad range of learning activities of the course as well as with the formative assessment of the students. Furthermore, this precisoning allows for a comprehensive evaluation of the whole course as described in this paper.

3 EVALUATION OF THE ANONYMOUS COURSE

The Anonymous Course is part of an ESD. As such, it provides a highly demanding and complex learning environment where students have to define and solve problems themselves. Therefore, it does not aim at simple competences that can be assessed in laboratory-like settings where the learning outcome is reached if students would answer, react or behave in one specific way alone and in that way only [5]. If the learning outcomes of a course are competences of an ESD neither one summative assessment, i.e. a multiple-choice test at the end, of the students seems applicable nor one summative assessment. Instead, a comprehensive triangulation of quantitative and qualitative data is necessary to ensure that all aspects of the learning outcomes and therefore all aspects of the 12 sub-competences of Gestaltungskompetenz are properly evaluated. For example, the qualitative evaluation is realized through the analysis of the learning journals as well as through written feedback at the end of particular lessons and at the end end of the course. Among other data acquisitions, a quantitative evaluation is realized through standardised questionnaires for the whole course which is the same for all courses on faculty level as well as the evaluation of particular lessons through questionnaires that are specific to this lesson. In addition, there are two mixed evaluations that are also specific to certain lessons of the Anonymous Course.

Table 1. Gestaltungskompetenz / Learning Outcomes / Questions for Self-Assessment

Sub-Competences of Gestaltungskompetenz (de Haan 2010)	**Learning Outcomes of the Anonymous Course on Course Level**	**Questions for Student Self-Assessment**
OECD - Competence Category - Tools - Using Tools Interactively		
T1 - Perspective-Taking - to gather knowledge in a spirit of openness to the world, integrating new perspectives	T1 - Students take perspectives, change points of view and gather diverse forms of knowledge (i.e. scientific, traditional, common sense) from various actors on the spatial and temporal effects of technology on individuals, society and nature.	T1.1 - argue from different points of view T1.2 - describe the influence of technology on nature and society
T2 - Anticipation - to think and act in a forward-looking manner	T2 - Students anticipate spatial and temporal effects of technology on individuals, society and nature.	T2.1 - consider present and future effects of one's own actions T2.2 - describe the local and global effects of technology
T3 - Gaining Interdisciplinary Knowledge - to acquire knowledge and to act in an interdisciplinary manner	T3 - Students gain knowledge of the reciprocal relations between technology, individuals, nature and society through inter- and transdisciplinary approaches.	T3.1 - find and incorporate knowledge outside of my own discipline
T4 - Deal with Incomplete and Overcomplex Informations - to deal with incomplete and overly complex information	T4 - Students deal with incomplete and over complex information on the reciprocal relations between technology, individuals, nature and society and the risks, dangers and uncertainties which arise from them.	T4.1 - choose an option, although possible consequences are unknown
OECD - Competence Category - Cooperation - Interacting in Heterogeneous Groups		
C1 - Cooperation - to co-operate in decision-making processes	C1 - Students cooperate for a democratic decision-making with regard to process, result and implementation.	C1.1 - reflect upon a group process with respect to process and result
C2- Cope with Dilemmas of Decision-Making - to cope with individual dilemmatic situation of decision-making	C2 - Students cope with dilemmas of decision-making when values and aims are conflicting.	C2.1 - mediate conflicts of goals and values with others

C3 - Participation - to participate in collective decision-making processes	C3 - Students participate at collective decision-making processes.	C3.1 - constructively introduce my point of view in a group discussion
C4 - Motivation - to motivate oneself as well as others to become active	C4 - Students motivate oneself and others to democratize the reciprocal relations between technology, individuals, nature and society.	C4.1 - spread knowledge towards other students C4.2 - prepare a didactical unit on a complex topic
OECD - Competence Category - Action - Acting Autonomously		
A1 - Reflect Principles - to reflect upon one's own principles and those of others	A1 - Students reflect principles which control the reciprocal relations of technology, individuals, nature and society.	A1.1 - know one's own attitude and values towards technology A1.2 - put oneself in the position of others to understand their motives
A2 - Act Morally - to refer to the idea of equity in decision-making and planning actions	A2 - Students identify the underlying values which shape the reciprocal relations of technology, nature, individuals and society and to use them to act morally.	A2.1 - act according to one's own attitudes and values
A3 - Act Independently - to plan and act autonomously	A3 - Students plan independently and act autonomously according to one's own values.	A3.1 - prepare one's own problem statement
A4 - Support Others - to show empathy for and solidarity with the disadvantaged	A4 - Students support others who are disadvantaged due to the dominating design of the reciprocal relations between technology, individuals, nature and society.	A4.1 - identify causes of social inequalities

4 STUDENT COMPARATIVE SELF-ASSESSMENT SURVEY

4.1 Design of the Student Comparative Self-Assessment Survey

A student comparative self-assessment survey is the central part of the quantitative evaluation. For this, each of the 12 specific learning outcomes has been reformulated to reflect a specific part of the course. See Table 1. In addition, to the listed items which were evaluated in every semester, there was a varying set of questions which were used in specific semesters alone. Each item was to be answered on a 6-Point Likert-Scale where students could rate their own competences ranging from 'high' to 'low'. The data collection took place as a classical comparative survey where the students self-assess their competences at two different points in time. In total, five consecutive semesters have been evaluated in this manner from winter-semester 2014/2015 up until the winter-semester 2016/2017. In the first three semesters the surveys were conducted in a pre-post manner, meaning that the survey was filled out in the very first lesson (pre) as well as in the very last lesson of the course (post). For the past two semesters the same items were put into a then-post survey which was filled out at the end of the course. For this, the participants were asked to recall how competent they would judge themselves at the beginning of the course (then) and to judge how competent they are now at the end of the course (post).

4.2 Results of the Student Comparative Self-Assessment Survey

Table 2 shows the major results of the student comparative self-assessment survey. In total, 354 students have successfully completed the Anonymous course in the five evaluated semesters. However, only 216 students have completed the survey at the end of the class, which equals 61%. This discrepancy is due to the fact that the participation in the survey was totally voluntary and that the attendance at the course is generally lower at the end of the semester as students start to prepare for their exams.

Overall, the students judge all of the tested competences much higher at the end of the course than at the beginning of the course. Figure 1 shows the aggregated answers of the pre/then and post survey in a heat map. In addition, this finding is backed up with t-test results usually below $p = 0.01$ which would indicated a significant change. It has to be noted, that the then-post surveys do not show as strong positive gains in self-assessed competences as the pre-post surveys. However, this is in line with other research which stresses the point that then-post surveys might stronger be affected by the impact of implicit theories of change [10]. These quantitative results can also be verified through the qualitative evaluation.

5 CONCLUSION

This paper argues for the adaption of an existing set of ESD competences in a design down process in order to render them useful in a concrete course setting. It further shows how these specific competences can be implemented as learning outcomes. Course specific learning outcomes proved to be helpful for the design of aligned teaching/learning activities and corresponding assessments of students. In addition, specific learning outcomes that are based on competences can also be used for the evaluation of the course itself which may help to reveal if students judge themselves more competent after attending the course.

The workload of the lecturers can further be reduced by conducting the self-evaluation as a then-/post-survey as this type of survey requires only one survey at the end. This method does not endanger the comparative self-evaluation as it also may reveal significant competence gains on the side of the students.

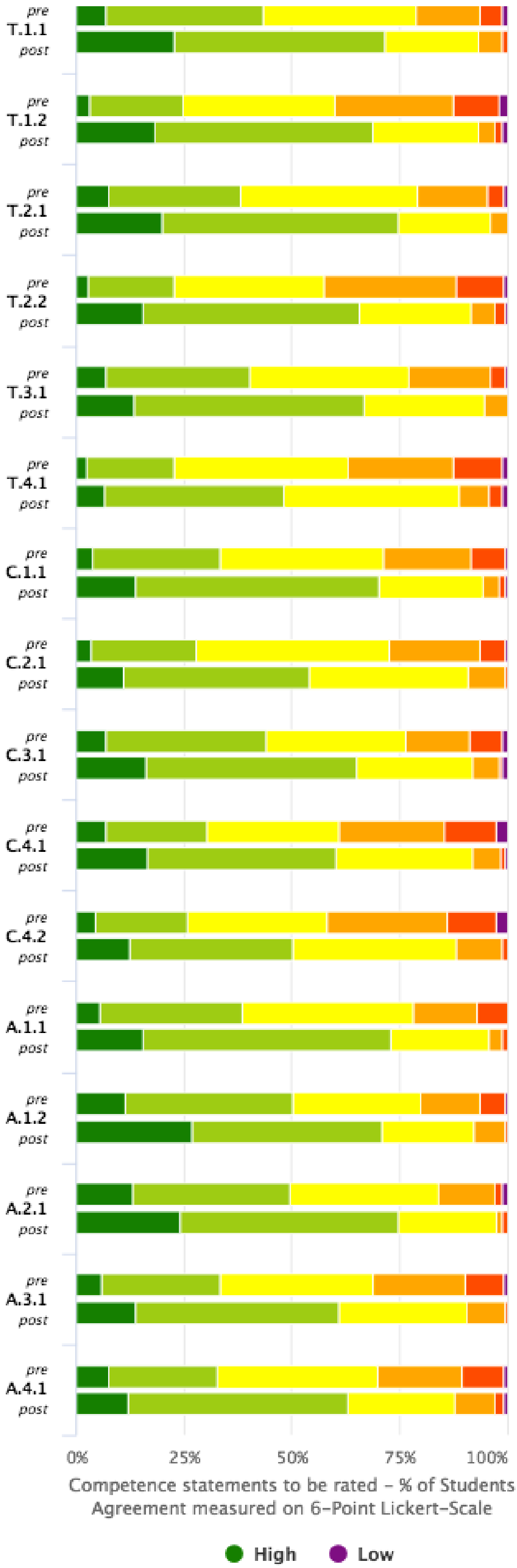
The description of the learning outcomes for the Blue Engineering Course has been a demanding and tiring process. It is has not been concluded yet, as the course itself is continually restructured every semester in order to incorporate new developments and students' feedback. However, so far the description of learning outcomes has been worthwhile as it proved to be helpful not only to reflect upon the course's design and activities but also to evaluate the course accordingly.

Overall, this paper advocates the use of course specific learning outcomes as various synergies may arise which may help to create better and more successful courses.

Table 2. Results of Student Self-Assessment Survey

	2014_2		2015_1		2015_2		2016_1		2016_2		Mean
	course n = 74 pre n = 75 post n = 47		course n = 79 pre n = 78 post n = 48		course n = 66 pre n = 69 post n = 40		course n = 78 then n = 46 post n = 46		course n = 57 then n = 35 post n = 35		course n ~ 70 then n ~ 61 post n ~ 43
	pre post	diff ttest	pre post	diff ttest	pre post	diff ttest	then post	diff ttest	then post	diff ttest	pre post
T1.1	3,97 4,67	0,7 <0,01	4,11 5,00	0,89 <0,01	4,59 5,13	0,53 <0,01	4,23 4,86	0,64 <0,01	4,25 4,67	0,42 0,11	4,23 4,87
T1.2	3,57 4,85	1,28 <0,01	3,71 4,84	1,13 <0,01	4,03 4,70	0,67 <0,01	3,55 4,79	1,24 <0,01	3,83 4,61	0,78 0,01	3,74 4,76
T2.1	4,20 4,79	0,58 <0,01	4,10 4,90	0,8 <0,01	4,62 4,87	0,25 0,14	3,91 4,95	1,04 <0,01	4,00 5,08	1,08 <0,01	4,17 4,92
T2.2	3,22 4,47	1,24 <0,01	3,82 4,62	0,8 <0,01	4,09 4,60	0,51 0,01	3,70 5,07	1,36 <0,01	3,78 4,78	1,00 <0,01	3,72 4,71
T3.1	4,20 4,76	0,56 <0,01	4,09 4,76	0,67 <0,01	4,32 4,83	0,51 0,01	4,20 4,70	0,49 0,02	4,23 4,72	0,49 <0,01	4,21 4,75
T4.1	3,80 4,32	0,52 <0,01	3,57 4,62	1,05 <0,01	4,03 4,63	0,6 <0,01	3,73 4,30	0,57 <0,01	3,56 4,00	0,44 0,09	3,74 4,37
C1.1	3,79 4,54	0,76 <0,01	3,82 4,76	0,94 <0,01	4,33 4,98	0,64 <0,01	4,09 4,68	0,59 0,01	4,09 4,91	0,83 <0,01	4,02 4,77
C2.1	3,79 4,36	0,57 <0,01	3,81 4,70	0,89 <0,01	4,32 4,60	0,28 0,11	4,02 4,56	0,54 <0,01	4,00 4,58	0,58 <0,01	3,99 4,56
C3.1	4,33 4,89	0,56 <0,01	4,16 4,86	0,69 <0,01	4,50 4,70	0,2 0,27	3,95 4,57	0,61 0,01	3,56 4,44	0,89 <0,01	4,1 4,69
C4.1	3,71 4,60	0,89 <0,01	3,58 4,82	1,24 <0,01	3,95 4,69	0,74 <0,01	4,05 4,59	0,54 0,03	4,06 4,64	0,58 0,02	3,87 4,67
C4.2	3,55 4,51	0,96 <0,01	3,32 4,40	1,08 <0,01	4,01 4,45	0,44 0,04	3,98 4,52	0,55 0,01	4,15 4,69	0,54 0,02	3,8 4,51
A1.1	4,05 4,72	0,67 <0,01	4,18 4,85	0,68 <0,01	4,55 5,00	0,45 0,01	3,72 4,70	0,98 <0,01	4,09 4,92	0,83 <0,01	4,12 4,84
A1.2	4,33 4,89	0,56 <0,01	4,24 5,02	0,78 <0,01	4,43 4,75	0,32 0,12	4,41 4,98	0,57 0,01	4,42 4,83	0,41 0,07	4,37 4,89
A2.1	4,34 5,09	0,74 <0,01	4,32 5,02	0,70 <0,01	4,75 4,95	0,2 0,33	4,52 5,05	0,52 0,01	4,14 4,61	0,47 0,04	4,42 4,94
A3.1	3,76 4,51	0,75 <0,01	3,67 4,71	1,04 <0,01	4,29 4,78	0,49 0,02	4,34 4,80	0,45 0,01	4,08 4,44	0,36 0,07	4,03 4,65
A4.1	-	-	-	-	4,13 4,54	0,41 0,04	3,86 4,60	0,74 <0,01	3,89 4,65	0,76 0,01	3,96 4,6

Figure 1. Heat Chart.



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Engineering and Sustainability Education in Nigeria

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ABSTRACT

Since gaining independence in 1960, Nigeria has witnessed spiralling engineering infrastructural developments, such as road construction and development of Ajaokuta steel plant and refineries. Nigerian Higher Education Institutions (HEIs) have trained engineers who occupy important engineering posts in the public service and private sectors that administer some of these projects. With Nigeria's ratification of several sustainability pacts, it is pertinent to consider the extent to which sustainability education is reflected in its engineering education. This paper presents a review of Nigerian engineering education based on an analysis of the Benchmark Minimum Academic Standards for Undergraduate Engineering Programmes in Nigeria (BMAS) document issued by Council for the Regulation of Engineering in Nigeria (COREN). The analysis finds that of the 30 engineering programmes listed in the BMAS document, none directly addresses sustainability. The paper therefore highlights the need to mainstream sustainability education into the Nigerian engineering education curriculum. A vital means of achieving such mainstreaming is through the inclusion of a sustainable engineering programme in the BMAS for engineering.

Keywords: Sustainability education, engineering education, sustainable engineering, professional accreditation

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INTRODUCTION

The impact of human development on the natural environment has been a cause of increasing concern in recent decades. An important outcome of these deliberations about the environment is sustainable development, which aims to reconcile economic growth and environmental protection. Engineering has been implicated in sustainability crises, including climate change, pollution and resource depletion. Sustainable engineering arose as a strategy to deliver positive engineering solutions and systems to benefit the environment, economy and society. Guiding it is a sustainability worldview which also necessitates sustainability education [1]. As the upshot of international declarations, sustainability education aims to induce in individuals the cognitive orientation needed for an increasingly complex and unpredictable world. The UN Decade of Education for Sustainable Development (UNDESD; 2004-2014) enhanced global efforts to mainstream sustainability education into various higher education institutions (HEIs). In 2004, the engineering education community issued the Barcelona Declaration, actively embracing sustainability education. The Declaration has since underpinned sustainable engineering education worldwide.

Knowledge of sustainability is now a learning outcome of engineering programmes defined by various accreditation bodies including the Engineering Council, UK, the Accreditation Board for Engineering and Technology, USA and the Council for the Regulation of Engineering in Nigeria (COREN). Being a signatory to a number of sustainability-related treaties and resolutions such as Agenda 21, UNDESD and UN 2030 Agenda for Sustainable Development, Nigeria has endorsed sustainability education. Since the colonial era however, Nigeria has engineered many infrastructure such as crude oil refineries, Ajaokuta steel plant, roads, railways, and many residential and office buildings. Nigerian HEIs have produced engineers who administer these projects. Nevertheless, Nigerian engineering education has not been assessed for its sustainability content. COREN, a body tasked with the accreditation of engineering programmes amongst other functions, has developed and issued Benchmark Minimum Academic Standards for Undergraduate Engineering Programmes in Nigeria (BMAS). This document presents an important resource and opportunity for a baseline assessment of the sustainability content of Nigerian engineering programmes.

The purpose of this paper is to appraise Nigerian engineering education with a view to assessing its sustainability content. The paper highlights engineering practice in Nigeria before discussing the education of Nigerian engineers. Nigerian sustainability experience and efforts including sustainability education initiatives are considered. Thereafter, the sustainability content analysis of the BMAS document is presented. Finally, the paper suggests possible sustainability education interventions for Nigerian engineering education.

1 ENGINEERING EDUCATION IN NIGERIA

1.1 Engineering in Nigeria

Engineering in Nigeria evolved as a necessary outcome of colonialism. Engineering activities were undertaken to advance the goals of colonialism centred on governing Nigerian territories [2]. Road and railroad construction, water supply, mining, dredging, housing, electrical and mechanical works featured prominently amongst recurrent projects in colonial Nigeria. The engineering legacy bequeathed to Nigeria by the British continued without much change. Indigenisation efforts progressed very slowly as British and other foreign engineers continued to direct various engineering works across the country. Over the years, Nigeria took full ownership of engineering practice in the country. Professional associations emerged including Nigerian Society of Engineers, COREN, and Nigerian Academy of Engineering. These organisations acted as consultants to successive Nigerian governments and to the academia broadening the purview of engineering knowledge and ensuring professionalism. Engineering in Nigeria now occurs within the structure of governmental regulation and professional associations' guidance. Only registered engineers are legally allowed to practice engineering in Nigeria. Thirty engineering fields are presently recognised in Nigeria [3].

1.2 Educating Nigerian engineers

At independence in 1960, Nigeria had an educational system modelled on the British framework. Since then, successive Nigerian governments have made efforts to modify the colonial legacy for more effective and meaningful outcomes. Higher education institutions (HEIs) grew from only 2 technical colleges in 1944 to a total of 143 in 2016 comprising 40 federal universities, 42 state universities and 61 private universities [4]. Today, the Federal Ministry of Education (FME) has the mandate to formulate and oversee enactment of national educational policies. Educational policies formulated by FME shape the route to an engineering career in Nigeria. Students desiring to study any engineering field are required to take such science subjects as mathematics, physics, and chemistry at senior secondary level. A minimum of credit score in these subjects and in two others including English Language at the West African Examination Council-conducted examinations or the national equivalent is mandatory. Initially modelled on the British system that operates a 3-year programme, engineering degrees in Nigeria are now acquired over a 5-year period. General physical and chemical science subjects accompanied by one or two social science subjects including Use of English are taught to first- and second-year engineering students. Students are progressively exposed to the core of their chosen disciplines over the next 3 years. A compulsory industrial work experience scheme is sandwiched in the engineering programme. In the final year of their programme, engineering students undertake a research project either individually or collaboratively under the supervision of an academic. A Bachelor of Engineering or Bachelor of Technology in Engineering is typically awarded upon successful completion of the 5-year programme.

2 SUSTAINABLE DEVELOPMENT IN NIGERIA

2.1 Nigerian sustainability experience and response

Nigeria's interest in sustainability was piqued by an environmental disaster in 1987 in which about 4000 tonnes of toxic waste originating from Italy were deposited in Delta State. This incident prompted the enactment of Federal Environmental Protection Agency (FEPA) Decree and Harmful Waste Decree in 1988 proscribing dumping and trafficking in toxic wastes across Nigerian territorial boundaries including its Exclusive Economic Zone. The FEPA Decree led to the formation of an environmental agency tasked to protect and manage the environment. In 1999, the Federal Ministry of Environment (FMEnv) was established to coordinate all environmental matters. FEPA metamorphosed into National Environmental Standards and Regulations Enforcement Agency in 2007 and was subsumed by FMEnv. With a vision "to ensure a Nigeria that develops in harmony with the environment", FMEnv has engaged in a number of sustainable development efforts [5]. Sustainable development concerns in Nigeria have followed the typical sustainability ideas' pattern of percolation into societies in which social and economic dimensions are preceded by the environmental component. Following its participation at the United Nations Conference on Environment and Development in Rio de Janeiro in 1992, Nigeria attempted to implement the outcome of the summit by drafting Nigeria's Agenda 21. In response to the emergence of MDGs in 2000, Nigeria created the Office of the Senior Special Assistant to the President on MDGs [6].The expiration of MDGs in 2015 ushered in the UN 2030 Agenda for Sustainable Development comprising 17 Sustainable Development Goals which Nigeria endorsed. Given the abysmal outcome of Nigeria's MDGs efforts, speculations are rife that the Sustainable Development Goals may not fare any better.

2.2 Nigerian sustainability education

Allusions to education in several sustainability-related documents such as Nigeria's Agenda 21 are either in reference to "education for all" or to "environmental education". Given such impression, Nigerian educational system has responded to sustainability education with chiefly environment-related courses. Lessons on such environmental subjects as natural resources, sanitation, and pollution permeate Nigerian primary education. The secondary schools are introduced to some relatively advanced environmental issues such as waste and land pollution, ecology and water pollution. The HEIs offer a variety of degree level environmental courses titled variously as *environmental engineering*, e*nvironmental management, environmental technology* and e*nvironmental resources management.* Sixteen Nigerian universities currently run these courses [7]. Sustainability education in the strict sense of Education for Sustainable Development (ESD) has not gained much recognition in the Nigerian educational system. Nigeria has no explicit sustainability education framework and there is no Nigerian HEI that offers a sustainable engineering degree, course or module[2]. This absence of active ESD programmes in Nigeria is corroborated by a study that finds sustainability education to be slowly evolving in Africa [8]. The UNDESD Final Report suggests that "sustainable development is only an emerging interest among African HEIs" [9]. The prospect of an accelerated uptake of sustainability education in Nigeria has equally not been realised even with the existence of 4 UN-established Regional Centres of Expertise (RCEs) on ESD in the country. Although appreciable progress has been made in terms of the informal and non-formal ESD components, the formal element is inadequately attended to [10]. Contributing to this undesirability is the failure of the RCEs to successfully network with Nigerian HEIs thereby fragmenting the ESD initiative. Renewed networking is required to mainstream ESD into Nigerian HEIs. An important means of achieving such nexus is through FME, FMEnv and other HEIs stakeholders including COREN and National Universities Commission.

3 SUSTAINABILITY ASSESSMENT

Sustainability assessment in HEIs has been undertaken since the emergence of sustainability education. Several sustainability assessment tools have been developed to evaluate the sustainability efforts of various HEIs around the world. A number of these tools generally assess sustainability initiatives in the customary HEI functions of education, research, community outreach, and university operation [11]. However, some of the assessment tools focus exclusively on curriculum with sustainability content having a central importance.

3.1 Sustainability content

What qualifies as sustainability content is an important question in sustainability assessment research. The defining principles of sustainability have rightly guided most assessment tools. However, as sustainability concept is highly fluid, these principles are somewhat difficult to pin down. Hence, various measures of sustainability content in curriculum exist. The point of departure for most researchers is the use of expert-

[2] This is based on the Joint Admissions and Matriculation Board Brochure which contains all the courses offered in Nigerian HEIs.

derived sustainability themes which allows curricular sustainability content to be measured in terms of the spread of these themes. An example of such approach is the Sustainability Tool for Assessing Universities Curricula Holistically made up of 40 sustainability topics under the 4 categories of environment, economy, society and crosscutting themes [12]. Sustainability content can therefore be considered as the spread or coverage of sustainability topics or ideas in a curriculum highlighting the interdependence of environment, economy and society along with the multidimensional problem-solving strategies for addressing sustainability challenges. This operational definition guided the documentary analysis of the BMAS document.

3.2 BMAS document

BMAS is a document issued and reviewed episodically by COREN to set out standards for running undergraduate engineering programmes in Nigeria. A 367-page document containing over 100,000 words, the BMAS lists 30 approved engineering programmes with a description of all required courses for each programme. The scope of each course details prerequisite and co-requisite topics as well as admission requirements and list of laboratory equipment. Common engineering courses are equally detailed. The document is divided into 3 parts including general requirements section, specific requirements subdivision and accreditation score sheet. The BMAS is an outcome of deliberations by engineering practitioners and academics in Nigeria. Deans and heads of engineering departments from Nigerian universities as well as COREN management are involved in the development of the document. Each Nigerian HEI submits syllabus of its engineering programmes highlighting course contents, philosophy, and minimum facilities. A workshop is held to deliberate on these submissions. Courses are included in the BMAS on the basis of global best practice and contextual relevance. The BMAS standardises the syllabi and becomes the official guideline for all undergraduate engineering programmes in Nigeria. The preamble of the BMAS itemises 9 learning outcomes for engineering programmes. Item 6 states that "a graduate of an engineering programme accredited by COREN is expected to have *ability to consider the environment and sustainability in finding solutions to problems*" [3]. An interesting fact about the BMAS is that it informs all handbooks of engineering faculties in Nigerian HEIs. Furthermore, Nigerian HEIs refer to the BMAS for purposes of accreditation and curricular development. The BMAS is the basis upon which COREN accredits engineering programmes. The mention of sustainability as a competence expected of engineering graduates is, therefore, reassuring. However, this can only be effective with an actual integration of sustainability education in the programmes. The BMAS documentary analysis set out to discover if such alignment exists.

3.3 Analysis procedure

The question that informed analysis of the BMAS is whether or not sustainability topics are covered in the document. It was therefore of interest to analyse the mentions of a sustainability topic or idea in any engineering programme. The documentary analysis involved the use of NVivo 11. The BMAS document was converted to an editable PDF form and uploaded into the NVivo 11 software. Thirty engineering programmes listed in the BMAS with preamble and common engineering courses formed a total of 32 cases. A priori codes based on 4 categories of environmental concepts, economic concepts, social concepts, and multidimensional concepts became parent nodes. In line with the classification of Sustainability Tool for Assessing Universities Curricula Holistically, the environment node had 9 child nodes each being an important environment topic. Similarly, economic topics gave rise to 6 child nodes under the economic parent node, while the social parent node had 12 child nodes derived from myriad social issues like poverty, etc. The multidimensional node contained 10 child nodes based on a range of crosscutting themes such as systems thinking, etc. The entire document was then scrutinised and coded at the cases and nodes. Words such as 'sustainable' used in the literal sense were not coded. Topics had to clearly embody sustainability ideas before being coded.

4 BMAS SUSTAINABILITY CONTENT

The analysis shows that the BMAS document has an extremely low sustainability content. Contained in merely 2% of the entire document, sustainability topics have not received much attention in Nigerian engineering programmes. Compared to 2 common engineering topics, namely engineering materials and engineering mathematics, which both cover nearly 5% of the BMAS, the 37 sustainability topics assessed in this study are poorly featured. Nonetheless, from Figure 1 and Table 1, economic and environmental concepts are featured in the BMAS document more than the social and multidimensional themes.

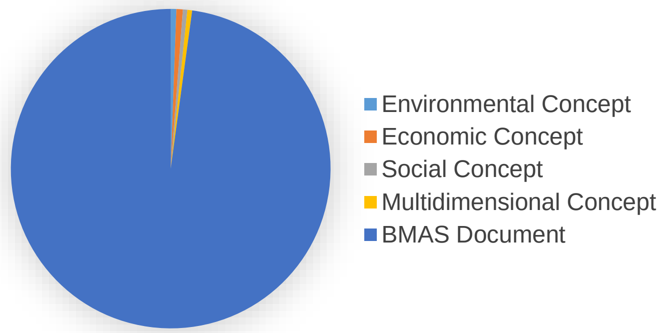

Fig 1. Spread of sustainability concepts across BMAS Document

Table 1. Sustainability coverage

Sustainability Concept	Coverage
Environmental	0.57%
Economic	0.65%
Social	0.45%
Multidimensional	0.48%
BMAS Document	97.85%

4.1 Environmental and economic contents

Figures 2 and 3 show the distribution of environmental and economic concepts across the engineering programmes in the BMAS document. Eleven programmes feature at least one environmental topic with Environmental Engineering containing 4 topics. Four environmental themes are completely absent in all of the programmes. Similarly, only 12 programmes cover economic topics and 2 economic themes, namely GNP and 'Accountability' are not mentioned in any of the programmes.

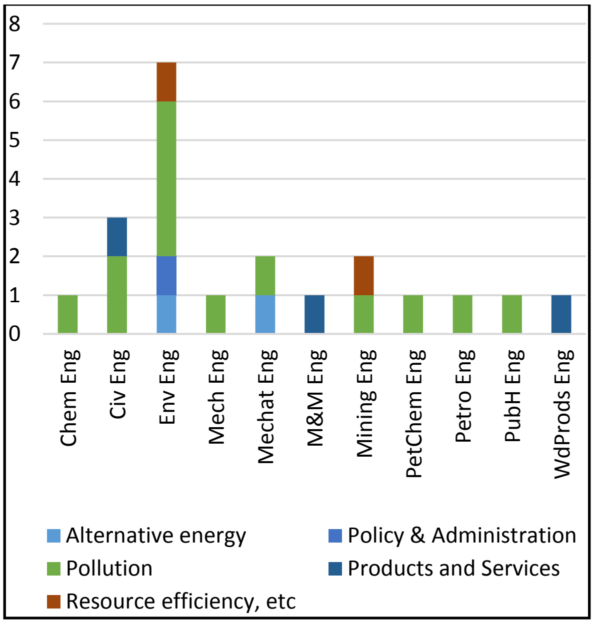

Fig 2. Environmental Concepts Distribution

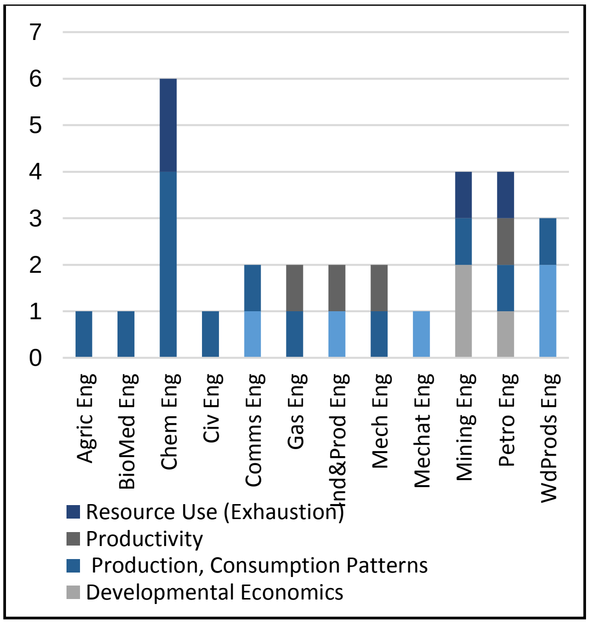

Fig 3. Economic Concepts Distribution

4.2 Social and multidimensional contents

Figures 4 and 5 present the spread of the social and multidimensional concepts in the engineering programmes. Whilst 9 programmes feature some social concepts, only 7 programmes mention at least one multidimensional theme. Equity and justice, long-term thinking as well as communication and ethics/philosophy are covered in the common engineering courses. Eight social and 6 multidimensional themes do not feature in any of the courses.

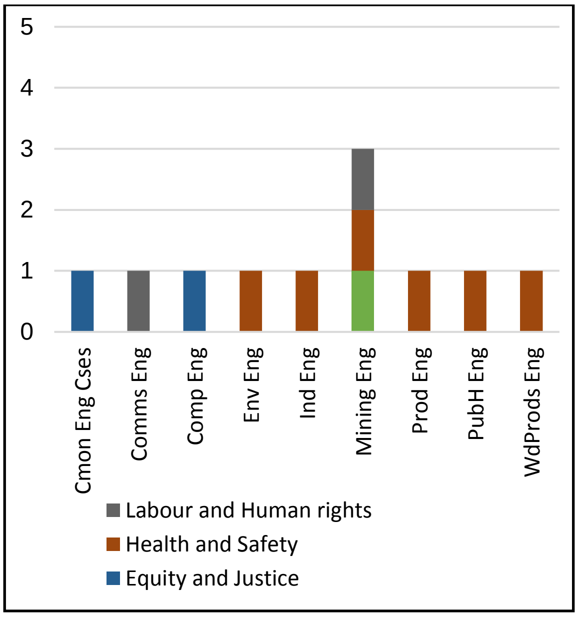

Fig 4. Social Concepts Distribution

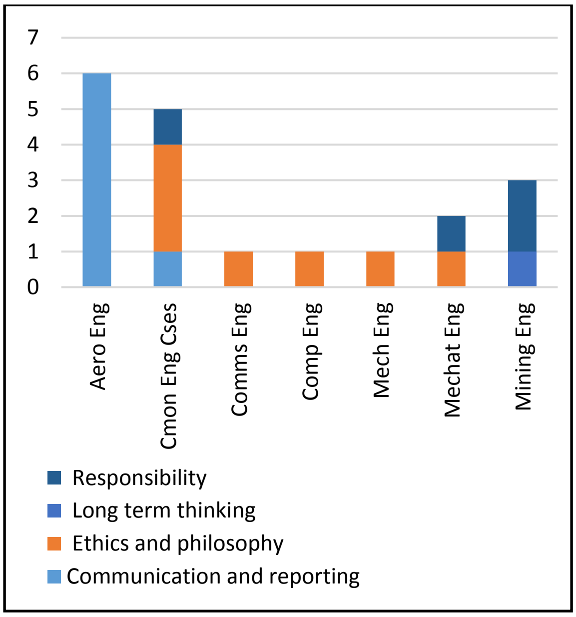

Fig 5. Multidimensional Concepts Distribution

5 SUSTAINABILITY EDUCATION INTERVENTION

The trajectory of engineering and sustainability in Nigeria is dotted with episodic interventions. Consequently, an education intervention to accommodate sustainability topics in the BMAS document is appropriate. The BMAS documentary analysis reveals dissonance between the required learning outcomes for engineering programmes and the imperative of sustainability education. Sustainability expertise has been clearly identified as a skill required of all engineering graduates, but the BMAS document shows no evidence of concrete sustainability education. Evidently, no engineering programme directly addresses sustainability. A possible intervention could be the substitution of the common engineering courses with sustainable engineering modules. Since the common engineering courses already feature some sustainability themes, albeit inchoately, sustainable engineering can aptly subsume these courses and give them the necessary sustainability finesse. Alternatively, COREN could insert in the BMAS a course entitled *Introduction to Sustainable Engineering* which could be made a core requirement from the third year onwards. This is because the third year marks the beginning of core courses for students of all engineering disciplines. Thus, beginning this stage with a sustainable engineering course could be an immensely effective sustainability education strategy. Such approach would ensure that sustainability eventually features in the final-year projects of engineering students.

6 SUMMARY

Engineering and sustainability education in Nigeria are as yet not properly aligned. Engineering has been practised in Nigeria since the colonial era. Nigerian engineers are trained in various HEIs across the country. The imperative of sustainability education suggests a complex dimension for Nigerian engineering education. In spite of being a signatory to many sustainability pacts and its experience of an environmental disaster, Nigeria has no sustainability education framework. This paper appraised Nigerian engineering education and assessed its sustainability content based on the BMAS document. The paper highlighted engineering practice in Nigeria and discussed the education of Nigerian engineers. Nigerian sustainability experience and efforts were examined. Thereafter, the sustainability content analysis of the BMAS document was presented. Finally, the paper suggested possible sustainability education interventions for Nigerian engineering education.

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Teaching sustainability to engineers: a systematic literature review

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ABSTRACT

Since the publication of the UN-sponsored World Commission on Environment and Development report [1] in 1987, thousands of initiatives have been undertaken to address the different aspects of environmental challenges [2]. Among these initiatives, in 2002 the UN General Assembly proclaimed the UN Decade of Education for Sustainable Development, 2005-2014, 'emphasising that education is an indispensable element for achieving sustainable development'.

Sustainability has been on the agenda of many engineering faculties since the late 1990s [3]. It has become clear that “a new kind of engineer is needed, an engineer who is fully aware of what is going on in society and who has the skills to deal with societal aspects of technologies” [4]. Literature covering this topic is abundant. The discussion on how sustainability can be successfully integrated into engineering programmes is still receiving attention.

This paper aims to present a literature review focused on sustainability in engineering education. The review is based on the Systematic Literature Network Analysis (SLNA), a methodology including a collection of computer-based tools that analyses bibliographic data, and that have been applied to the continuous improvement of Higher Education [5]. The SLNA is adopted in this work in order to unfold the dynamics of sustainability in engineering education and identify the directions in which engineering faculties are moving.

Conference Key Areas: Sustainability and Engineering Education; Curriculum Development; Engineering Education Research.

Keywords: Sustainability development, education, curriculum development, Systematic Literature Network Analysis.

1. INTRODUCTION

The first definition of sustainability development was given by World Commission on Environment and Development (Brundtland Commission) in 1987 and states that sustainability development is the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. To pursue this policy, Education on Sustainable Development (ESD) was recognised by the United Nations Economic Commission for Europe (UNECE) to play a major role in this process. ESD is a main activity of UNECE, which, together with the United Nations Educational, Scientific and Cultural Organisation (UNESCO), implemented a road map for ESD in 2005. The road map consisted of three steps: Phase I (2005-2007), i.e. Stocktaking, where the Member States had to identify existing initiatives; Phase II (2008-2010), i.e. Integration, where the Member States had to begin the integration of SD in the curricula; Phase III (2011-2015), i.e. Implementation, where the Member States had to ensure the introduction of ESD in every school and promoting teachers’ education.

The final comment in the report published after the end of Phase III (May 2016, [6]) was that “significant advancements have been made on four of the seven Strategy issue areas: *policy integration*, *curricula*, *tools and resources*, and *cooperation and networking*” but “more systematic attention should be given to progress on non-formal and informal learning, and special consideration given to advancing ESD research, monitoring and evaluation as essential inputs to strengthening ESD”.

Hence, in order to contribute to advancing ESD the goal of this paper is to depict a landscape of the scientific literature on SD in the curricula of engineers through the adoption of the dynamic literature review method called “Systematic Literature Network Analysis (SLNA)”. This method was introduced by [7] and combines the systematic literature review approach with bibliographic network analyses. The successful adoption of such an approach to other contexts, e.g. [8], [9], [10], proves its potential value in the identification of research trends and evolutionary trajectories.

2. Material and methods

SLNA starts with the application of a systematic procedure (Systematic Literature Review, SLR) to identify and select relevant papers. Then, the selected papers are analysed using bibliometric tools, such as the Citation Network Analysis (CNA) that provides information on the evolution of the more active research areas; the citation is assumed to represent the influence of the cited work on an author’s new work [11].

The first phase, i.e. SLR, includes the following steps: *scope of the analysis*, to define the boundaries of the study; *locating studies* to retrieve papers form databases through keywords, search strings and other criteria (e.g. type of document, time window); *study selection and evaluation*, to isolate the most relevant papers.

The second phase of SLNA takes into account the papers selected in the first phase and applies bibliographic network analyses and network visualisation tools.

Nevertheless, delineating and representing a research field only by means of papers linked by citations may lead to biased results since some important contributions, even if their content is relevant, may be not yet cited due to various causes. For this reason, the results of citation network analysis is combined with those provided by other bibliometric tools.

Papers were collected from the Scopus database, which is, together with Web of Science (WoS), the most commonly used scholar citation database. Scopus is very similar to the WoS database but Scopus has a wider coverage [11]. To build the citation network VoS Viewer (http://www.vosviewer.com/, [31]), a software package able to analyse bibliometric networks, was adopted. The citation network was then studied using Pajek [13] which is a software package for Social Network Analysis.

3. First phase of SLNA methodology: SLR

3.1. Scope of the analysis

As mentioned in the introduction, many efforts have been made by international organisations to introduce SD concept into the educational curricula. The scope of the analysis of this paper is to find research directions in the field of engineering education on SD and to understand if the interest of international organisations was reflected in the content of the papers analysed.

3.2. Locating study

For locating the study it is necessary to define some keywords. The keywords were discussed with a panel of experts composed of mechanical and environmental engineers. It is important to underline that this step of the analysis is very critical to reduce the individuals' bias. The final search string used in Scopus is as follows: 'curricul*' AND 'development' AND 'sustainability'. This was searched in the field "keywords", which includes author keywords and keywords assigned by Scopus and the Engineering area was selected.

3.3. Study selection and evaluation

The search was performed on April 2017, without any restriction on document type (conference paper, article, review, article in press, letter) and on time window (the first document dates to 1990): 267 documents were retrieved.

4. Second phase of SLNA methodology: bibliographic network analyses

The works identified in the first phase were used as input for the second phase of SLNA. A local analysis using citation network was performed to detect the evolution of the main concepts. Some of the 267 papers may be not included in the citation network but cited many times in Scopus and then a complementary analysis of the most cited papers in 2016 in Scopus was performed.

4.1. Citation Network Analysis (CNA)

To perform CNA it is firstly necessary to exclude the isolated nodes that are papers nor cited neither citing others in the network. This is the case of 188 documents. The remaining 79 documents form connected components. In details, 68 documents form a big connected component and the remaining papers are connected in other four small components. The amount of information that can be extracted from the biggest component is more structured than the one emerging from small components with only a very limited number of connected nodes [10]. Based on this consideration, only the connected component with 68 documents will be analysed.

4.1.1. The analysis of the Biggest Connected Component

Figure 1 depicts the biggest connected component. To analyse this component the Main Path (MP) algorithm [12] was used. MP extracts main trends in the evolution of paper contents identifying papers that constitute part of the backbone of the research tradition. This backbone is composed of papers lying on the shortest paths between source and sink nodes. A source is a paper cited by but not citing other papers of the network while a sink is a paper citing but not cited by other papers of the network.

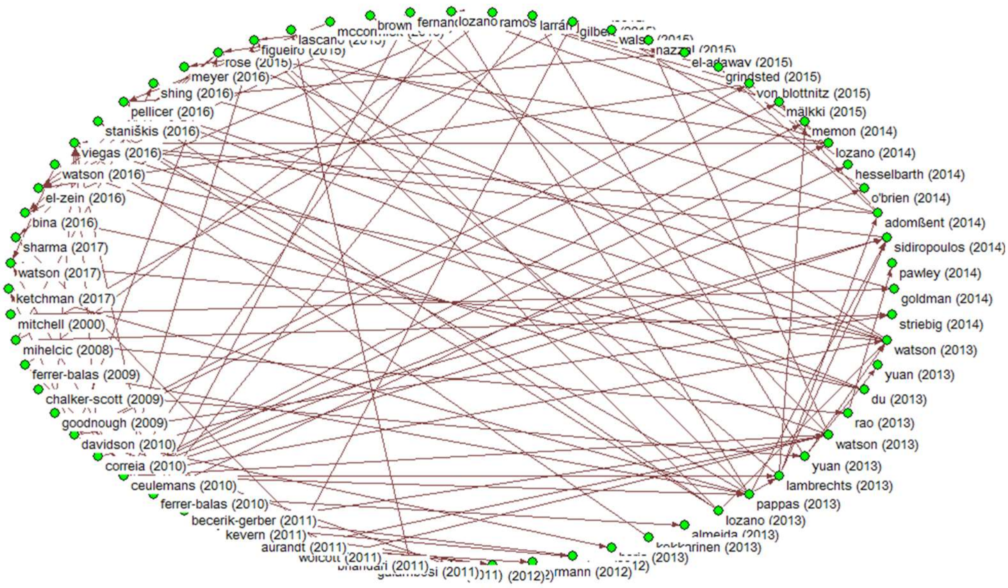

Figure 1. The biggest connected component of the citation network.

In [14] it has been observed that the MP obtained in this way provides the most significant path. Nevertheless, if a discipline has many sub-areas, this is not enough to uncover all the milestones of the research tradition. [14] propose to relaxe some constraints of the process to build the MP to generate the so-called *key-route*. In Figure 2 the *key-route* of the biggest connected component is presented. The papers range from 2009 to 2017 and the flow of knowledge shows a change in the research interests in engineering education on SD, starting from the need to present a systemic and holistic vision of SD passing through the development of instruments helping to develop a curriculum to arrive, recently, to the development of measures to quantify the SD content of curricula or to quantify learning outcomes related to SD.

- *The need for a systemic vision of sustainability development.*
  [15] suggested to involve external stakeholder in the curriculum development; [16] observed that SD in engineers' curricula helps students to think using system theory perspective including social, environmental, economic and technical aspects. [17] stated that the competencies on sustainability, provided by many courses, are fragmented and this calls for adjusting programmes of study to embrace a system thinking approach. A holistic approach is highlighted by [18] too, which suggested introducing geography in the SD curriculum due to its strong tradition within the human-environment theme.
- *Instruments helping the integration of sustainability development in the curriculum.*
  [19] proposed a very accessible teacher's manual for SD integration. [20] presented a process for developing a curriculum in Engineering for SD. They succeed to represent and integrate different courses using Concept Maps and 'Sustainability Tool for Assessing Universities' Curricula Holistically" (STAUNCH). [21] proposed a web-based sustainability portal to support curriculum renewal based on a sequence of workshops and meetings that help teachers to meet the needs of students.

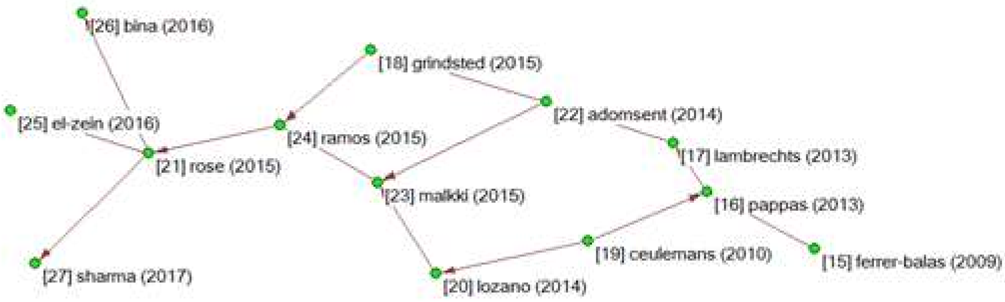

Figure 2. The *key-route* of the biggest connected component.

- *Necessity to quantify the learning outcomes and the content of curricula* .
The importance of quantifying learning outcomes was underlined by [22]. [23] proposed an index (Relevant Ratio) to measure the amount of content on SD of curricula. This ratio indicates the weight of sustainability topics in a programme.

Morever, the necessity to organise the works on the curricula on SD is shown by [24] where 33 papers on curriculum development in higher education institutions are commented; [25] demonstrated that an approach to engineering education strongly based on problem-solving is an obstacle for a complete understanding of SD; [26] analysed 25 top master programmes worldwide for urban development; [27] proposed a mixed approach based on qualitative (thematic groups) and quantitative (survey pre and post assessment) techniques in a multidisciplinary class of students. The methodology was tested and the advantages and disadvantages presented.

The research directions identified in the *key-route* works have been then compared with the aim of the UNECE initiative, to understand their degree of alignment even if none of the papers was funded by this framework. Results are shown in Table 1.

Table 1. Comparison between the UNECE initiative and the research directions identified in the *key-route*.

Time window	UNECE Phases	***key-route*** **Papers**
2005-2007	Phase I. *Stocktaking*: the Member States had to identify existing initiatives;	
2008-2010	Phase II. *Integration*: the Member States had to begin the integration of SD in the curricula;	The necessity of a systemic vision and the stakeholders' involvement [15]. Development of instruments for the integration of SD: a teacher's manual [19] . A method for developing a curriculum in SD engineering [20].
2011-2015	Phase III. *Implementation*: the Member States had to ensure the introduction of ESD in every school and to promote teachers' education and measuring the outcomes.	Necessity to quantify the learning outcomes and the curricula contents ([22], [23]). Obstacles to the implementation of the ESD [25].

In particular, it is interesting to observe that during Phase II (i.e. Integration), some papers were published on practical tools for the integration of SD into curricula, while during Phase III (i.e. Implementation) papers related to quantifying learning outcomes, content and implementation obstacles appear ([22], [23] and [25]). It is possible to conclude that the UNECE initiative, reflected in many national initiatives, influenced research directions in the engineers' curriculum development on SD.

4.2. Global Analysis

As mentioned, it is necessary to cross the information provided by citation network with a global analysis. The first step consists in analysing all the papers from the point of view of distribution over time, authors and journals. In Figure 3 the 267 papers by year of publication are represented. A fast increase starts after 2007 and this is interesting in the light of the efforts of the international organisations after 2005. The number of works seems to reach a plateau around 2014 (data on 2017 is partial). Most of the works are conference papers or articles. The most productive authors are Lozano R. and Ceulemans K. who authored/co-authored many papers of the *key-route* too. Another author appearing in the *key-route* is Ferrer-Balas D. who wrote the oldest paper of 2009, which seems a milestone of the research tradition. The journal more often publishing papers on this subject is *Journal of Cleaner Production.* Also all papers on the *key-route* are published in this Journal.

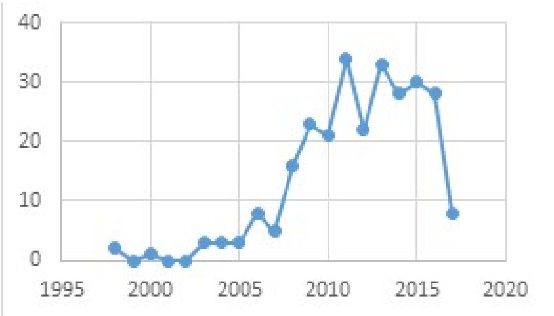

Figure 3. Number of works published over time.

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Another shortcoming of the citation network and of the *key-route* is their inability to isolate papers gaining attention recently, since they did not have time to be cited or because they are cited by papers not included in the connected component. In Table 2 the ranking of the most cited papers in 2016 is provided together with the evolution of the number of citations they received in Scopus over time.

Table 2 - Ranking of the top cited papers in 2016.

Rank	Publication year	Reference	Part of the connected component (CC) and Key-Route (KR)	2010	2011	2012	2013	2014	2015	2016	2017
1	2011	[28]	CC	0	2	5	13	6	11	12	0
2	2013	[29]	isolated node	0	0	0	1	6	0	10	2
3	2010	[30]	CC	1	2	3	21	7	17	8	2
4	2014	[22]	CC and KR	0	0	0	0	0	7	8	5
5	2015	[24]	CC and KR	0	0	0	0	0	0	8	4
6	2010	[19]	CC and KR	0	2	1	10	7	17	7	2

Among the top six papers, three belong to the connected component and to the *key-route*. The first three works ([28], [29], 30]), although not very recent, seem to have recently acquired interest and this deserves special attention. [28] studied, using a survey, the introduction of Building Information Modeling and sustainability in the Architecture, Engineering and Construction (AEC) curricula. The importance of education on SD for civil engineering it is not a new theme but it is recently gaining more importance due to the fast development of new materials and technologies and the related employment opportunities. [29] proposed a new methodology for the introduction of SD in the curricula of the energy engineers using multimedia internet-based technology. [30] is a review of the papers presented at the 5th Environmental Management for Sustainable Universities, an international conference held in 2008 in Barcelona (Spain). Some of the top ranked papers are literature reviews (traditionally receiving many citations) but the presence of [28] and [29] showed the higher level of importance of SD for AEC and Energy engineering than for other areas.

5. SUMMARY

In this paper we have applied SLNA to perform a literature review of the research on the introduction of SD in engineers' curricula. The necessity to perform research and develop tools to this end is recognised and fostered by UNECE. The analysis using citation network highlights an alignment between research directions and the UNECE initiative, i.e. the implementation of tools to help teachers to introduce SD in the curricula and the development of new measures to quantify the SD content of curricula or to measure the learning outcome.The ranking of the most cited papers in 2016 pointed out two additional papers not included in the *key-route,* which show a great interest in the introduction of SD especially in curricula of energy engineers and AEC. This can be due to the fast development of new material and technologies and the employment opportunities in these areas. Hence the importance to pay attention to SD becomes even more important. Nevertheless, even if this analysis shows the general importance to introduce SD in the engineers' curricula, it seems that efforts have concentrated mostly on some specific areas (AEC and energy) while other areas seem overlooked (e.g. industrial ([32],[33]) or electronic engineering). As [25] point out, "a deeper change in the engineers' vision is necessary to change their mode of engagement with the world and their ability to tackle root causes of social and environmental issues in technologically advanced society".

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Introducing Sustainability in Engineering Education Curricula: an achievable outcome or a utopia?

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ABSTRACT

Sustainability, social and environmental responsibility become more and more relevant for professional engineering. This is recognized by universities that are doing their best to introduce these issues in the curricula. But this is not a trivial issue and their integration with the existent and news issues must be total. So, a lot of authors, academics, researchers are always concerned with this and are trying different approaches and learning methodologies in order to achieve successfully sustainability integration. This paper presents and explores some of these approaches and perspectives from four different countries: Portugal, Brazil, Canada and Spain. The study is based on the analyses of papers, presentations and debate session results from a previous engineering education conference. In spite of the reduced sample, it was a lived sample that shared personal and team perspectives about the issue through the debate. Also, it is discussed how the participants introduced sustainability, corroborating that this integration could be an achievable outcome and not a utopia.

Conference Key Areas: Sustainability, Engineering Education, Research
Keywords: Sustainability, Engineering Education

INTRODUCTION

Pappas [1] defined a sustainable society as *"A sustainable society possesses the ability to survive and prosper, not just with respect to environmental resources, but also with respect to quality of life as it pertains to social, economic, technical and individual contexts, and especially the values and conditions that promote continued human prosperity and growth (…). A sustainable society meets these needs simultaneously,*

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and in the context of human respect and the ability to negotiate differences without violence.".

The same author [1][2], assuming that individual sustainability dimension is probably the most influential factor in the success of activities in other dimensions of sustainability, proposed that the individual's understanding of the complexities and interconnections between their own sustainability contexts is necessary to further understanding of the community and global sustainability. Thus, the promotion of true learning about sustainability is, firstly, to develop in these individuals the understanding and appropriation of the values of individual sustainability and the ability to change oneself intentionally.

In this sense, universities have a significant role in promoting the Sustainability concept in its different spheres: teaching, research, extension, and management. In fact, Education for Sustainable Development (EDS) has been on the agenda of many universities especially promoted and guided by the Decade of Education for Sustainable Development (DESD) (2005-2014) [3], which was completed with some achievements and its follow-up, the Global Action Program (GAP) on EDS [4].

Universities have begun the way to ESD, but there are still new concepts in most universities [5–7] or they are far from a complete integration into university operations and curricula [8–10]. Only 15 of more than 14,000 universities worldwide have published their sustainability reports [11]. However, as it has been shown, it is accepted that education is a key element in the change and transformation of behavior and practices towards a sustainable society [12].

Attending to this context, the main objective pursued by this study was to analyze different approaches towards Engineering Education for Sustainable Development (EESD) from different countries and contexts presented in a real and live debate session of a previous Engineering Education conference. Also, in this paper are presented the results of the discussion among the authors of the proposed approaches and others participants in the debate session. As a secondary objective was expected to answer or contribute to the answer or make deeper questions about future challenges in a real implementation of EESD based on real case studies.
This paper is divided into five main sections. After this introduction, a brief literature review is presented. The research methodology is presented in the second section. The study context is presented in section three. A debate to discuss the sustainability theme in engineering curricula took place in this study context which main results are highlighted in the fourth section. Finally, conclusions are drawn up in section five.

1. BRIEF LITERATURE REVIEW

Attending to the sociocultural complexity in which we live and the multiplicity of fields in which sustainability can and should be worked on, its concept and dimensions are not yet a consensus in the literature, assuming a polysemy and multi-disciplinary sense applicable to different situations, contexts, and objectives. Approaches varies according to different areas of knowledge and often within the same area. Likewise, Sustainability and Sustainable Development (SD) are approached as common concepts, albeit with differences between them.

Since the sixties, Sustainability has been aimed into the direction of development when, in the Brundtland Report [13], the concept of SD was proposed. This concept evolved, not only to harmonize but to integrate development with the environment when the concepts of Sustainability and SD emerged to translate this integration. Thus, from the 1980s, the term SD was assumed, whose concept was widely diffused assuming this as a form of development that seeks to meet the needs of the present without compromising the ability of future generations to attend to theirs as well.

It should also be noted that although the perception of the need to remain within limits of recovery has begun in the nature dimension, it is necessary to broaden the spectrum of what needs to be maintained, which must not be destroyed, as by cultural diversity. The idea of sustainability, then, it is not restricted to the beings of nature, it also involves other dimensions [14]. From the first five Pappas [1] dimensions: Social-cultural, Economic-financial, Environmental or Ecological, Technical or Technological, and Individual; three more were added by different authors: Relational or Convivial, Territorial or Geographical and Epistemological [15].

To introduce this model of development in the society, UNESCO [4] proposed that sustainability should be integrated at different levels of education, calling it ESD. According to UNESCO [4], ESD empowers learners to take informed decisions and responsible actions for environmental integrity, economic viability, and a just society, for present and future generations, while respecting cultural diversity. It is about lifelong learning and is an integral part of quality education. ESD is holistic and transformational education which addresses learning content and outcomes, pedagogy and the learning environment. It achieves its purpose by transforming society.

The ESD must be integrated into the learning content by integrating critical issues, such as climate change, biodiversity, disaster risk reduction (DRR), and sustainable consumption and production (SCP), into the curriculum. Also, ESD should be integrated in the pedagogy and learning environments by designing teaching and learning in an interactive, learner-centred way that enables exploratory, action-oriented and transformative learning and by rethinking learning environments – physical as well as virtual and online – to inspire learners to act for sustainability.

Additionally, should be integrated in societal transformation by empowering learners of any age, in any education setting, to transform themselves and the society they live in order to: 1) Enabling a transition to greener economies and societies (equipping learners with skills for 'green jobs' and motivating people to adopt sustainable lifestyles); 2) Empowering people to be 'global citizens' who engage and assume active roles, both locally and globally, to face and to resolve global challenges and ultimately to become proactive contributors to creating a more just, peaceful, tolerant, inclusive, secure and sustainable world.

The integration of sustainability into higher education, according to Wals [16], could follow two approaches: "bolt-on": adding new courses and modules that have elements of ESD; 2) "built-in": integrating sustainability in existing studies and research programs as well as in staff development. Resembling these, Rusinko [17] previously proposed four forms of integration that vary, depending on the combination of two variables: the maintenance of the general structures of the degree (or creating a new structure) for the implementation of sustainable aspects and the focus given to sustainability (specific for each discipline or more cross-cutting and interdisciplinary).

In addition, and related with the responsibility to implement ESD, this could be a process: 1) top-down process, posing it at the institutional level and transmitting it to schools, departments, degrees, and faculty; and/or 2) bottom-up, from active faculty but with definitive need of institutional support [8]. Other studies about how to introduce sustainability in curricula could be seen, namely, in Hansen et al. [18], Allen et al. [19], Dewulf et al. [20], Holgaard et al. [21] and Colombo et al. [22].

Working sustainability as specific disciplines is of fundamental importance, by one hand, because as Dewulf et al. [20] said when it is only transversal can have negative points such as, the fact of being worked by a non-specialist teacher in the area the subject becomes fragmented in other disciplines and, thus, there are overlap or aspects not covered, and to integrate it into another discipline does not have a logical sequence.

On the other hand, the lack of a transversal approach in all disciplines can put the theme as disconnected from the rest and thus the perception of its importance is diminished. Therefore, the teaching-learning methodology adopted is fundamental to minimize these negative points. For instance, project-based teaching, still with different denominations as Fourez [23] did when he proposed his "Island of Rationality" method to the diffused Project Based Learning [24,25], has already been highlighted as the most appropriate method for the construction of rooted sustainability knowledge for the training of future professionals.

This methodology is adequate for the interdisciplinary structure of education, in which there is the interaction of all agents of education. At the same time, the work is more interdisciplinary, promoting the interaction and integration of knowledge both for students and educators, thus favoring that Sustainability is placed at the same level as the other themes addressed in the different disciplines. Some examples have been exposed that evidence this [18,26–30]. The promotion of true learning about sustainability firstly involves developing in individuals the understanding and appropriation of the values of individual sustainability and the ability to change oneself intentionally. Thus, teaching-learning approaches should enable this objective of individual transformation to be achieved so that collective transformation is possible in the search for a sustainable society.

2. RESEARCH METHODOLOGY

In this paper, the authors intend to discuss the introduction of Sustainability in EE curricula, based on their active participation in a debate session of an EE conference organized in 2016. In the context of the conference, four authors of submitted and approved papers were invited by conference organizers to participate in this specific session. These papers had in common case studies and studies of sustainability integration in engineering degrees and programs from different countries: Spain, Portugal, Canada, and Brazil.

From the debate discussion, moderated by one of this paper authors, and from the session results that joined so many different ideas and perspectives, a question comes to authors´ mind:

- Is the introduction of Sustainability in Engineering Education curricula an achievable outcome or a utopia?

To contribute to the answer to this question, the authors presents this paper findings that are, mainly, based on the papers and presentations exploration of different approaches and strategies towards EESD in similar degrees but totally different contexts (North America, South America, and Europe). Also, results of teams discussion formed during this session are presented. Among the participants of the session were some first-year students of engineering.

3. STUDY CONTEXT

This section presents the study context where this study was based that resulted, mainly, from a debate session related with Sustainability. The debate session objective and organization as also the driving questions raised in the debate are exposed.

3.1. Debate session objective and organization

Beyond the regular paper sessions, the referred conference included debate sessions to stimulate the conference participants' discussion. A total of 16 participants (among authors' papers invited, regular participants and students) attended this session. The moderator/facilitator organized three teams with five, six and four members (*Fig. 1*). At least, one author 'paper was on each team, as well, a student.

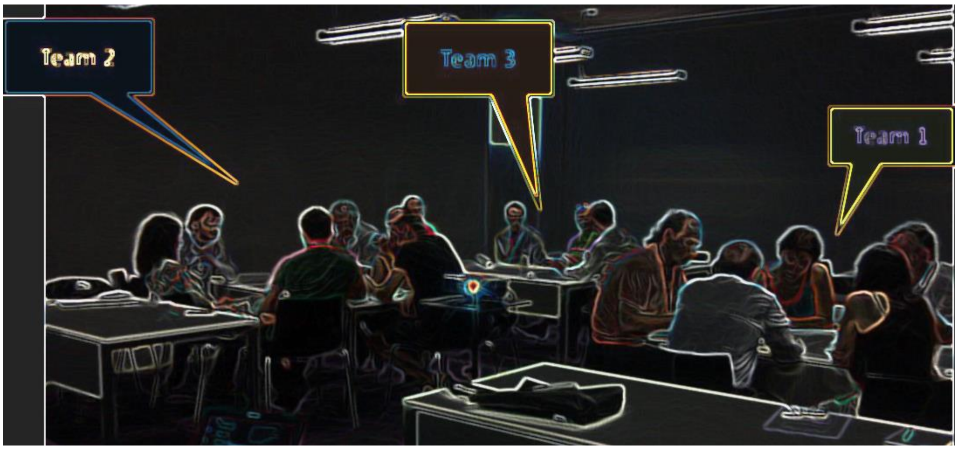

Fig. 1. Teams working (picture intentionally blurred for privacy purposes)

The debate session was organized in three main parts:

1) Contributors of each case study presented their findings and approaches in five minutes or less. Also, they launched one or two driving questions for the debate, according to findings from his/her paper. Main questions were registered and prioritized by consensus for the next phase.

2) Driving questions were registered after each presentation on the whiteboard, to facilitate the discussion phase and debate was started. A summary of consensus or disagreements reached was done for each team.

3) A short sum-up of main conclusions and ideas was developed altogether. It was tried to reach some answers (or new deeper questions) from the initial driving questions.

3.2. Driving questions for the discussion

In order to proceed with the debate (second part of the session), just eight driving questions, from 12 given by the authors invited were selected by consensus:

1. For an engineering education eminence level, which performance measures (in terms of efficiency, efficacy, effectiveness) could be used to evaluate sustainability competencies?
2. In addition to sustainability, should be used other drivers?
3. Sustainability approach: top down & bottom-up approaches - which should be first?
4. How to convince all instructors to include sustainability concepts in their courses?
5. How to ensure a proper scaffolding of the sustainability concepts from year to year?
6. Is there any consensus of what is a sustainable university? Is a comparison needed between universities? Or is it enough a self-comparison?
7. A great number of sustainability curriculum implementations and approaches but, how are students going to learn sustainability if the university is not sustainable?
8. Great efforts for cooperation for development in other countries, but what about solving real local problems?

Each team discussed a different group of questions, using a flip chart to collect the main ideas. Then, they were presented to all participants to be discussed.

4. RESULTS AND DISCUSSION

This section introduces the main key ideas from the papers and presentations as also the debate findings from each team.

4.1. EESD cases and studies key ideas

Each author had different objectives with the papers they submitted to the conference as can be seen in Table 1.

Table 1. Key ideas from papers and presentations

Countries	Key ideas
Brazil	Innovative experiences and proposals in EE for sustainability applied in a case of a Production Engineering program of a Brazilian university anchored on small projects (8) during the whole program.
Canada	Framework for implementing a sustainability curriculum in an Engineering Technology program. This framework should be implemented through a top-down and a bottom-up approach.
Portugal	Study of integration of sustainability in the engineering programs and courses of a Portuguese university through information contents in the university website. The authors revealed that very few programs and courses integrate sustainability.
Spain	Study of the contributions of different universities approaches to sustainability and social responsibility reports. This contribution was measured by sustainability assessment tools.

In the case of Brazil and Canada, the authors presented case studies of how they integrated or planned to integrated sustainability in specific engineering programs. Specifically, in the Brazil case, they considered that through projects, students could measure the sustainability performance by measuring the efficiency, efficacy, effectiveness and eminence level of these projects [31]. In the case of Canada, the authors also presented a framework to be used to integrate sustainability concepts into several courses of an Engineering Technology program [32]. They called this "Timeless Engineer Framework" where they defined "timeless engineer" as someone who is able to adjust to the needs of the world's dynamic challenges in order to create solutions that are consistent with the needs of current and future generations. This framework was not implemented at the time the author presented the paper.

In the cases of Portugal and Spain, the authors presented a more general view about sustainability. The authors from Portugal present the sustainability in engineering programs in their institution [10,33] and conclude that just a small percentage considered sustainability theme in their contents, in spite of sustainability initiatives in the university such as sustainability report, sustainability research centers, among others. The authors from Spain[34] presented a study developed by a sustainable engineering research team at Spanish university based on different university approaches to sustainability and university social responsibility reports. Their main objective was to better understand how to advance and measure sustainability in a university and the important role that students may play. They highlighted the important role of PBL as learning-by-doing methodology capable of enabling students understanding the SD.

4.2. Results of teams discussion

The results of the discussion of the teams were presented to the other participants in flip charts. These results were explained by each team at the moment they presented the flip chart to the others participants.

Team 1 answered to the questions 1 and 2 (section 3.2). Their filled flip chart exposed a need to have answers based on real facts (a real problem) to convince teachers and students in a reciprocal way to distinguish sustainable from what was not sustainable. Also, they considered a need of a system approach through a formation of a task force of consultants involving rectors, deans, teachers and students to produce a document with sustainability types and to evaluate them. Also, their opinion about how to teach were that students must teach students and sustainability evaluation must be mandatory. In order to achieve this, teachers must be trained in sustainability competencies and should be motivated to learn such competencies. In order to achieve this, teachers must be trained in sustainability competencies and should be motivated to learn such competencies (considered a driver).

Team 2 answered to questions 6, 7 and 8 (section 3.2). They showed two perspectives: 1) students are not able to be sustainable professionals if their academic environment is not. According to this team, it is necessary to instill sustainability mind-set; 2) joining forces of students' initiatives (developed in-class) and governmental support.

Team 3 discussed questions 3, 4 and 5 (section 3.2) and their opinion on these was that sustainability definition could have many meanings for different people. Nevertheless, ethical aspects, change minds and attitude should be present in all people to see sustainability in all dimensions, as referred in the literature review (section 2). Also, they considered that a bottom-up approach is better, starting with small projects and scaling up. Of course, this idea of bottom-up was not shared by all participants that considered both approaches are necessary, as also referred in the literature section.

To conclude this part, answers to the questions were marginally achieved what reinforces the difficulty to have direct responses to the questions formulated. But, at one point, they seemed to agree: all stakeholders (students, teachers, rectors, deans, society) must be involved in the on-going discussions and a mindset shift is needed because there are many universities where this did not yet happen. Involving all and with the proper mindset, sustainability integration in EE could be an achievable outcome. Right now, is still more a utopia than reality, but it was possible to see through some examples (e.g. case from Brazil) this can rather be achieved and come reality. It also seems consensual that the learning methodologies to concretize this achievement are learning-by-doing approaches or active learning. These methodologies seem a more suitable approach because involves the students in their own learning.

A lot of questions and challenges, also raised in the debate and that remained without an answer were: What should be the contents of courses/programs and how they should be related to integrating sustainability issues in a natural way? How to put the sustainability in the learning outcomes? What learning methodologies/tools to use in Higher Education Institutions in order to effectively change students' roles from spectators to sustainability key actors and change agents? The session revealed to be a short time-frame to discuss so many important topics related with sustainability.

5. CONCLUSIONS

This paper intended to give a contribution to the debate about introducing Sustainability in the EE curricula. The authors identified two case studies and two more general studies presented in an EE conference organized in 2016. The case studies focused on specific programs of specific universities of Brazil and Canada and the studies were developed in Portugal and Spain. The case study from Brazil is successful implemented, while Canada case was not and his author was afraid of the difficulties they will face (e.g. teachers' resistance). The other two studies showed that there is an effort to integrate sustainability in EE but more is needed. Though the different context and country, it seems concerns are the same: EESD and how it has been implemented and could be implemented. Also, how this should be achieved to form "timeless engineers" that attend sustainability issues in their professional practice. Active learning methodologies, and, in particular, PBL seems to provide a good solution defended by many authors, including the ones involved in this study.

It was also clear that the sustainability integration in curricula implies a mindset that is not yet achieved in all, and needs to be worked out, because, as stated earlier, true learning about sustainability involves, firstly, developing in individuals the understanding and appropriation of the values of individual sustainability and the ability to change oneself intentionally. As Colombo [14] said, based on Morin [35] this change needs to start at one point, and it seems that the best is with teachers, through training in the subject, which is corroborated by many authors. However, continues without being addressed. This was also one of the questions raised by the participants in the debate: Should we teach teachers to teach sustainability? The answer is yes, because, after all, teachers are more near to the students and act more directly in teaching, research, extension, but, mainly, in the construction/reconstruction of the curricular structures. Also, teachers have a role both in the top-down and bottom-up processes of integrating sustainability. These processes, which, as shown by several authors, including those analyzed here, must be worked on two lines. It must be a movement from the base, but also must be supported and institutionalized by the dome.

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Circular Economy Design Forum
– Introducing Entrepreneurial Mindset and Circularity to Teaching

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ABSTRACT

The Circular Economy Design Forum (CEDF) is an EIT RawMaterials educational project aimed at incorporating an entrepreneurial mind-set into engineering education, particularly in topics related to circular economy (CE). As part of this initiative, a new course was developed as a platform to promote a dialog between students, industry and academia. To use this educational platform effectively, a "Training the trainers" event was organized where teaching staff learned how to integrate an entrepreneurial mind-set into courses with technical content and how to support student innovation capabilities. In this paper, the objective is to explore the impact on the mind-set and motivation of students when: i) a circular thinking is promoted though iterative project work within the circular economy context, and ii) a customer-centric approach is incorporated in an engineering course, by letting the students identify real industrial needs together with stakeholders. According to the student's feedback, most of the participants (15/18) felt that the course supported well their learning on CE topics and enhanced their study motivation. However, it was also evident that additional support is needed for timid students that have trouble contacting stakeholders directly.

Conference Key Areas: Sustainability and Engineering Education, Curriculum Development, Skills and Engineering Education

Keywords: Circular Economy, Entrepreneurial Mindset, Project work, Industrial Collaboration

INTRODUCTION

The European Institute of Innovation and Technology (EIT) is a European initiative supporting innovators and entrepreneurs in the creation of solutions to tackle some of the most pressing societal challenges. One of such topics requiring attention is the increasing demand for raw materials, resulting of the continuous growth in world population and the demand of manufactured products per capita. The EIT RawMaterials Knowledge Innovation Community (KIC) was created with that aim, also supporting educational programs. In addition, the EU framework for education and training 2020 (ET2020) points strengthening entrepreneurship competencies as a strategic objective, and promotion of excellence in teaching as well as sustainable investment in education as priority areas [1]. Education has an important role in improving the entrepreneurship competencies and mind-set, especially for young people [2].

“Circular Economy” (CE) is one of the concepts that has drawn most attention in the area of raw materials production in recent years. CE aims at alleviating the need for primary raw materials in a sustainable manner by maintaining the intrinsic value of raw materials through efficient recycling practices. However, to understand and apply the main concepts of CE in industry, multidisciplinary ideas are required. As value generation lies at the core of the CE concept, an entrepreneurial mind-set of the actors involved in the materials production cycle is required. This need led to the “Circular Economy Design Forum” (CEDF), an educational project funded by EIT RawMaterials.

The CEDF offers an innovative approach as it started with the premise that the teaching staff in engineering education programs are not typically familiar with the basic aspects of entrepreneurship. Thus, this project offered a training session for teaching staff (in December 2016) and produced an entrepreneurial education “toolbox” to support the course development. In this event, staff members were introduced to customer-based thinking and other relevant entrepreneurship concepts.

In engineering education, problem-based learning [3] with the use of project work is a popular approach that is believed to promote the creativity of students [4]. However, in most cases, the students are typically assigned a pre-defined problem to be solved applying the main concepts of the course. In this kind of approach, it is not uncommon that the students start looking for an answer based on what they think will satisfy the teacher, thus limiting the development of creative learning. Furthermore, in real engineering work life, the search for solutions for pre-defined problems is seldom the case.

In contrast to the typical “linear” problem solving education, we aimed at implementing the CE philosophy in education and think rather circularly. For the student project work, this can be implemented in a form where the students discover a problem by themselves. To find a real working case, the students are forced to reach out to clients and stakeholders, making this a customer-centric approach to learning. Once the problem is identified, a potential solution can be proposed, but then, together with a mentor, the problem-solution pair needs to be evaluated and redefined iteratively, to find both a better problem definition and an attractive solution.

After various cycles – the most relevant problem can be discovered. This iterative process thus becomes a tool to foster innovation.

An entrepreneurial mind-set is not only valid for the creation of new ventures and start-ups but should be considered a general skill [2]. One crucial difference from learning based on pre-defined problem solving, is that entrepreneurs actively work to identify the problems that need solving in the first place. Thus, this skill is important for all engineers, whether they work in their own company or as employees [5,6]. An entrepreneurial mind-set can be learned via real development projects that are initiated by an active discussion with stakeholders to understand their needs [7]. Evidently, for this process, the students need careful advice and instructions on how to proceed, as it might feel scary and therefore, the students need constant checkpoints and transparent feedback of the evaluation process [8] to find the right motivation. The teacher may not be in charge on the project, but is still very much so in the educational process.

1 DEVELOPMENT OF THE CIRCULAR ECONOMY DESIGN FORUM

Effective implementation of an entrepreneurial mind-set into engineering teaching cannot be obtained by adding a few dedicated contact sessions in a course, but rather as a mind-set involving teaching style and assignments. The objective of this paper is to study how to implement these concepts to an engineering course having technical content, namely, the understanding of CE in raw materials processing. To ensure this integration, prior to the planning of the CEDF course content, a training event for teaching staff was organised to share good practices in the development of course structures involving entrepreneurship.

1.1 Training the trainers event

As mentioned in the Introduction section, the CEDF project was used as a training platform on which the teaching staff from various universities could learn from experience to work within an entrepreneurial framework. The staff worked in teams to learn how innovation-driven projects can be directed and how to provide effective feedback. The learning outcomes for this event:

- Help teachers add hands-on, entrepreneurial elements to their teaching
- (Re)design a course from the teacher’s local university to include elements of entrepreneurship in an interactive and hypothesis based approach

The event took place on December 2016, and was hosted by Aalto Ventures Program (AVP), a program within Aalto University with a strong history on the teaching of entrepreneurial skills at various levels of higher education. Nonetheless, AVP had no previous history on training educators in such a systematic way, upon which future training workshops can be provided. The timetable of the event and the themes discussed in the workshops can be seen in Table 1.

Table 1. Workshop topics for the CEDF "Training the Trainers" event.

Day 1	Day 2	Day 3
Intro to the workshop Pre-work video session	Lecture: Circular Economy by Markus Reuter	Teaching event with local students
Morning WS: "Student assigments and uncertainty"	Morning WS: "Feedback and teacher presence"	Student presentions
Afternoon WS: "Class culture + learning process"	Afternoon WS: "Learning objectives + grading + work load"	Feedback and discussion of the event
Own Course development	Own Course development	-

For the first two days the teachers were divided into teams that used one of the courses identified during the preliminary tasks as working examples. At the beginning of each workshop, the experiences obtained during a similar integration of entrepreneurial mind-set to a pilot Capstone course named Materials Processes and Synthesis (MPS, held Fall 2016), were introduced and reflected upon. Afterwards, the topic of the workshop was processed in the context of the developed courses in a team. Feedback on the content development but also on the team performance was provided to give the teachers an impression on how it feels to receive feedback. Thus, it became clear that constructive feedback for the students is important, since a negative or extremely critical environment does not encourage innovation.

During the last training day, a group of volunteer students from the MPS course (i.e., who had already experienced an entrepreneurial mind-set teaching) was invited to work on a case study. The task for the students was to develop a Stakeholders Analysis for sustainable business ideas and they were guided by the trained staff. Various iterations were carried out based on the feedback provided by the trainers. On the closing sessions, both the students and the staff members received feedback from each other and from the facilitators on their performance (*Fig. 1*). Since engineering teachers and professors tend to work with projects where is only a "one way to the solution", it was pointed out that the trainers tend to direct the students to the path they had considered appropriate. It is important to be able to guide the students at the direction they had decided and only set proper frameworks to encourage the students to identify their own path, however difficult that might be.

Teachers liked:
"Feedback provided new way of thinking and tools"
"Being as a student"
"The active way of teaching"
"Good experience the student group mentoring"
"The way of how the class were performed"
"I also liked the teachers giving creative feedbacks"

Fig. 1. Feedback session with the students and teachers [Photo by R. Serna] as well as written feedback provided by the participants.

1.2 Selected teaching methods and their alignment

With the aim of creating a "forum" as its name suggests, the overall approach for the CEDF course was that, instead of the classical "lecture + exercise" model, a dialogue-based education was promoted. We invited experts on the field of CE from different organizations willing to engage the students into considering the CE concept from different angles. To promote the discussion of the various aspects of CE and promoting a dialogue with industry, the teaching and assessment methods were carefully selected to support the intended learning outcomes (ILO). The ILOs presented in *Table 2* are aligned with the teaching methods and assessments as suggested by Biggs and Tangs [9].

Table 2. The ILOs aligned with the teaching method and assessments.

ILOs	Teaching method	Assessment
The student has learned the main concepts of CE and their relevance in the production and processing of metallic raw materials	Workshops (Introduction, Re-Think, Sitra), group discussion, Excursion	Circular Economy Essay 1 and 2, Project work
Developed entrepreneurial thinking from a CE perspective	Workshops (Re-Start and introduction) Group discussion	Circular Economy Essay 2, Project work
Modeled innovative recycling processes to determine their feasibility and environmental impact	HSC training, Re-Act workshop	Disassemble report (Re-ACT)
Applied their knowledge to solve project relevant for industry, including aspects of economic analysis	Re-Act workshop, Project work	Project work
Worked in a multicultural team	Project work	Project work

The largest individual assessment method was the 2 CE Essays where the first was written at the beginning of the course to determine their initial level of understanding of CE, and the relevance of entrepreneurship and value creation on it. The second essay was prepared at the end of the course as a reflection to learning. Both Essays included a graphical representation of CE. The assumption in this study was that the depth of the CE concepts in the second essay should reflect the efforts that each student had invested to the course. In total, the essays formed 25 % of the total grade and the rest 25 % by other individual tasks. Additional activities to support the lectures included a hands-on workshop on WEEE dismantling and an excursion to an industrial recycling facility.

Thus, the group project work used to evaluate how the students apply the concepts of CE provided the rest 50 % of the grade. The aim of this study was to discover if the students could generate a dialogue to industry and identify issues on CE that address industrial needs and have the potential to create some added value. Another hypothesis in this work was that when the students are required to identify a stakeholder company and a topic by themselves, they will feel more engaged. This also puts in practice the idea that with an entrepreneurial mind-set, relevant problems are discovered through dialogue with clients [7]. Four feedback sessions were set between teacher and the student groups to assess the problem-solution pair in an iterative manner.

2 LESSONS LEARNED FROM THE CEDF COURSE

In Spring 2017, a pilot CEDF course was held with the participation of 18 students: 15 from Master's and 3 from Doctoral level. The participants were students from different disciplines, including process engineering, materials science, chemistry, mechanical engineering, physics, business and arts. In addition, the students formed a multicultural group, having representatives from various nationalities.

As the CEDF course was quite short (5 ECTS) it was necessary to maximize the active learning process during the contact sessions and minimize information sharing by lecturing. A detailed schedule of the course is presented in *Fig. 2*. The black text indicates the topics of workshops, while the blue text shows the project work milestones. There was also relevant literature provided to the students that they could select according to their specific interests and use as reference a material in the essays. By week 2, an industrial process simulation software (HSC SIM 9, Outotec) was introduced as a tool that could be utilized in the project work to assess the resource efficiency and footprint of selected technological business opportunities [10]. This was utilized by 3 out of the 5 groups in their project work.

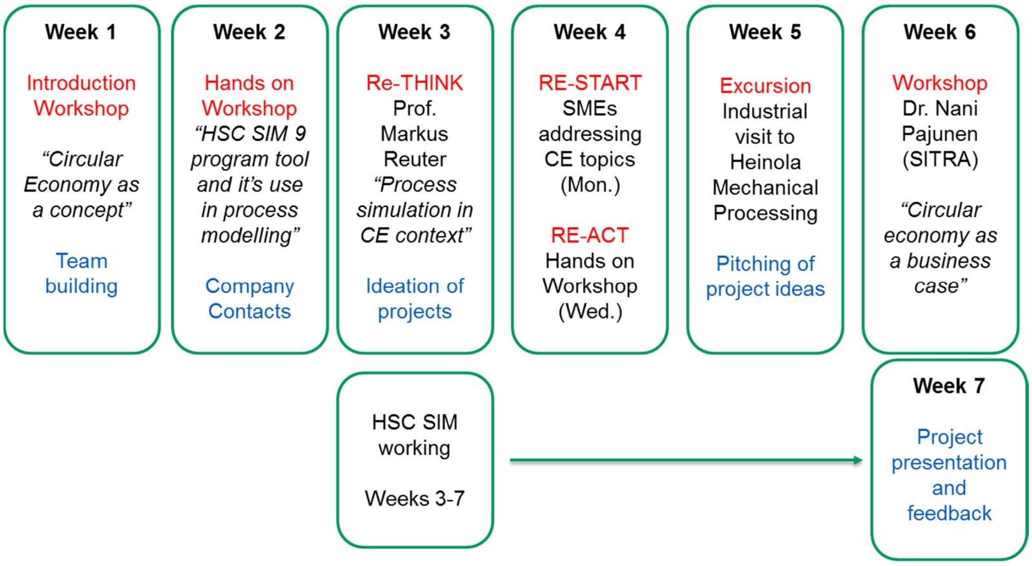
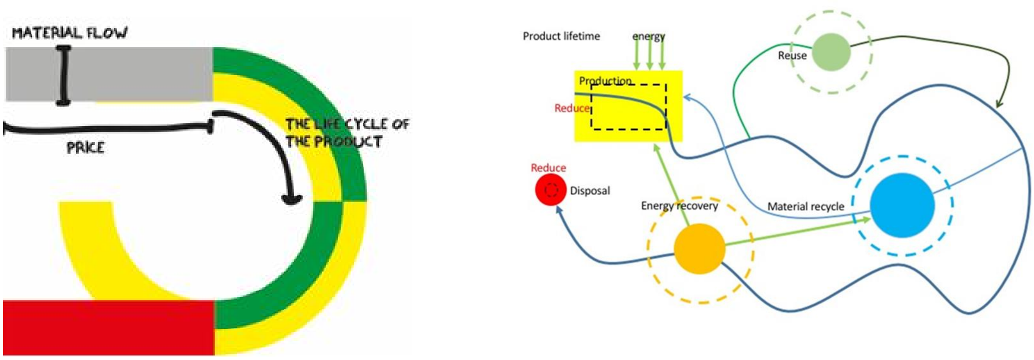


Fig. 2. CEDF structure: black text describes the events and blue project milestones.

For the personal assessment, students prepared two essays to show if the CE concepts had been strengthened during the course. These essays also involved visualization as exemplified in in *Fig. 3*, where it can be clearly seen that at the beginning of the course, most of the students had implemented just linear or basic round visualization for CE.



Before CEDF After CEDF

Fig. 3. Example of a student's visualization of the CE before and after the course.

In comparison, after the course, all the students had implemented a round visualization but with iterative nature. In most of the second visualizations, scenarios that are more complex were presented: waste creation at different stages, additional energy input, social and economic aspects. New ways to utilize end-of-life products were taken into consideration and the possibilities for new business models like leasing or renting were considered. Especially with the students that participated in most of the workshops, numerous references were included in the essays and the conceptual understanding of CE was deep. It is worth mentioning that at no point was any memorization encouraged (essays were prepared from home).

Each team selected a company that they interviewed on their ideas and needs on CE solutions. The selected companies represented wider range of industry than if selected merely by the teaching staff: from metal industry to real estate business. As was aimed in the study, all groups were able to identify interesting development targets by the interviews; however, all topics were scoped during the mentoring sessions. In the end, the projects proposed different improvements to CE practices in the selected companies, for instance by utilization of side or waste streams, improving logistics efficiency or new business models (leasing).

From the student feedback, it was observed that most of the students (15 out of 18) stated that the teaching methods supported their learning and their study motivation had improved slightly or notably during the course. The students also pointed out that they felt very engaged in the project because they felt excitement about developing a project with a typical entrepreneurial approach. In addition, they considered that the course content was very relevant for their future career and they enjoyed working at the interface with industry. Admittedly, some students expressed that this approach felt intimidating and is more demanding than their typical Master's degree courses.

3 CONCLUSIONS AND FUTURE WORK

The aim of this project was to incorporate an entrepreneurial mind-set to engineering courses having technical content, and to discover if this approach supports the development of circular thinking required in CE. In the first approach the participants prepared project works where they interviewed stakeholders and identified problems. All groups found projects that were very innovative and provided interesting CE solutions, thus some groups needed additional mentoring to narrow down their topic. According to the student feedback, most of the participants felt more engaged in these projects than with regular pre-defined projects and reported that this course clearly enhanced their study motivation. In the second approach, reading material and workshops with stakeholders were provided to enhance the learning of concepts on CE and this clearly influenced on the students thinking, as reflected by the second essays and especially in their more intricate visualisations.

For the teaching staff, one key finding during the course is how multidisciplinary the CE concepts are. If real innovation on this area is needed, multidisciplinary teams are required to provide solutions from engineering, business and design perspectives. In the future, the forum may be developed towards a platform where different stakeholders meet and discuss the challenges of CE. As additional material, videos created as part of the CEDF project describing the experience of introducing entrepreneurial aspects in engineering teaching are available in the following links:

Ideas before the course: https://www.youtube.com/watch?v=BsILM0n2wG4

Ideas after the course: https://www.youtube.com/watch?v=s3JjNLAVRps

4 ACKNOWLEDGMENTS

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Engineering Education for Sustainable Cities in Africa:

Conversations from Kenya

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ABSTRACT

Projected urban growth in Kenya will require increased engineering talent and resources to facilitate the infrastructure demands of growing urban centers [1]. This study aims to understand how Kenyan institutions are currently equipped to support engineering programs and what factors need to be considered to reform the curricula to support rapid urban growth in the region. To investigate these questions, a research team travelled to Kenya in July, 2016 to study the engineering programs and interview faculty members at two universities. The method of currere was used as a framework for analyzing the regressive, the progressive, the analytical and the synthetical. Four key insights emerged from the study: opportunities exist for curriculum reform of Kenyan engineering curricula to mirror emerging engineering pedagogy and practice, context is a critical factor in curriculum reform, accreditation is a key consideration for online learning in engineering education, and there was an openness to collaboration regarding curriculum reform. This study focused on the perspective of the educational institution. As such, further research is suggested regarding the institutional factors, notably the accreditation standards for online learning, the industry objectives and the policy objectives to inform the context of the conversations of engineering education in Kenya.

Conference Key Areas: Sustainability and Engineering Education, Open and Online Engineering Education, Curriculum Development

Keywords: Engineering Education, Online Learning, Curriculum Reform, Accreditation

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INTRODUCTION

Kenya is experiencing significant urban population growth [2]. In order to accommodate this growth, there is a substantial need for additional engineering talent and resources to design, build and manage new and sustainable city infrastructure. A large component of this capacity building will be achieved through the education and training of engineers who can use sustainable approaches to build and maintain new infrastructure [1].

Researchers from the University of Toronto recently met with faculty members in engineering at two large public universities in Kenya. Their visit was part of a larger project that is exploring a curriculum for engineering education for sustainable cities in Africa. The goals of this particular study were to build on the literature surrounding engineering education in Kenya, discover how the country is prepared to manage current and future urban growth rates through engineering education, and explore the potential of developing an online engineering education curriculum that is accessible and locally contextualized to promote the sustainable development of growing urban centers. The findings from the study will set the stage for deeper study in to the larger research.

The method of currere [3] was used to explore the conversations regarding engineering curricula, those involved in the conversations and the surrounding contexts in Kenya. The method of currere encourages researchers to analyze their own experiences in relation to the cultural, historical and political contexts of education to understand more fully, with more complexity and subtlety, the current realities [4]. This is accomplished through consideration of the regressive, the progressive, the analytical and the synthetical aspects [3].

Both researchers felt it was important to discuss the intent of the project due to the prospect of interfering as opposed to supporting, as other prior interventions were criticized of being neoliberal in nature. Extensive and proper consideration was taken when framing the following research questions:

1. How are institutions currently equipped to support engineering education in Kenya?
2. What factors need to be considered to reform the engineering curricula to support rapid urban growth in Kenya?
3. What lessons can we learn from conversations with universities in Kenya?

1 LITERATURE REVIEW

Engineering education was introduced in Eastern Africa in 1956 as part of the University of East Africa, which separated into three distinct universities in 1970: one in Kenya, Tanzania and Uganda. The presence of accredited engineering programs has since expanded to nine universities in Kenya recognized under the Engineers Board of Kenya (EBK) accreditation body.

Amutabi (2003) and Case et. al (2016) note that politics play an important role in the development of society as they impact the structures of modern societies [5], [6]. Gaining its independence from England in 1963, the political climate in Kenya had a significant impact on the development of the country's education system [6]. The country experienced a period of politically motivated, rapid expansion in universities during the 1980s [5]. Universities were overloaded as their infrastructures and resources were not equipped to handle such a large number of students. This was especially challenging for engineering programs which require a balance of theoretical, practical and experiential learning [7], often requiring many resources outside of the classroom, including laboratory space and equipment, in addition to the human capacity required to facilitate this learning.

The emphasis on financial investment in tertiary education was later diverted to elementary and secondary education [6]. As a result, universities removed tutorial sessions - an important part of engineering education - to deal with the problem of underfunded and understaffed faculty. Tutorial sessions provided opportunities for students to participate in discussion: an important part of student curricula due to the importance of reflection in learning [8].

Acknowledging the historical context that shaped the engineering programs in Kenya, this research study aimed to understand the current state of the engineering programs, how they were influenced by this historical context and how the engineering curricula may reform in the wake of engineering education research and evolving societal needs.

Curriculum reform is a popular topic in engineering education literature as engineering education and the training of engineers are considered key to the progression of the economy [6]. Kenya's rapid urban growth brings to light two pressing questions regarding curriculum reform: how can the engineering curriculum evolve to incorporate emerging knowledge regarding sustainable urban development?; and, how can engineering curriculum be scaled to build the engineering capacity required to tackle the growing infrastructure demands expected to emerge as the cities continue to grow?

With the increase in popularity around online education, specifically in engineering related courses, there is a growing opportunity to share educational resources internationally and to seek ways in leveraging the benefits in a Kenyan context. Online learning is viewed as a way to increase access to education to students who cannot afford the cost of tuition, and decrease the commuting volume of students who are already registered.

As an attempt to capitalize on this potential, the World Bank introduced the African Virtual University (AVU) project in 1998 [9]. The goal of the project was to support what it viewed as failing higher education in Sub-Saharan Africa by introducing high quality education to Kenya through modern information technology systems. The hope was to educate individuals through distance education and increase the number of well-trained African scientists, technicians, engineers and business managers required for economic development [9]. However, the World Bank's association with the AVU project was viewed by some as a source of neoliberal policy models imposed on developing countries. Despite the intent of offering courses focused on engineering, a search for engineering courses on the AVU website yields no results.

The literature on engineering education in Kenya paints an incomplete picture of the country's ability to deliver to the discipline in an online setting. Studies of the status of engineering education in Kenya were few and far between. Based on their impressions and experiences in engineering and education research, the researchers felt that such little information available presented a need to study the institutions more closely and in person.

2 METHODS

This study into engineering education in Kenya used data collected from a larger project for the development of engineering education for sustainable cities in Africa. The project collected data from a variety of educational and cultural contexts that included engineering education at universities in Africa. Interview data relevant to the Kenyan context were selected from the larger project.

2.1 Participants

Ten faculty members from two public Kenyan universities were interviewed for this study. Participants were chosen based on their experience in engineering education and their availability during the visit. For each case, participants underwent a formal consent process prior to their involvement. This process followed the ethics procedures of the University of Toronto. The identities of both universities have been anonymized to KU1 and KU2 (i.e. Kenyan University 1 and Kenyan University 2). The identities of the participants have been anonymized to participant 1, 2, etc. Participants 1 to 4 were from KU1 and participants 5 to 8 were from KU2.

2.2 Data Collection

A semi-structured group interview was conducted at each university, recorded, and then transcribed. Interviews lasted 60 to 90 minutes. Interview questions were structured around seven themes: cities and urbanization, engineering education, online and distance learning, scalability, sustainability, virtual labs, and engineering employment. Group interviews were used to explore contemporary engineering-education contexts in East Africa, survey engineering-education approaches including online learning strategies and methods, and integrate knowledge gained to devise highly scalable engineering education approaches suitable to resource-constrained settings. All interviews were contextualized by individuals' learning and cultural contexts. Field notes were also taken as part of the data collection.

2.3 Data Analysis

Using the currere method [8], data from conversations related to engineering education were extracted from the interview transcripts. Both researchers analyzed both sets of the transcripts. They then reviewed and discussed relevant information. An inductive approach led to the extraction of relevant information and avoided the biasing of the results [10]. Selected information emerged from the phrases that revealed details related to devise highly scalable engineering education approaches suitable to resource-constrained settings. The identified details were then triangulated across locations and participant roles. The combination of the two data sources facilitated a deeper understanding of engineering education in Kenyan universities.

3 FINDINGS AND DISCUSSION

A strength of the method of currere originates from framing the curriculum as a conversation or a series of conversations [4]. The interview questions elicited several conversations surrounding the state of engineering education in Kenya. The content of the conversations varied from one university to another, however, the topics below were present in each interview.

3.1 Opportunity for Curriculum Reform

The opportunity for curriculum reform emerged throughout the interviews. Participants acknowledged that there is a need to revisit traditional approaches to engineering education from a pedagogical and content perspective to keep up to date with emerging technologies and advances in engineering pedagogy and practice.

It was noted that the undergraduate curriculum had not been extensively updated from the initial curriculum developed in the 1960's (KU1) which was created under British influence. Topics that have since gained attention, such as sustainability, have not been explicitly incorporated into the curricula. The universities "teach the hard engineering" (participant 1), focused on theory, and acknowledge that "the curriculum is long due for review" (participant 1). Faculty, however, did not see this as an independently driven initiative, suggesting that "[we] need the innovation, the outreach, [and] the new ideas from the developed world institutions… [such as] America, Britain, [and] Canada" (participant 2).

These institutions have content connected to emerging practice in engineering. However, the inclusion of these topics is generally limited to graduate degrees, such as programs dedicated to climate change and hydrology, and are not formally a part of the undergraduate curriculum. Informal inclusion of emerging topics in engineering in the undergraduate curriculum stem from individual instructors who choose to adapt their course curricula to include topics of interest (KU1).

In addition to the potential for updating content, participants discussed the opportunity for reform of the pedagogical approach to their engineering programs. In the current structure, the universities provide the theory in the classroom and the graduates need to gain exposure to the field outside of their studies. This may come in the form of practical attachments, where students have the opportunity to work in industry throughout or following their studies, or through other experiences sought after by the student (KU1 and KU2). The challenges with incorporating these practical experiences into the curriculum come from limited resources. As one participant stated, "it's difficult to [increase the practical component] in the university with the number [of students], with minimal finances [and] with minimal equipment" (participant 5).

Further, the demand for these programs, notably civil engineering, far exceeds the capacity of the program to accept the students, noted by one participant "we find that many students would like to come to civil engineering … but we don't have the capacity to absorb them all" (participant 3).

These issues produced conversations about the need for several changes including classroom setup, delivery method and curriculum design that may allow for a shift in the teaching approach and the increase in program capacity. Through these conversations, the opportunities for emerging technology in engineering education came to light allowing us to explore whether there are ways that online resources could be used to assist with the pedagogical shift facing the engineering programs and the apparent limited capacity for growth.

3.2 Importance of Context in Curriculum Reform

Context emerged as a key factor in the conversations regarding curriculum reform as it impacts both curriculum content and engineering pedagogy.

In the case of urban infrastructure, participants noted the disparity in urban development between developed and developing countries:

> In the context of our cities, I would say it is a little bit different than developed countries where the government puts infrastructure first and then people second. Here we settle first. Then people come ... then infrastructure comes. So, we develop from our village then to a town then to a city. And in that transition, the key challenges will be socio[technical]. (participant 3)

These types of localized differences with regards to urban development would lend themselves to different course content: different case studies, different approaches to design, or use of different technologies. As such, content developed for the Canadian context would not necessarily be relevant for the Kenyan context.

The political and institutional contexts were noted as a factor in curriculum reform with regards to pedagogy and content. Participant 4 described their lack of autonomy in curriculum development as follows:

> The main stumbling block has been the accreditation body. They tend to be quite traditional and, I think, in the future as those members are phased out, we will be able to offer some of this new program because some of these sustainable concepts, I think, they cannot wrap their minds around it.

This contradicted another participant who indicated that the "accreditation does not get involved in the material. They look at the curriculum and how we deliver. They really don't get involved" (participant 6).

This localized context can play a significant role in the development of curriculum, where one institution feels stifled by the accreditation body and another institution feels like they have autonomy in their curriculum development. In this case, one solution that may be appropriate for one institution may not be appropriate for the other. The accreditation factor is further explored in the subsequent section as it plays a role in the considerations for online learning.

These findings were consistent with a research study that focused on the significance of context for curriculum development in engineering education in Kenya, Tanzania and South Africa. This study highlighted the importance in considering context in curriculum design, finding that historical context, political objectives, industry objectives and institutional objectives influence curriculum reform through accreditation and funding, availability of resources, expectations of graduates and departmental autonomy [6]. Without an understanding and consideration of context, interventions are at risk of being less effective.

3.3 Accreditation Considerations for Online Learning

Accreditation emerged as another topic conversation in the design and development of online learning material. Differing opinions between universities arose during the conversations of online learning implementation. Participant 3 from KU1 stated:

> We cannot replace the existing [curriculum] because EBK has an issue especially for undergraduate. So, the only thing that can be done is, as he said, when we look at the soft or easy options [for online learning]. First engineers who are in the field we upgrade them to online. At the same time, there are those who want to do their masters where EBK does not play a role [in the curriculum]... But then later on when maybe EBK [becomes] a bit more understanding then [online learning] can be scaled down to bachelors.

This excerpt demonstrates barriers to the introduction of online learning in undergraduate engineering courses and suggests using online learning in graduate courses first. Participant 4 from KU1 further added to the accreditation barrier of implementing online engineering courses at the bachelor level.

> So, that has been a challenge in terms of incorporating teaching the open [online] learning. I think some courses can be replaced such that you have distance learners using technology, video conferencing satellite and so on. But

> these are concepts that the [EBK] currently, as constituted, cannot accept. So, as those members are phased out and we bring in you guys with fresh ideas, we will be able to catch up with the rest of the world.

A different response was provided regarding involvement of the accreditation body during our conversation with the participants form KU2. One of the researchers asked if the accreditation board limited what they could put online as far as course material. Participant 7 responded, “no.” Participant 6 added that “accreditation does not get involved in the material. They look at the curriculum and how we deliver. They really don't get involved.” The conversation progressed to a discussion around the implementation and evaluation of their online courses.

> We have caught areas where we are able to have parallel groups. Group going through conventional way purely another one going through blended mode purely, but they take the same examination and then you check: is this mechanism or the style of delivery mode capable of teaching? And we have proved that the distance education is capable of teaching just as well as the conventional teaching. So, the end product is one way of judging and so on. (participant 8)

These differing responses provide direction for further exploration into the standards for online learning set by the accrediting body, EBK. It is not clear why participants 6 and 7 responded to the question with optimistic certainty while participant 4 professed a lack of optimism and the presentation of a barrier by the same accrediting body. It was disclosed to us during our visit to Kenya that the accrediting board was made up of members primarily from a single university. If this is true, it may begin to explain a difference in comfort with new ways of teaching at the different institutions, and expand the scope of the research to include the role of the accreditation board.

3.4 Openness to Collaborate

Ensuring that the project team was pursuing the study ethically with the universities in Kenya was an important aspect stated at the beginning of the paper. The researchers did not want to be perceived as interfering in their affairs or imposing their own doctrine. Fortunately, participant feedback from both universities validated our inquiry into engineering education in Kenya. A sentiment shared by participant 8 when they expressed an openness and desire to collaborate:

> [We] are generally ready to collaborate in this process in seeing how it can translate into some tangible things later on when the research part of it is completed and recommendations and suggestions started.

This sentiment affirmed our belief in a beneficial outcome of our team’s presence in the region and undertaking of the study. A senior administrator also made an appearance while we were conducting our interviews. They expressed an interest in signing a memorandum of understanding for further collaboration between our universities on this matter. This confirmed an openness and desire for collaboration between the research team and both universities in Kenya.

4 CONCLUSION

Using the method of currere framed under the three research questions, four key insights emerged from this study:

1. Opportunities exist for curriculum reform of Kenyan engineering curricula to

mirror emerging engineering pedagogy and practice;

2. Context is a critical factor in curriculum reform, especially when considering inter-institutional or international collaboration of developing learning resources;
3. Accreditation is a key consideration for online learning in engineering education; and,
4. There exists an openness to collaboration regarding curriculum reform.

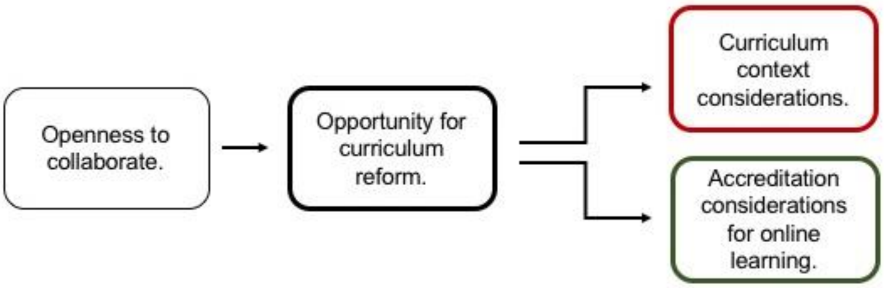

Fig 1. Progression of four key insights.

Although there is opportunity for reform, challenges for addressing the growing need for engineers in Kenya emerged throughout the research study. Limited institutional capacity, including physical, human and technological capacity, limited funding, and unclear curriculum accreditation standards all present challenges for the scalability of the engineering programs. These findings, coupled with an openness from both universities to collaborate, present an opportunity to explore online and distance learning initiatives that have the potential to address both pedagogical challenges, as well as curriculum content challenges.

The findings from this study may be used to inform design and collaboration considerations of the larger research project, or any other similar undertaking in the region. As context emerged as a critical factor in curriculum reform, more research is suggested regarding the institutional factors, notably the accreditation standards for online learning, the industry objectives and the policy objectives to inform the context of the conversations of engineering education in Kenya.

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Hands-on Experiments vs. Computer-based Simulations in Energy Storage Laboratories

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ABSTRACT

This cross-over study compares student laboratory work conducted in two different learning modes: first as a practical hands-on exercise and second using computer-based simulations. The research methodology was optimized to avoid other effects on the learning outcome. To evaluate the influence of the mode, short tests on knowledge gained during the previous experiment were conducted at the beginning of the next laboratory session. In 2016, forty students have taken part. Overall learning results of hands-on experiments were slightly better than those of simulated laboratories, but the difference in performance was not statistically significant. The study is continuing in 2017 with 30 participants. In addition to the knowledge tests, after each laboratory session the students were asked for their opinion in an online survey. A similar percentage of the students stated the execution of the experiments is beneficial for their future professional life. In the hands-on learning mode more students expressed they have acquired new knowledge. Although more students assessed the simulated laboratories as more challenging compared to hands-on experiments, more students mentioned obstacles while conducting the hands-on equivalents.

Conference Key Areas: Open and Online Engineering Education, Engineering Education Research, Sustainability and Engineering Education

Keywords: Hands-on experiment, Simulated experiment, Battery experiment, Learning-modes comparison

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INTRODUCTION

It has been shown that hands-on student laboratory work can significantly influence the outcomes of student learning [1]. Nevertheless, many universities and vocational training institutions conduct laboratories as simulated experiments instead [2]. This is due to the costs of proper laboratory equipment to engage students in effective learning. Another reason is the increased amount of supervision to conduct hands-on labs safely, especially when the object of the experiment is potentially dangerous, such as lithium-ion battery cells [3].

1 RATIONALE

Numerous studies have presented mixed opinions on whether hands-on laboratory work is more conducive to learning than the simulated laboratory [4, 5, 6].

Reflecting on the results of such studies, Ma and Nickerson concluded that many studies did not allow the researchers to reach definite conclusions [2].

Making clear conclusion on learning effectiveness of different modes of laboratory exercises is hampered by design of the abovementioned studies. For example, students conduct hands-on experiments in groups whilst on campus, but are engaged in simulated exercises over the web and individually [6]. As the learning mode is mixed with other influences (in this case supervision, cooperative learning effects, distance learning, instructional papers, synchronicity, etc.), such research compares the combination of all aspects and is unable to specifically identify the difference in learning effectiveness of hands-on and simulated experiments.

The present study compares learning outcomes of student laboratory work conducted in two different modes: first as a practical hands-on exercise and second using computer-based simulations. In order to provide more reliable insights, this study optimized research methodology to avoid other effects on the learning outcome during laboratory work. The student experiments were strictly designed in such a way that the content and procedure were identical in each mode.

2 APPROACH

Each group was taught the same four content areas related to lithium-ion battery cells: two as practical hands-on experiments and two as computer-based simulations. The first group completed the even laboratory sessions as hands-on experiments and the odd ones as computer-based simulations. Planned as a cross-over study, the second group of students were taught the same topics by means of the opposite learning mode. To evaluate the influence of the mode on student learning, short tests on knowledge gained during the previous experiment were conducted at the beginning of the following laboratory session. The mean group results were compared, to answer the question: which mode has been more successful? Additionally, the students were asked for their opinions on each laboratory session in an online survey.

2.1 Learning objectives of the laboratory

Electrochemical cells are a wide and rapidly evolving field. It was therefore decided to limit the new laboratory to teach the most relevant transferable skills and knowledge that are beneficial for the students' future careers. First, they should strengthen their understanding of the characteristic behaviour of battery cells. Second, there is a focus on gaining practical knowledge of the most important parameters of cells and how to determine these parameters self-sufficiently by means of appropriate experimental setups. With these competencies students are enabled to design experiments with energy storage systems.

The identified learning objectives where grouped to four main content areas: (A) contact and isolation resistance, (B) open-circuit voltage, (C) internal resistance and power, and (D) energy of cells. Grouped in these areas, seven laboratory experiments were designed in such a way that they could be conducted in both modes in the same manner:

- Low Resistance Measurements (A1): Students discover that a multimeter is an inaccurate tool for low ohmic measurements, in the mΩ range, and why such measurement is a misuse of the multimeter. They learn how to use alternative procedures for low ohmic measurements, including a four-wire measurement in AC and DC.
- Contact Resistance (A2): Students conduct experiments with a variety of contact resistance values of typical electrical connections in battery systems.
- Isolation Resistance (A3): Students learn to estimate the influence of moisture on the isolation resistance.
- Open Circuit Voltage Curve (B): Students investigate the dependency of the open circuit voltage of a cell on the state of charge. They use two different types of lithium-ion cells.
- Internal Resistance (C1): Students learn to use AC- and DC- methods to measure internal resistances, being aware of the temperature dependency of battery cells. Students learn to approximate temperature changes caused by a power loss inside a cell.
- Power (C2): Students investigate the maximum discharge rate of battery cells. Students discover the dependency of maximum discharge power from state of charge, pulse duration, and temperature.
- Energy and Capacity (D): Students determine the capacity of a lithium-ion cell and learn about the factors influencing it. They learn to calculate the energy efficiency of both charge and discharge cycles.

Instructions affect the learning outcome of an experiment, e.g. the guidance level can strongly influence student exploration [7]. Thus, for each experiment only a single set of instructions was created and then used in both laboratory modes.

2.2 Creating two comparable groups for the cross-over study

Over the last two years, students enrolled in the energy storages course, were split into two comparable groups based on their prior practical experience to ensure a similar group environment for the individual students.

Forty students were enrolled in the laboratory subject in summer-semester 2016. Thirty students were enrolled in summer-semester 2017. The full semester group in the study program "Electrical Engineering and Electric Mobility" at Technische Hochshule Ingolstadt (THI) is participating in the mandatory laboratory. All students were asked to join the study.

To conduct this educational research as a cross-over study, it was essential to separate the enrolled students into two comparable groups. In this type of study, differences of the compared groups' average performances are detected and equalized by statistics. With the goal of isolating the learning mode in the experiment, we have to consider the in-group interaction in laboratories. Webb found that the same student may have different experiences in different groups, with consequent effects on his or her learning [8].

It was assumed that students with more practical experience may perform better in laboratories than their peers with a lesser practical background. Therefore, in order to assess the level of students' practical experience a preliminary questionnaire was developed. Each year, after analysis of the student responses, students were assigned to two laboratory groups to ensure a similar mix of students with practical experience in each group. [9]

Each student created a code-word that could be used to identify the same individual, while keeping all participants anonymous. Later two lists with code-words were publicized to inform the students which group they were assigned for the laboratory sessions.

2.3 Conducting laboratories in content areas A to D

Each group completed experiments in the four main content areas, two as practical hands-on experiments and two as computer-based simulations. The first group completed the even experiments as hands-on experiments and the odd ones as computer-based simulations. Planned as cross-over study, the second group of students were taught the same topics by means of the opposite learning mode.

For the content area A in simulation-mode, a newly created simulation-website was used. For areas B to D a black box simulation of the hands-on equipment [10] and the battery cell was used. To minimize influences from the user interface to control the experiments, the simulation was accessed through the same graphical user interface as the real hands-on devices. The simulation model emulates all observed effects of the real battery cell and the hands-on devices. The cell simulation model was parametrized to match the outcome of the hands-on experiments.

Each group was split into smaller learning groups of three to five students. The laboratory groups and the learning groups remained unchanged to limit any effects on the result caused by changing cooperative learning.

The students worked autonomously in a supervised environment. All groups were asked to prepare a written laboratory report for each content area before the following session.

2.4 Online survey after conducting the experiments

The students where asked for their thoughts on each laboratory session in a short and fully anonymous online survey. This survey is conducted in both laboratories of the department (chemistry and energy storages) to improve the laboratories. Adequate questions were evaluated to compare the learning modes:

(1) “By conducting the experiment I gained new insights today.” (Original: “Ich habe heute durch den Versuch neue Erkenntnisse gewonnen.“) This was a yes/no answer and coded 1 or 0.

(2) “At which point in the experiment did you have the biggest problem proceeding with the experiment?” (Original: „An welcher Stelle im Versuch hatten Sie am meisten Probleme voranzukommen?“) This was a free text question which was not compulsory. For data evaluation, the information was coded to 1 if any problem was mentioned or to 0 if students wrote nothing or were expressing they had no problems.

(3) “The procedure of the experiment is quite difficult (1) / feasible (0.5) / easy (0)” (Original: „Die Versuchsdurchführung ist recht schwer (1) / machbar (0.5) / leicht (0)“) The answers were coded in a three step Likert scale.

(4) “The content of the experiment is also relevant for me outside the university; I can imagine that it will be beneficial for my future professional life.” (Original: „Der Inhalt des Versuchs hat auch außerhalb der TH Relevanz für mich; ich kann mir vorstellen, im Berufsleben Gewinn aus dieser Versuchsdurchführung zu ziehen.“) The answers were coded in a five step Likert scale: fully agree (1) / somewhat agree (0.75) / maybe (0.50) / somewhat disagree (0.25) / disagree (0)

2.5 Testing the learning outcome

To evaluate the influence of the mode on the student learning, written tests on knowledge gained during the previous experiment were conducted at the beginning of the next laboratory session.

These tests lasted ten minutes and contained a mix of descriptive and multiple choice questions, free answers, and drawings. A positive point system (similar to tests for giving a mark) was used to evaluate the results.

The tests were conducted anonymously. Students were coded through the same self-created code-word used in the questionnaire for grouping.

A priority while planning both semesters was to keep time gaps between experiment and the corresponding test equal for both groups. For organizational reasons, this was not possible at the first content area A in 2016 [9]. In 2017 the laboratories are on the same weekday morning and afternoon, making it easier to keep the experiment – test time gaps equal for both groups.

For the tests, the goal was to always use the computer lab to provide the same environment sitting at a desk while completing the tests. The tests were evaluated and rated using a point system. The average group results between the hands-on and simulated modes were compared, to answer the question: which mode was more successful to transfer the knowledge of the experiment?

3 FINDINGS

3.1 Learning outcome (ten minute tests)

The second run of the experiment is conducted with 30 students in summer semester 2017. In year 2016 with 40 students the range of individual scores was from 12% to 85% for hands-on, and from 12% to 88% for the simulated mode. The distribution of all results was normal. As seen in *Table 1*, for three content areas (A to C) a weak effect towards benefits of the hands-on mode was measured. There was a slight trend demonstrating hands-on laboratory sessions led to a better knowledge acquisition compared to simulated experiments. Content area D showed no difference between the modes. [9]

Overall learning results of hands-on experiments were slightly better than those of simulated laboratories (weak effect, Cohen's d = 0.22), but the difference in performance was not statistically significant ($p=0.215>>0.05$). [9]

3.2 Student feedback

The student feedback results are based on all results of the first iteration and the results of content area A of the current ongoing laboratory in 2017.

(1) In hands-on mode more students expressed they gained new insights (81% vs. 55%, Cohen's d = 0.56, medium effect). Pearson’s correlation between mode and new insights was 0.28 and significant ($p=0.005$).

(2) A similarly large share of the students mentioned problems while conducting the hands-on experiments or their simulation equivalents (42% hands-on vs. 43% in simulation); Cohen's d = -0.02 is showing that there was no effect.

(3) The engagement in the simulated experiments was stated to be a small amount (8% of scale) more difficult (0.38 hands-on vs. 0.46 simulation). Cohen's d = -0.33 demonstrates a weak effect.

Table 1. Results of 2016 [9], Effect hands-on vs. simulated

Content Area	Sample Size	Percentage of points Mean Value **hands-on**	Percentage of points Mean Value **simulated**	Percentage of points Std. Deviation both modes	Effect size (Cohen's d) "hands-on led to better learning outcome"
A	37	38%	33%	16%	0.28
B	39	54%	49%	16%	0.32
C	35	52%	47%	18%	0.30
D	37	45%	45%	15%	0.04
all	148	47%	44%	17%	0.22

(4) Students who conducted the experiments in the hands-on mode rated the execution of the experiments a little more beneficial for their future professional life (0.58 hands-on vs. 0.55 simulation, Cohen's d = 0.19, very weak effect).

No significant correlations between these items were found except between (1) and (4), where Pearson's correlation was 0.41 ($p<0.001$) and Spearman's rho was 0.38. Looking at both modes separately, the correlation in the simulation mode was stronger (Pearson's r 0.52, p<0,001; Spearman's rho 0.52; N=49) compared to the hands-on mode (Pearson's r 0.23, p=0,115; Spearman's rho 0.14; N=48).

Due to a low response rate for this questionnaire (31%) in the first year (2016), in the second year (2017) the students were recompensed for their time to fill out a questionnaire. Additional 5% of points were added to the grading of the laboratory protocol, which makes it easier to reach the minimum level to pass the subject. In experiment A, which had already been conducted at the writing of this publication, the return rate increased to 77%.

4 CONCLUSIONS

4.1 Learning outcome

This study showed that the described methodology is applicable to focus on the comparison of two learning modes. By excluding many other influences on the comparison of the learning outcome, the results show only a small difference. The slightly better learning results of the hands-on mode are not significant. Some of the excluded factors might have greater impact on student learning than estimated previously. To get statistically significant results more data collection is necessary. This study is going on through 2018 at THI and the methodology will be tested at more universities with different types of students (e.g. international students, summer schools).

4.2 Online survey

The contrast between both modes in the student's subjective opinion about gained knowledge (1) is much more significant than in the objective results of the ten minute tests. The students' opinions show advantages of the hands-on mode: although one cannot determine the students understood more in this mode, one can conclude they gain more confidence in performing similar tasks. In a limited capacity, self-confidence can be considered beneficial for the students' further development by increasing their intrinsic motivation.

The correlation between (1) and (4) shows that students who claimed that they gained new insights also tend to believe that the execution of the experiment will help them in their future professional life. The weaker correlation between (1) and (4) in the hands-on mode suggests that even when the students think they gained additional insights, the students do not consider all of the insights relevant for their profession. Identifying these insights may be beneficial for the improvement of the experiments. Therefore, future surveys will ask for the most beneficial insights gained and whether they consider them useful for their future work outside the university.

Regardless of the learning mode, more than forty percent of the students think they do not benefit in their professional life (4) from the experiments. This is quite disappointing and leads to the possibility of asking for missing content students estimate as important for their future profession.

On one hand less students mention problems with the hands-on experiments (2), while on the other hand they feel the simulated variants to be more difficult (3). When taking a deeper look at the answers from the students, it becomes clear that these results are not correlated. A common mentioned problem was the lack of available measurement devices. Also problems tied to the use of the software could be considered as neutral, as the same software was used in both modes. The difference between the described levels of difficulty of the learning modes (3) raises the question for these reasons. At the time of writing we do not have a final conclusion on this weak effect. For the future evaluation of the study we will ask the students to describe the difficulty in a free text answer.

The actual methodology does not allow one to find correlations between individual learning outcome and student's feedback, as the standard online feedback form is not asking for the self-created code-word that was used in the tests. We plan to implement the new questions and this missing information to a new questionnaire in paper form and use it for the next iteration.

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The European Project Semester at ISEP (EPS@ISEP) Programme
Implementation Results and Ideas for Improvement

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ABSTRACT
EPS is a one semester student-centred capstone programme designed by Arvid Andersen in Denmark, being currently offered by several European engineering schools. Its goal is to promote the development of scientific, technical and soft skills in students through multicultural teamwork and open, multidisciplinary project based learning. EPS, while an active learning framework, is focussed on problem-solving, communication, creativity, leadership, entrepreneurship, ethical reasoning and global contextual analysis. The School of Engineering of the Porto Polytechnic is an EPS provider since 2011, offering a 30 ECTU package with two-thirds assigned to the project module and one-third to project supportive complementary modules. A total of 138 students from 18 countries participated in the EPS@ISEP, while developing 28 multidisciplinary projects. Based on this experience, this paper identifies strengths, weaknesses and proposes ideas for the improvement of the programme.

Conference Key Areas: Skills and Engineering Education, Curriculum Development, Sustainability and Engineering Education

Keywords: Engineering Education, Project based Learning, Multicultural and Multidisciplinary Teamwork, Sustainable and Ethical Practices

INTRODUCTION
The challenges faced by engineering education are multiple and hard to address. Institutions and students are experiencing constant changes, including financial constraints, focus shifting and the need to develop new competences. Project and problem based learning approaches are particularly fitted for engineering education, but no longer provide *per se* all the competences required in future engineers, which

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are expected to act in the global market, work in multicultural multidisciplinary teams, hold expertise in a specific engineering field and be proactive lifelong learners. This is the context that led to the creation of the European Project Semester (EPS) [1].

The EPS framework is a one semester student-centred international capstone project/internship programme offered to engineering, product design and business undergraduates, designed by Arvid Andersen [2]. EPS started in 1995 in Denmark and is currently offered by a group of 18 European engineering schools, from 12 countries, called the EPS Providers, as part of their student exchange programme portfolio. The goal of the programme is to prepare future engineers to think and act globally, by adopting project-based learning and teamwork methodologies, fostering the development of scientific, technical and soft skills. In particular, multidisciplinary and multicultural collaborative learning and sustainable and ethical development are pervasive concerns within EPS projects. The programme provides an integrated framework to undertake engineering capstone projects supported by a project-based learning methodology. Moreover, it focusses on teamwork and exposes students to cultural, scientific and technical diversity. The EPS package is organised around one central module – the EPS project – and a set of complementary supportive modules. The project proposals should refer to open multidisciplinary real world problems, empowering the teams for the conduction of their projects [3].

The EPS providers have discussed, agreed upon and posted on the EPS Providers site[2] the specification of the EPS framework – the so-called “10 Golden Rules of EPS” that an EPS provider must comply with: (*i*) English is the working language of EPS; (*ii*) EPS is multinational with a group size of minimum three and maximum six students, being four or five the ideal number; a minimum of three nationalities must be represented in each EPS group; (*iii*) ideally, but not necessarily, an EPS project is multidisciplinary; (*iv*) an EPS semester is a 30 ECTU package, the duration of which is not less than 15 weeks; (*v*) an EPS project has a minimum of 20 ECTU and the complementary subjects account for a minimum of 5 ECTU and a maximum of 10 ECTU; (*vi*) the main focus on EPS is on teamwork; (*vii*) the subjects included in the EPS must be project supportive; English and a basic crash course in the local language must be offered; (*viii*) the subjects must include Teambuilding in the very beginning and Project Management in the beginning of an EPS semester; (*ix*) project supervision/coaching must focus on the process as well as the product; and (*x*) EPS must have continuous assessment including an Interim Report and a Final Report. The different EPS programmes are not only compliant with this generic framework, but also with “diverse flavours”. There are programmes focused on engineering (most providers), business, product design or media and with different operational approaches. By default, EPS, as an engineering capstone programme framework, is intended for the final year of the engineering programme. There are programmes offered to 3rd year students (all providers), to 3rd and 4th year students (Polytechnic Institute of Porto) and 3rd, 4th and 5th year students.

Bearing these ideas in mind, Section 2 describes the EPS@ISEP programme. Next, Section 3 identifies the problems and strengths of this implementation and Section 4 proposes a set of improvement suggestions for near future implementation. Finally, Section 5, draws the main conclusions.

1 EPS@ISEP

The School of Engineering of the Porto Polytechnic (ISEP/PPorto) became an EPS provider in 2011 and has since welcomed 3rd and 4th year mobility students during

[2] http://www.europeanprojectsemester.eu

the spring semester. EPS@ISEP – the EPS programme provided by ISEP/PPorto – targets engineering, business and product design students and aims to prepare them for their professional life by fostering the autonomous development of scientific, technical, personal and social skills

The EPS@ISEP programme is a 30 European Credit Transfer Units (ECTU) package structured in six modules: 20 ECTU assigned for the project module and 10 ECTU for complementary modules: Project Management and Team Work (2 ECTU), Marketing and Communication (2 ECTU), Foreign Language (2 ECTU), Energy and Sustainable Development (2 ECTU) and Ethics and Deontology (2 ECTU). The latter are project supportive seminars, oriented towards the specificities of each project, focussed on the development of the soft skills essential in the training of twenty-first century engineers: communication (including technical-scientific English) contributes to the development of the project deliverables; project management focuses on task identification, human resource allocation, task planning and scheduling, resource management, plan enforcing and eventual rescheduling; sustainability addresses the ecological footprint; ethics and deontology analyses the ethical and deontological concerns; and marketing tackles the market analysis, segmentation and positioning of the prototype [4]. Furthermore, there is also an Arduino crash course to provide students with basic knowledge about this simple control platform. Figure 1 presents the EPS@ISEP schedule and illustrates the concretization of golden rules *viii* and *x*.

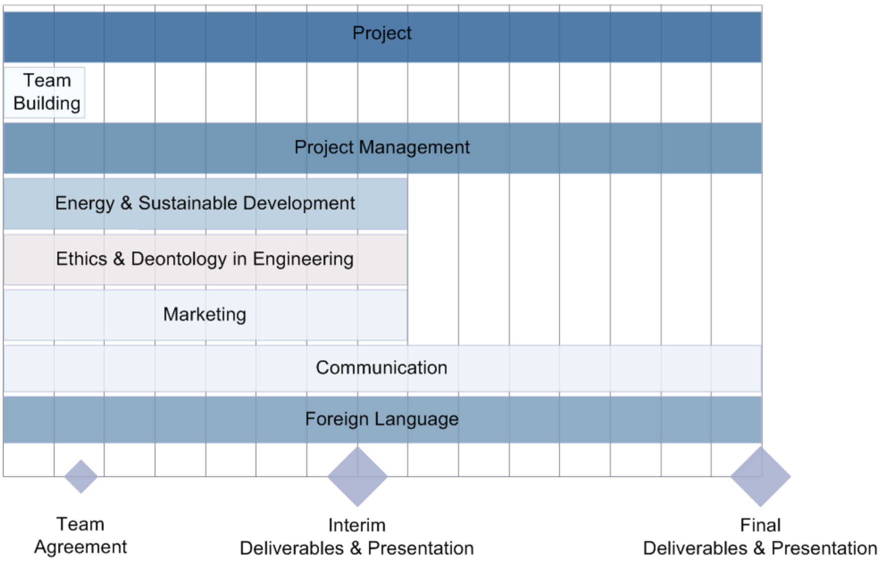

Fig. 1. EPS@ISEP schedule

Before the beginning of the semester, a set of project proposals regarding real world problems are collected, each one with a specific client, with a strong focus on sustainability, to raise the student's awareness to the problem, and in multidisciplinary topics, so each team member can contribute to the project with his/her previous knowledge and background experience. The origin of proposals ranges from industry, services, R&D institutions or the school itself. The proposals tend to be multidisciplinary problems, i.e., require the integration of multiple technical and scientific competences. A proposal defines the problem/challenge to tackle, the minimal set of requirements, mostly mandatory directives and standards, and the maximum budget. This type of proposal directs the team towards the design thinking stages and, then, towards the development and operation stages of the capstone project/internship. As all proposed projects are open ended, team discussions about the possible solutions provide an opportunity for the students to expose their different beliefs and values, in a multicultural setting. Depending on the complexity of the projects, the average cost of an EPS@ISEP project is approximately 200 €.

Before the start of the semester, each student is asked to fill a Belbin questionnaire, which will be used to identify the individual teamwork profile and design of teams according to rule *ii*. According to the EPS rules, not only the teams must incorporate students from different fields of expertise and nationalities, but team building activities must be offered to allow team members to discover and perceive the existing cultural, scientific and personality differences. One of the first tasks team members are faced with during team building activities (rule *viii*), is to define their own set of conflict resolution rules – Team Work Agreement – using the mechanism proposed by Hansen [5]. The resulting document is signed by all team members and archived in the team folder. Next, the teams select the project of their choice from the list of project proposals available and start their learning journey by conducting studies on marketing, ethics, deontology and sustainability together with scientific research (a state of the art analysis of the problem domain) to decide on the structure design & materials, as well as on the system design & control system.

EPS@ISEP adopts a unique supervision model where a panel of multidisciplinary experts, consisting of teachers from various study fields, acts as a consulting committee (Figure 2). Every week, this panel meets with each team for about 40 min.

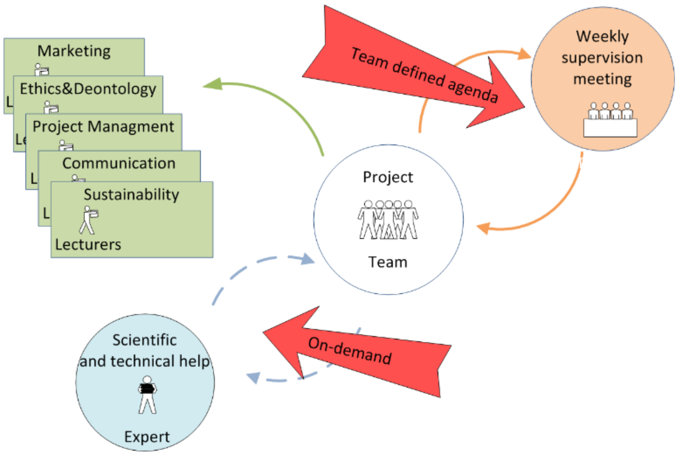

Fig. 2. EPS@ISEP model of student supervision

In the meeting with the panel, the teams conduct the meeting, and only the topics previously specified by the team in the wiki agenda are discussed. In this meeting, the teams are challenged to explain and justify any decisions taken during the previous week (shared in advance on the project wiki) and motivated to explore further. In order to be effective, the coaching panel is aware that it is interacting with students from diverse scientific and cultural backgrounds as well as that it must provide prompt feedback. In addition, the teams hold weekly meetings with their direct project supervisor(s) to promote further brainstorming, debugging, assembling and testing of the project. The teams can take the initiative to propose additional coaching meetings.

Assessment drives learning and hence a good assessment design is the key to effective student development [6]. EPS@ISEP uses the assessment scheme proposed by Hansen [5]. Assessment occurs twice during the semester and contemplates self and peer (S&P) and supervisor assessment (SA). The S&P assessment considers the quality and quantity of the technical contribution, openness to others ideas, teamwork performance, leadership, attitude and initiative shown [7]. The SA assessment reflects both team performance as well as the individual performance of each student. The interim assessment is intended to give individuals and teams feedback about their performance so far, from the point of view of their peers and of the supervisors. The supervisors use the assessment to monitor team working and to give constructive feedback and advice where needed [7].

The teams must produce several deliverables, including the project wiki, report, video, paper, manual, brochure and a proof of concept prototype. The report structure (provided beforehand) includes as mandatory sections the introduction, state of the art, marketing, sustainability, ethical concerns, project development and conclusions. Some chapters are produced and refined within the corresponding complementary modules. The structure and presentation of the deliverables are addressed in the communication seminar. The wiki is a key tool to the EPS process since it acts as a collaborative work platform and as the project show case.

2 REFLECTION ON EPS@ISEP

Since 2011, EPS@ISEP has welcomed 138 students from 18 countries, as depicted in Figure 3. These participants successfully conducted 28 projects.

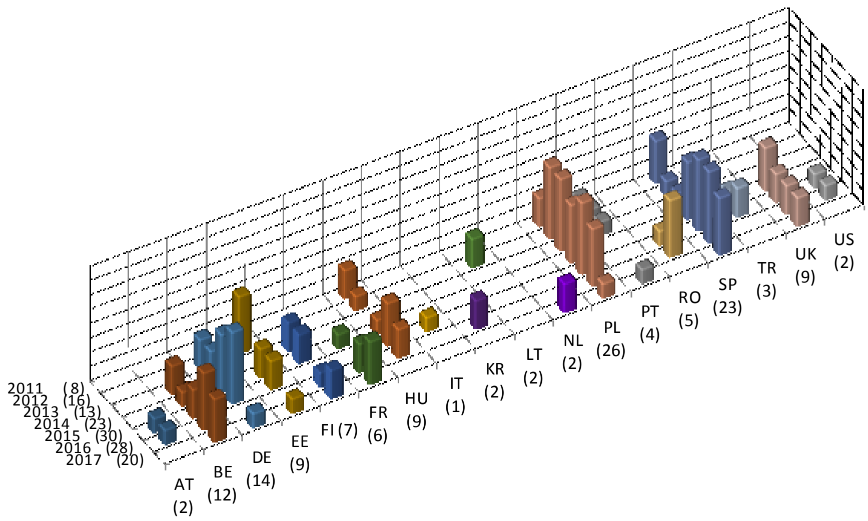

Fig. 3. EPS@ISEP: Number and nationality of students

The scheduled classroom activities involve thirteen teachers from seven ISEP departments and account for a total of 472 h/semester. Dislocated EU students are supported by EU Erasmus+ mobility grants, typically covering one round trip and the accommodation costs. These figures allowed the identification of several strengths, but also weaknesses related with the programme management and costs, the students profile and their motivation and the teaching and support staff.

2.1 Programme Management

Concerning the managerial aspects, the programme involves a 470 h of teaching and a dedicated room is allocated to all activities during the entire semester. However, since this programme implements hands-on practical training, there is the need to use different laboratories, mainly related to the development and construction of the prototypes. Typically, due to the wide range of the problem domains, there is the need to use several laboratories from different departments, *e.g.*, the mechanical, electrical, electronics and chemistry laboratories. This dependency presents problems related with the authorisation and availability.

Another aspect related to this topic is the financing of the projects. While initially the projects were financed by ISEP, nowadays they are financed by sponsors, clients, prizes, organisation of events and the fees of international (non-EU) and free mover students. The materials and components acquisition is a cumbersome process, due to the requirements for public procurement of goods and services in Portugal. The teams participating in the EPS@ISEP provide the supervisors with their list of materials and suppliers. These lists must be thoroughly inspected, to check if the suppliers fulfil the existing acquisition rules, and submitted to the financial department for approval. After authorisation, orders are placed and, typically within a week, the materials are received and delivered to the teams. During this process, teams often suggest suppliers which do not fulfil ISEP's acquisition rules, typically companies operating on the Internet, such as Amazon, eBay or Alibaba, and despite repeated warnings, make non-authorised purchases.

There is also a problem with the grading system. The EPS grading system privileges the process instead of the product, but this presents some drawbacks, since it tends to penalize good, hard-working, students who belong to weak groups, and favour weak, non-working students, participating in strong groups. This aspect has led to situations on which hard-working students feel wronged and lazy students feel lucky. These students, after returning to their home institutions, advertise against and in favour of the programme, respectively, preventing the application of students from these institutions with the desirable profile in subsequent years.

2.2 Student Issues

Regarding the students, there are four main drawbacks: insufficient mastery of the English language, insufficient technical-scientific background knowledge, pending academic activities at home school and wrong motivation for participating in an exchange programme. Although applicants must provide a B2 Common European Framework of Reference for Languages (CEFR) level of English, in some cases their actual level of English is below. The second aspect is related to the fact that some students enrol without sufficient technical-scientific background knowledge. In other cases, they have not yet accomplished the necessary 150 ECTU to enrol in a capstone/internship module and still have pending academic at their home schools. Such activities, *e.g.*, exams, are highly disruptive and involve returning for a few days. This is particularly inconvenient when it occurs in the last months of the semester, a period of heavy workload involving the assembly and test of the prototype and the subsequent preparation of the final deliverables. Finally, there are still students with the wrong motivation to participate in an exchange programme, *i.e.*, focussed on travelling and recreational activities rather than on the personal growth and international multidisciplinary teamwork offered by EPS@ISEP.

To minimise the first problem, all students are asked to send a B2 CEFR level English certificate as part of the application documentation. Regarding the second and third issues, the acceptance letter, sent to the accepted applicants and their home institutions, specifies the programme acceptance rules, stating that students must not have pending activities at their home schools during the spring semester, nor have less than 150 ECTU accomplished at the moment of their arrival. Unfortunately, there are still students and partner schools disregarding these rules.

2.3 Staff Issues

Although the programme involves, on average, around 20 students, thirteen teachers and account for a total of 472 h each semester, there is no support staff to help manage the programme activities. This implies that all bureaucracies inherent to the programme, as well as student problems must be solved, mainly, by the team of supervisors, which is a time-consuming activity. The only exception is the mobility documentation processed by the International Office.

Concerning the seven project supervisors, it should be mentioned that coaching EPS students is an additional activity involving large amounts of unaccounted time and effort. However, despite this, the team of supervisors has worked together with most teams to publish a project paper on reputed international conferences and, in some cases, even in international journals with peer-reviewing.

Finally, the six project supportive module teachers are from distinct departments and it is, sometimes, difficult to keep the same teachers between editions. Also, some of these teachers are not fully aware of the particularities of the programme and of its objectives, and have some difficulty in organizing and teaching their modules in a way that is fully supportive of the project that the students are developing.

3 IMPROVEMENT SUGGESTIONS

The first improvement suggestion is to allocate a laboratory/room equipped with basic consumption materials, tools (mechanical and electrical/electronic) and equipment. This laboratory should also be equipped with basic machines for wood working since several project prototypes have been developed in wood. Finally, this space should include a technician to support the students during the development of their project prototypes and conduct, whenever necessary, the purchase process.

Regarding the use of the budget allocated to the project, an effort should be made to have most of the project proposals sponsored by companies / institutions outside of ISEP. In these cases, what has been negotiated with the companies if that the acquisitions are performed directly by the team of supervisors, the receipts have the data from the companies, and the expenses are latter directly reimbursed to the people that acquired the materials (teachers or students), without the inherent bureaucracy.

In relation to the EPS grading system, the problem is difficult to tackle since a decision should be made among the providers to change it. Anyway, the supervisors should have the possibility to “bypass” the “regular” grading system under justified circumstances, *i.e.*, whenever they believe any student has been unfairly assessed.

Concerning the problems related to students, it is impossible to assess their motivation, English and technical knowledge before they arrive. This can only be solved with the cooperation of the partner schools. In particular, it is easy to ensure that applicants have accomplished at least 150 ECTU and do not have pending exams. In addition, this should be discussed and agreed among the providers.

Finally, internally, an effort should be made to consider the actual number of teaching hours involved in the coaching of EPS students and the departments should assign teachers motivated to foster multidisciplinary project-based learning.

The authors recognize that some of these ideas are difficult to implement, but must be considered if the programme is to be improved.

4 SUMMARY AND ACKNOWLEDGEMENTS

The EPS student-centred learning process is based on promoting the autonomy and responsibility in the teams, adopting technical and scientific coaching and offering project supportive and soft skills complementary modules. This process drives the teams to design and develop a concrete prototype and produce multiple deliverables, while learning to manage the project, to study the state of the art in the different fields of the project, to create a marketing plan, to work together and to justify all design, materials and development decisions based on the analysis of the sustainability, ethics, scientific and technological aspects. However, the objective of this programme is more ambitious than just expecting the students to implement prototypes – it is also to make them contribute with their distinct visions of the problem to a common consensual solution. This process is not always easy, since at this educational level the students are not used to collaborate with peers from different nationalities (implying distinct cultural backgrounds) and from different study backgrounds (engineering students tend to think differently from business and product design students). Given these ideas, this paper described the EPS program, reflects on its implementation at ISEP and proposes improvement suggestions regarding the EPS@ISEP implementation.

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Sustainability accreditation in engineering education:
Comparison between Danish and French contexts

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ABSTRACT

Even though international organisations and engineering professional organisations recognise the need for engineering education institutions to prepare future engineers to contribute to a sustainable society, there are considerable differences in the push from national regulations and accreditation systems to ensure engineering education for sustainable development (EESD). This system paper presents an outcome of collaboration in the SEFI working group on Sustainability in Engineering Education set out to compare the accreditation frameworks for engineering education in two European countries, Denmark and France, with specific attention to the integration of sustainability. The study outlines the range of accreditation frameworks in terms of their call for sustainability, from sustainability as a possible (yet not explicitly formulated) approach to contextualise engineering in a societal perspective, to sustainability integration as an explicit accreditation requirement.

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Conference Key Areas: Quality Assurance and Accreditation

Keywords: Engineering Education, Sustainability, Accreditation frameworks

1. INTRODUCTION

International organisations and engineering professional organizations recognize sustainability challenges and complex contexts that engineering students have to address. For example, the European Society for Engineering Education (SEFI), through the working group on Sustainability in Engineering Education stresses the need to implement sustainability in engineering education. The overall aim is to equip engineers with knowledge, competences and skills such as systems thinking, critical thinking, problem solving skills, communication, teamwork, interdisciplinary knowledge, flexibility, and adaptability, to address sustainability problems.

Even though, the engineering education for sustainable development (EESD) societies have achieved much in the last decades (by establishment of thematic conferences, journal publications, working groups, etc.), sustainability integration in engineering education has been slow and behind the needs. Integration of sustainability in engineering education responds to local conditions, resources and national accreditation systems where different frameworks are adopted and differ from country to country.

This system paper presents an outcome of collaboration in the SEFI working group on Sustainability in Engineering Education of examining the role of accreditation in supporting the integration of sustainability in engineering education. We have done that by comparing accreditation frameworks and standards from two European countries, France and Denmark.

The story takes point of departure in the Danish system of Accreditation of Engineering Institutions and Programmes, which illustrates a system with high attention to the quality management process and an emphasis on overall accreditation criteria. The focus then shifts to France, illustrating a case with a similar high focus on Quality management aspects but with more specific accreditation criteria for Engineering Education for sustainability.

2. ACCREDITATION OF ENGINEERING EDUCATION IN DENMARK

In Denmark, The Danish Accreditation Institution is the specific organization responsible for accrediting higher education, including institutions and programmes. The purpose of the Accreditation framework is formulated in a quality management perspective with focus on development whereas the quality assurance and control is to be seen as inputs to this process, as noted by the Danish Accreditation Institution [1:3].

“The purpose of the accreditation system and institutional accreditation is to strengthen the work carried out at education institutions to develop programmes to an increasingly high level of academic quality and relevance.”

There are two different levels of accreditation in Denmark – institutional accreditation and accreditation of specific programmes. In the following, we will focus on presenting the different types of accreditations and the criteria for the Danish Accreditation framework. For more information about the accreditation process, please see [2] and [1].

2.1 Different levels of accreditations

Accreditation processes take place periodically and it is done at an institutional and a programme level. The accreditation guide refers to five main criteria [1][3]:

- I: Quality assurance policy and strategy; e.g. goals for overall quality assurance and development and also inclusiveness of all educational programmes
- II: Quality management and organisation; e.g. the requirement to include all relevant actors and management levels.
- III: The programmes' knowledge base, e.g the relevance and quality of the related academic environments and staff development.
- IV: Programme level and content, e.g. compliance with the Danish qualification framework for higher education programmes and on-going evaluations on program level.
- V: Programme relevance, e.g. ensuring that the programmes reflect the needs of the labour market and include external actors involvement in development of programmes.

On the programme level there are also five criteria [3]:

- I: Demand and relevance including employability for existing educations and the relevance for the labour market (relates to Criteria V in the Institutional accreditation).
- II: Knowledge base including research base and relevance (relates to Criteria III in institutional accreditation)
- III: Learning goals e.g. whether the learning objectives for the education is aligned with the Danish qualification framework (relates to Criteria IV in the Institutional accreditation)
- IV: Planning and implementation including the structure and pedagogical quality of teaching.
- V: Internal quality assurance and development, e.g. focusing on evaluations of the actual practice (relates to Criteria II in the institutional accreditation)

If an institution has a positive institutional accreditation, they have the opportunities to establish new programmes and new local provision of programmes when they have been pre-qualified (only in relation to aspects of programme criterion I) and approved, and to make adjustment to existing programmes. If the institution on the other hand has a conditional accreditation, all new programmes and local provision of programmes must be accredited before they are established, and a plan is drawn up for improving the conditions to apply for a positive accreditation. If the institutional accreditation is refused, the institution cannot establish new programmes or local provisions of programmes, and existing programmes must be accredited in accordance with a rota plan. Thereby, a huge interest exists in obtaining institutional accreditation.

2.2 Sustainability in the accreditations framework?

In regard to the more specific programme level content (Criterion IV-institutional accreditation; Criterion II-III – programme criteria), a reference occurs to the Danish qualification framework and the Act for Bachelor and Master Educations at Universities.

The Danish qualification framework [4] specify generic qualification levels at Bachelor and Master level, as for example interdisciplinary collaboration, however with no specific mentioning of specific cross-cutting subjects as sustainability. On the contrary, subject(s) are mentioned in indefinite articles only. Neither does the programme criterion considering learning goals specify any requirements to content besides the relevance to the Danish qualification framework.

The Act for Bachelor and Master Educations at Universities, however, specify in relation to Engineering type of education that [5]:

"The candidates within the field of engineering have the purpose to qualify the student to solve complex technical problems, design and implement complex technological products and systems in a societal context"

However, no clear indication exists on how this relation to the societal context should be framed.

Thereby, neither the Danish qualification framework nor the Act for Bachelor and Master Educations in Engineering provide any mentioning of sustainability, and as the accreditation framework does not move into more detail considering learning objectives in different knowledge domains, a positive accreditation in this framework does not assure integration of sustainability in engineering education. Rasmussen [6] has characterised this as a paradox as higher quality was introduced as the goal in the political agenda, but there is no real direction for this quality improvements, as education does not have to do anything specifically, they just have to do it in a qualified manner. Furthermore, institutions have to document in detail what they do.

The current accreditation framework, on the other hand, provides Danish universities with a high degree of freedom in terms of curricula design, as long as they can argue for relevance from an employability perspective. In relation to sustainability education, this means that sustainability learning perspectives can be framed and closely related to different disciplinary domains. Currently, due to the urgent demand to get institutional accreditation, there is, however, a risk that engineering education for sustainable development is not prioritised.

3. SD IN EE CURRICULA IN FRANCE

The "Commission des Titres d'Ingénieurs" (CTI) realizes, in a mandatory way, the accreditation of Public and Private Engineering Universities in France, and on request abroad. This agency is a member of ENQA (European Network for Quality Assurance), this means that CTI satisfies some important requirements such as adapting its accreditation criteria to the evolutions of society and demands of its stakeholders.

Social responsibility is considered an important challenge for engineers, moreover, besides CTI's criteria concerning technical skills, there are strong criteria that concern teaching of soft skills: in French accreditations, human and social fields of teaching must represent about 25% of the programs.

Six years ago, the criteria concerning SD were not put in the mandatory ones, we had written a document called “Analysis and Prospective” which was available on our website to help institutions in their evolution towards SD. Then, they became part of the mandatory criteria that are in “Références et Orientations” (R&O) which is the reference book for French Accreditation [7].

The fact that CTI is a parity based organization composed of an academic college and a socio economic college is also a determinant factor: very often, norms concerning SD are already on application in companies, this made professional members very receptive to the problems linked to the domain of SD very soon.

3.1 The different attempts concerning SD in France

In France, the problems concerning SD have also been soon taken in account by students, as well as by organizations of deans such as Conférence des Grandes Ecoles (CGE) and by Ministries, some of them trying to act as positive lobby. CGE is still very active in this field, having recently edited a guide of skills concerning SD and its reflection group is in charge of the French evolution of the SUstainable LItteracy TEst.

In 2007-2008, the network of French students for SD [8] realised a survey among the students (15 000 of them gave their opinion about SD and SD education) in order to make propositions resulting from these statements and expectations. The outcome was that teaching of SD was either absent or very specialised in French education. The students expected more active pedagogies connected to the “real world”. One of their proposals was to make campuses exemplary and to define a minimal curriculum that should be taught to everybody. However, due to the autonomy of universities, it revealed very difficult for this group to make institutions evolve quickly.

A first attempt to evolve faster has been the Green Plan, perhaps because it is based on a law but also because it includes many of the aspects considered in previous attempts in Europe. According to a French law, the “Loi de Grenelle” of 2009, the Higher Education Institutions have to elaborate a Green Plan which is a plan intended for sustainable development including environmental preoccupations but also a social and economic one.

The success of “Plan Vert” needs:

- the SD strategy to be elaborated
- the institution mission to dedicate a person responsible for the animation, the setting and the evaluation of the SD process; this person must have human and financial resources

A framework has been defined after promulgation of “Loi de Grenelle”, it has been named Green Plan Reference system [9]: it is a toolbox helping to define a SD strategy, its steering and its self-evaluation. 5 dimensions are to be considered for elaboration of the “Plan Vert” of an institution: Strategy and governance, Teaching and education, Research, Environmental management, Social policy and Territorial management.

3.2 CTI requirements

In February 2014, CTI, considering that teaching social responsibility to engineers was a critical point for society and a duty for engineering institutions, decided to include immediately SD not only in the intended learning outcomes as it was previously, but also in the description of the global policy of the institution: this was an important evolution of the accreditation criteria [10].

The strategic guidance note of the institution being evaluated should include the orientation chosen by the institution regarding SD and particularly quote the Green Plan that describes the institution’s strategy, its implementation and evaluation. The strategic guidance note is an important part of the self-assessment report because the institution’s administrative council votes it, and when this institution is part of a group of faculties, the university council also votes it.

CTI strongly wishes that institutions really integrate SD through curricula in the education of engineers but also apply the principles of SD in their own management, working in an exemplary way.

When an institution is accredited or reaccredited, the implementation of Green Plan has to be explained within the quality process of the institution. CTI has quoted eight dimensions of operational actions to be verified during the evaluation process:

- strategy and governance
- social management and local integration
- environmental management
- research
- curricula
- documentation
- industrial rooting
- quality management and continuous improvement

CTI stresses that a specific innovative active pedagogy has to be put in place for SD, this pedagogy of action puts the engineering student in the situation of finding and building solutions to “real world” matters. CTI also specifies that the recruitment of students must guarantee diversity according to a policy concerning chances equity.

Learning outcomes

However, regarding the curricula, the major point of the accreditation audit is the observation by the experts of the expected learning outcomes that the graduates must possess at the end of the curriculum.

Three of them are in direct relation with SD:

- The capacity to take into account the stakes of relationships at work, of ethics, of safety and health at work
- The capacity to take into account environmental challenges especially by application of principles of SD
- The capacity to take into account society’s stakes and needs.

During the audit of programs, CTI’s members have to check the conformity of these LO but also how they are really assessed.

3.3 Results

The first results were, however, not completely satisfactory, because very often, either the dean of the school or either the experts in charge of this audit did not really realize that criteria had changed or did not know how to act for SD.

In February 2016, CTI decided to go further. Because some new points of view concerning engineering were out of the traditional field of investigation of CTI, and because those points presented some difficulties, not only for schools but also for experts, we decided to put in place what we call “Focus” on SD. A focus is a specific point developed by the institution in 3 or 4 pages that will be delivered by the institution together with its Self-Evaluation Report [11].

The results were really satisfying and were broadcasted to all institutions.

4. CONCLUSION

In this paper, we have provided an example of the Danish Accreditation framework, which, comparable to other quality management frameworks, focuses on developing processes for quality control, assurance and integration. Crosscutting subjects of broader societal concern, like sustainability, are not even mentioned. Education for sustainability is to be defined by the institutions in an employability perspective.

If the universities take the lead in pushing for sustainable development, the degree of freedom to specify sustainability learning outcomes, which are aligned with the profession, might be an advantage. In other cases, it can just be concluded that there is only a vague and rather indirect push for education for sustainability in the Danish accreditation and legal framework for higher education. The integration of sustainable development as part of the qualification profile of Danish engineers, on the institutional as well as on programme level, is thereby left to the educational institutions to act on.

The CTI work in France shows how sustainability can be more explicitly included in the accreditation criteria. However, the lesson learned is also that the process from explicating sustainability in the accreditation criteria to actual change in the institution has to be carefully facilitated. The France case also points to potential future elaborations as to consider sustainability introduced in the management of the institutions as well as in the learning outcomes of graduates. These new recommendations have already made considerable changes at the institutions in France. A question for further research is how this change process can inspire similar change processes in Denmark, as well as in other European countries. The first step, however, is political will to push for sustainable development thought accreditation of Engineering Education.

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Sustainable Transfer of a German PPBL Model to a Mongolian Environment: Intercultural Experiences, Reflections, & Recommendations

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ABSTRACT

In our increasingly connected and global society, it is necessary for students to have interdisciplinary and intercultural skills to work with people from all over the world, for successful knowledge transfer, and for life-long-learning and encouragement of collaborative skills. Since 1998, a German technical university developed and continually improves upon a project-oriented and problem-based learning (PPBL) model that integrates both teamwork and systems thinking (engineering design) into an intensive, immersive project week. This model was then transferred to a newly formed Mongolian university. At the beginning, German academic staff introduced the Mongolian faculty to the PPBL model and taught the course for two years. For full empowerment and transfer of procedural and informal knowledge of the PPBL model, Mongolian academic staff attended a week-long workshop to learn and adapt the German model. This past year, the course was taught by Mongolian staff with mentoring from the German faculty. Our current snapshot shows that the transfer of the German PPBL model to a Mongolian university is on the path to be successful. Based on our experiences, we propose a feedback style which focuses on positive reinforcement of team resources in social environments where participants are not used to constructive feedback.

Conference Key Areas: Continuing Engineering Education and Lifelong Learning; Sustainability in Engineering Education; Engineering Skills

Keywords: PPBL model; sustainable knowledge transfer; intercultural experiences; cultural adaptations

1 INTRODUCTION

As we are living in a progressively complex and globally connected world, there is an increased need for students with project skills (teamwork and system thinking) and knowledge transfer between individuals, disciplines, universities, cultures, and countries to further encourage collaborative skills and life-long learning.

Accelerating global change includes socio-economic, earth system, and technological developments such as “Industry 4.0” and “big data”[1-4]. This has led to three major trends that impact and change the workplace: informatization, globalization, and financialization[5,6], which further lead to an informational capitalism with the specific characteristics of a “knowledge society”[7-9].

As a result, work has become organized in a more temporal, network-like structure and more knowledge-intensive[5,6]. Highly qualified workers should be creative, socially competent, and self-organized and be able to move easily between the “real” and virtual worlds along with knowing and efficiently using the related communication channels needed for these transitions[10].

The increase of complexity and flexibility at the work space leads to a continuous entanglement of working (doing) and learning[11]. Employees need to be proactive and adaptable with twenty-first century skills to be successful within this setting[12] and requirements along with the ability and readiness for lifelong learning[13,14].

Along with these developments and trends in the workplace, learning in higher education focuses on the approaches of constructivism[15] and connectivism[16,17]. Therefore, learning environments should be designed that will prepare students fully for the future, an increasingly interconnected, global world and workplace. These learning environments typically combine learner-centered, knowledge-centered, assessment-centered, and community-centered aspects[18], and goes hand in hand with a blurring of the separation between formal and informal learning[19]. These trends in higher education learning highlight and support “pervasive learning”[20] in “enabling learning environments”[21].

Project-orientated learning and design courses enables concurrent teaching and learning of teamwork and systems thinking (application of design) skills in a structured learning environment that combines aspects of their future workplace. This allows students to witness and experience the “messiness” of real-life industrial and teamwork problems, and has been shown to have long-term, positive impact on teamwork skills[22-26].

Drawing from this background, this paper discusses an innovative learning environment developed at a technical university in Germany and further describes the knowledge transfer of the concept to a Mongolian university. First, we will shortly introduce the project-oriented and problem-based learning (PPBL) model developed as an interdisciplinary, international project course. Next, we will report on and reflect upon our intercultural experience with our cooperation with a Mongolian university, and the shared learning experience of transferring the PPBL model as well as practical, informal knowledge to their academic staff.

2 GERMAN PPBL MODEL

The German PPBL model has been detailed previously[27-32]. Shortly, this model was originally developed in 1998 in collaboration with the Center for Educational Development at the German university as a monodisciplinary intensive, immersive, one-week design project course for first year students in mechanical and process engineering. In 2011, the mondisciplinary course was expanded and transformed into an interdisciplinary course and in 2012 was further expanded into an international, interdisciplinary course with German and American engineering students.

The core tenant of the German PPBL model is the concurrent teaching of teamwork and design skills in an innovative learning environment where students apply these skills through practice and reflection. The task teams are given is designed to be open-ended, complex, challenging, and similar to a team-orientated industrial project, and this leads to each team having finite resources e.g. time and knowledge that they must manage throughout the week to develop a solution. To support and not overwhelm the students, a support system consists of the following elements was developed:

- Team advising. Team advisers are mostly students of sociology, psychology, and pedagogy who have been intensely trained by the Center for Educational Development in team building and team competences. They establish standards and criteria of behavior modeled by professional (industrial) teams emphasizing team working techniques, communication, and problem solving e.g., discussion, moderation, visualization, through self-reflection, team-reflection, team-feedback, and additional feedback from the team adviser. The team advisers co-advise teams tandemly with a technical adviser.

- Technical advising. Technical advisers are academic staff who follow the principle of minimum help[33] and the Socratic questioning method. This means empowering teams with as minimum help as possible but as much as needed or necessary. Technical advisers give mostly general strategic, problem solving, and design process advice along with motivation and content-specific advice as needed.
- Help desk. The help desk is a scientific research resource for teams and is also orientated by the principle of minimum help. It follows the motto of, “Good answers to good questions,” meaning teams need to have pre-formed questions for the help desk and not just ask for a solution and/or if they are correct or wrong about an idea.
- Experts. The teams have the opportunity during the middle of the project week to consult with outside experts, typically professors and/or industrial experts. Each interview is approximately 10-15 minutes so each team needs to be prepared for these consultations.
- Jury panel. At the end of the week, teams present their final solution to a jury panel of experts, professors, etc.
- Project leaders and supervision. The project leaders not only organize the project week, develop the task(s), train the team and technical advisers and help desk members but also supervise and provide technical and didactic support to all the staff during the project week as needed.

The positive, value-added impact of this PPBL model at the German university has previously been shown[27-32]. Shortly, students are meeting the desired learning outcomes of the model including learning teamwork skills, disciplinary skills, and interdisciplinary integration along with increasing intrinsic motivation for their further studies.

3 TRANSFER OF PPBL MODEL – INTERNALIZATION OF STUDY PROJECTS

In 2014, the German PPBL model was expanded once more and brought to a Mongolian university. The model was transferred following a scaffolding procedure from introducing the Mongolian staff to the project to empowering them to identify, adapt, and make the model their own. The first step introduced them to the project and model with German staff traveling to Mongolia to lead the project week and perform the major roles. This was followed by Mongolian staff attending a workshop held at the German university to train them in the major aspects of the PPBL model, followed by mentoring the Mongolian staff during the following project week at their university. The last step will be for the Mongolian staff to continuously improve and implement the model for their needs.

3.1 Step 1 – Experiences in Mongolia

For two years, the German PPBL model was implemented with German academic staff maintaining the major roles, i.e., team and technical advisers, experts, and help desk, while the Mongolian academic staff had more supporting roles, i.e., organization at the university level and experts. Tasks similar in scope to German project courses were developed but adapted with relevance to Mongolian society, e.g., development of an autonomous robot that is capable of collecting and sorting litter alongside the road and removal of nitrogen oxides from diesel exhaust using urea. Due to the smaller size in comparison to the German project courses (two groups, each with approximately 10 students), the help desk and expert interviews were not utilized, but German staff were available to meet with groups as needed to discuss solutions and problems as they arose. Mongolian students were in their first semester of studies in mechanical engineering, environmental engineering, or raw materials and process engineering, but all three programs have the same curriculum for the first four semesters.

One major difference seen between the original German PPBL model and the one adapted is the role and the level of interaction of the technical adviser. In the German PPBL model, the principle of minimum help[33] guides the interactions of the technical adviser with it being a more passive role unless asked specific questions by the team and providing more strategic advice and motivation than subject-intensive advice. However, it was experienced that the project courses led by the German staff that the technical adviser needed to take on a more active role in the teams by providing subject assisted learning, direct information about design approach, and more general motivation.

There is a standard evaluation procedure developed for the underlying, core PPBL model which consists of three main parts. One part is the daily reflection with the student groups for their learning process. Another part is the daily review with the team and technical advisers and project leaders for the advisers' learning process and for learning adjustments that need to be made in the student groups. The third part is the final evaluation for improving the model for the next year(s). For the the first two Mongolian cohorts, there is only data for the 2014 cohort, but we do not have permission of students (small cohort of approximately 20 students) to publish. It was only gathered and used for internal use, e.g., improving the learning process (of students, advisers, and project leaders) and improving the model for future courses.

3.2 Step 2 – Workshop in Germany

After two years of leading the course at the Mongolian university by German staff, a training workshop was developed to fully transfer the PPBL model and enable the Mongolian university staff to learn and adapt the model. The workshop followed a constructivist approach with half of the day working directly with the trainers and the afternoons were for self-directed study where the content could be deepened by additional literature reading, guided reflection questions, and/or adapting and transferring the learned content to their own university. The learning outcomes from the workshop were as follows: The Mongolian university staff

- have received an overview of the organizational standard procedure of a project week,
- are empowered to qualify and implement the support system, mostly consisting of team and technical advisers,
- have practically applied the approach of constructive feedback as an intervention method at a team level as a team adviser and have practiced the steps involved in the principle of minimum help[33] as applied by technical advisers, and
- have reflected upon the concept and the connected challenges to generate ideas on how to adapt and sustainably implement the German PPBL model at their own university.

The workshop was broken down into five complementary building units.

- The first unit gave an overview of the German PPBL model including the concept, procedure, support system, and critical success factors regarding organization and didactic preparations for study projects grounded in the broader scope of project-orientated and problem-based learning.
- In the second unit, the participants learned about the didactic approach of team advising including goals, tasks, attitudes, settings, and competences of team advising as well as how to recruit and train team advisers. The method of constructive feedback as intervention was introduced, applied, and feed-backed by the trainers.
- Equivalent to the second unit, the third unit dealt with technical advising including goals, tasks, attitudes, settings, competences, and how to recruit and train future technical

advisers. The main method of technical advisers, the principle of minimum help, was trained and feed-backed by the trainers.

- The fourth unit combined and introduced team and technical advising as a tandem partnership, how advising is a collaboration between both advisers, the importance of communication between the advisers, and the kick-off to the project week.
- The last unit discussed further agents of support, such as the help desk and experts during the expert interviews, the project leadership, and supervision. The workshop ended with a general discussion crossing all topics and evaluation of the workshop itself.

A final reflection and evaluation with the participants indicated that they had learned how to adapt the German PPBL model structure at their university, how to manage a team, and how to implement the new teaching methods.

For future intercultural workshops, it is recommended based on our experiences to always remain in constant exchange with participants about their needs, experiences, and wishes to keep the material and topics relevant and suited for their world along with giving participants enough time to discuss, adapt, and implement learned knowledge. A critical success factor is using the pre-knowledge of participants to systematically build further practice and theory.

Generally constructive feedback is a significant tool for project teams to reflect upon their actions to constantly improve them. During the workshop, it was learned that the approach of giving and receiving feedback is unusual in Mongolian culture and tradition, even in everyday life communications. Nevertheless, the Mongolian staff were convinced that it would be fruitful for their students to learn and implement feedback during the study projects. The procedure needs to be adapted to be acceptable, culture-sensitive, and be valuable to Mongolian students. One needs to reflect on different feedback styles, traditions, and values whether it is German, American, or Mongolian and have an awareness of cultural differences. The focus should be placed on adapting feedback to concrete needs, resources, and capacities of the feedback receivers. Based on our experiences and discussions, we propose to gradually introduce and implement constructive feedback in these types of social environments by continuously scaffolding and successively deepening the intensity of feedback from day to day as follows in a one-week project course.

- On Monday, the teacher or team adviser should introduce the concept of the feedback approach on a meta-level and reflect upon and mediate unusual aspects with students along with introducing the rules of giving and receiving feedback. This should be followed by a demonstration of valuable resource-orientated feedback. Therefore, the team adviser might, at first, give solely positive reinforcements as feedback and exclusively at the team level (e.g. use of adequate working techniques applied by the team or collective team behaviors that could be seen as resources for effective teamwork). Thus, at the end of the day, students should have an idea of and the rules of feedback, and further be enabled to experience the reinforcing effect of receiving positive resource-oriented feedback.
- On Tuesday, the teacher or team adviser may repeat the philosophy and rules of constructive feedback while demonstrating the method themselves. Additionally, they should guide and encourage the students in groups of two to reflect upon their collaboration with the following questions: “Which techniques and team behaviors were supportive for teamwork and therefore should reinforced? What further ideas do you have to continuously improve your common teamwork?” It is suggested to use anonymous or semi-anonymous tools for this exercise. After collecting the responses, the team adviser should moderate a discussion over the named aspects and conclude

with additional regulating and resource-orientated feedback, including positive and negative aspects along with suggestions for improvement, and all should be supported with reasoning. The team adviser could also moderate a discussion with students about their experience with the feedback method.

- During the following days, the procedure should be continued with a successive increase in encouraging the students to expressing feedback to their own teamwork. Therefore, it depends on the students if the procedure should be more a partnership or use more (semi-) anonymous techniques. The aim of the scaffolding development should be to empower students to give feedback in a constructive, individual, and openly expressed way.
- Friday could end with a review and reflection on the entire week, guided by the team adviser. To aid understanding and to arrange feedback in a more tangible way for students, the procedure can be visualized each on a flipchart or on cards.

With this adapted approach of successively giving and receiving feedback in team advising, the procedure can be managed in a less direct way, and therefore, might be more accepted in social and cultural environments where participants are not used to this style of feedback. A focus on consequent positive reinforcement of team resources and constructive team behaviour is important to pave the way for a common basis of feedback. Further, team advisers need to not only introduce the practice of giving and receiving constructive feedback but also reiterate (many times) the underlying values and highlight the chances for collaboration within the team, learning and improvement, and the potential for personal growth and self-determination.

3.3 Step 3 – Mentoring by German staff

This past year, the Mongolian staff had the opportunity to practice, implement, and begin to adapt the German PPBL model at their university with mentoring from the German staff. Once more, as in the previous two years, a help desk was not utilized due to the small number of students, but expert interviews were with additional Mongolian academic staff participating and consulting on the student project solutions. Mongolian academic staff were the team advisers and introduced the key components of the PPBL model to the student teams with mentoring by the German staff along with technical advising. At the end of every day, a short reflection meeting was held between the Mongolian and German staff to discuss challenges and successes of that day and exchange ideas and thoughts for the next day. Overall, the project was run smoothly with good solutions presented by the student teams at the end of the project.

Additional informal reflection and discussion may be needed to help fully transition and transfer the model as challenges may arise in training new staff and involving upperclassman who took the project course as first year students.

4 LESSONS LEARNED, CHALLENGES, & RECOMMENDATIONS

Through this intercultural knowledge transfer of a PPBL model, we have learned to begin adapting the German PPBL model to a Mongolian university in collaboration between the German and Mongolian academic staff. Together, we have learned it is better to have more active technical advisers in teams and to have a modified feedback approach by team advisers. In consequence, this should empower the Mongolian university and staff to make the projects their own including materials and resources. Additionally, communication of different working styles at the beginning sets a basis for showing opportunities of possible adaptations of the concepts.

Challenges still remain in fully transferring and adapting the PPBL model. The major one is further training of team and technical advisers along with support staff to help run and organize the project courses and be self-sufficient.

From our experiences in an intercultural knowledge transfer, we recommend keeping the core part of the model similar between developed models but adapting as needed to be culture-specific such as the adapted, scaled, smooth fading-in practice of reflection and feedback. Developing local, “authentic problems” tasks that directly impact students is an easier way to get students excited and motivated about a project and for a university to adapt the model. For these knowledge transfers to successfully occur and for a new university to adapt and improve the model, there needs to be commitment and buy in from all stakeholders, including students, academic staff, and administration, by participation but minimally support these types of PPBL models. Any new adaptions to a system need time to be fully implemented; therefore, the adapted PPBL model will also need more time to show its full strengths.

Through critical reflection on our own practice in transferring the developed PPBL model, there is a need for further evaluation. We recommend collecting data and evaluating it (with appropriate permissions) to further quantify the quality and effectiveness of the adapted model along with identifying areas of improvement. It is also important to have future evaluations in the students’ mother tongue to reduce validity concerns over a potential language barrier.

In summary, international exchanges like these enables us to continuously improve and readjust the international and interdisciplinary PPBL model for culture-sensitive aspects, meaning not just handing over and teaching our PPBL model and tools to adapt it but also learning from our international colleagues and improving our project courses from this new knowledge we gain. Today’s needs for these types of transfers include eliciting formal organizational knowledge and tools and informal, more personal knowledge and experiences.

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Minor in sustainable design for engineering design education. Experience at UPC Barcelona Tech

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ABSTRACT

Sustainability and Internationalization are key factors within educational programmes and institutions nowadays. Offering programmes that focus on these factors at undergraduate level has been a priority at the School of Engineering of Vilanova i la Geltrú (EPSEVG), Barcelona, and since 2012, it has run the International Design Project Semester (IDPS) Erasmus mobility programme.

IDPS trains engineering design students by applying Project Based Learning in intercultural groups. The working language is English and the programme is designed for bachelor degree students in their 7th or 8th semester. The IDPS programme offered at the EPSEVG emphasises the introduction of competences in sustainability and human technology.

The main objective of the IDPS is to improve the learning outcomes and competences of industrial design engineering students especially in areas of Design for sustainability. It is divided into two parts. One part covers four (3 ECTS) credit core courses in specialist fields of study such as Eco Design strategies, Human Centred Design , Sustainable Design and Business Practicum, and the second part involves working on a project (18 ECTS). Additional seminars and workshops compliment the courses and vary from programme to programme. Local design companies and research groups propose the projects.

Since 2012, 43 students from 11 nationalities has participated in the IDPS working in nine real projects. This paper shows the design methodology used in the IDPS programme, its structure, the sustainability competences achieved by the students and the lessons learnt during the 5 years of the program.

Conference Key Areas: Sustainability and Engineering Education, Engineering Skills

Keywords: Engineering Design, Sustainable Design Education, Internationalizacion, Design Education

INTRODUCTION

Since 1991, the Universitat Politecnica de Catalunya (UPC) has focused on introducing Sustainability education in all its engineering and architectural programs through two environmental plans (1996-2000, 2000-2005), and currently through the UPC Sustainable 2015 [1] plan.

In 2009 UPC has introduced engineering design of product development degrees education at Bachelor level and in 2017 it is starting its first master degree in design. Due to its experience in embedding sustainability in the engineering degrees, when designing all this degrees sustainability has been at the core of the competences to be acquired by students.

Next sections will present the experience at undergraduate education where a minor in Sustainable Design, International Design Project Semester, at the School of Engineering of Vilanova I la Geltrú (EPSEVG) has been run since.

1 INTERNATIONAL DESIGN PROJECT SEMESTER

The International Design Project Semester (IDPS) is a 30 ECTS minor offered at Engineering Design and Design students that are finishing their undergraduate studies. Learning outcomes

1.1 Minor structure

The IDPS is a unique program in this respect and is totally adapted to the European Higher Education Area and is suited to Bachelor Design Engineering students in their final study semester. In brief, the program has the following characteristics:

- It is international and multicultural;
- It is for Industrial Design Engineering students
- English is the working language;
- It addresses the real needs of companies;
- It is an intensive, one-semester program;
- It is worth 30 ECTS credits;
- It works out the Sustainability competences.
- It combines both face to face and distance teaching methods (blended learning).

The IDPS has three complementary parts:

Part one: A project (18 ECTS): During the semester and under the guidance of an academic tutor, an international team of four to six students works on a real-life project for a Spanish for an international company. The teams are made up of students from an Industrial Design Engineering background from Europe and beyond. Individual and group tutorials are offered during the semester.

Part two: Core courses (12 ECTS): Four courses are offered, Eco-Design, Human Centred Design, Sustainable Value Design and a fourth course which varies from year to year to adapt to the demands and profiles of each program. Students are awarded 3 ECTS for each of them.

Part three: Seminars: short intensive practical workshops on topics related to sustainability, advertising, product system services etc. are also offered to broaden the students' vision on sustainability and to enhance the work related to the project. These complementary workshops also help students develop their communication and cooperation skills.

The projects are real-life projects proposed by companies. The project proposals from the companies must meet the following criteria:

- Sustainable in focus:
- Complexity: final year Bachelor students should be able to carry out the project.
- Difficulty: the project can be completed in 15 weeks.

- Supervisor: the company has to provide a supervisor and facilitate all the information needed to carry out the project in English.

The IDPS structure and agenda is illustrated below (Figure 1). The program lasts 15 weeks and the final week, week 16, is given over to evaluations, examinations and oral presentations: students deliver their assignments for the courses, submit their final report –scientific paper- and a poster on the project and present their conclusions orally in front of a scientific evaluation committee.

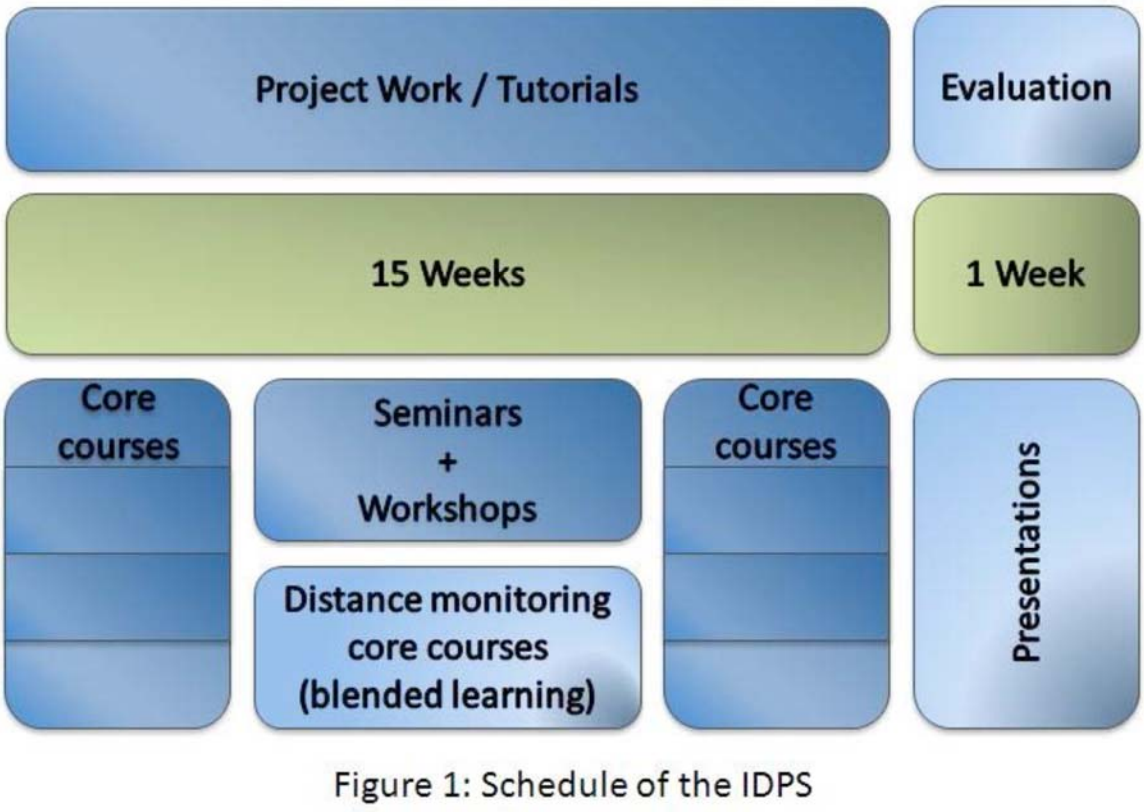

Fig. 1. Blended learning Schedule structure of IDPS

Project work begins when the program starts and lasts its entire length. The courses are split into two main blocks; one at the beginning and the other towards the end of the program. The interim period allows students time to continue developing the project, attend the additional workshops and seminars and interact with the course teachers using virtual platforms such as the digital campus, Skype, Wikis etc.

To make the project recognized for students, learning portfolio Erasmus mobility agreements are signed between universities with design degrees.

1.2 Projects

The projects are proposed by companies and are "modulated" by faculty in order to assure that project fit learning outcomes and competences of students involved.

Table shows a typical description of a project once it has been approved to be run at the IPDS program

Table 1.Exemple of Project description

Project
Title: (Title and pictures related to the project) Paediatric and neonatal lung simulator 
Introduction: (Explain the framework of the project and the problem to be solved) The objective is to design a neonatal/paediatric lung simulator. These devices are useful both for research and educational purposes. Nowadays there exists a wide variety of them from very simple ones, even homemade with garden connectors to very sophisticated ones like SIMVENT. Former lung simulators are designed for research studies in order to check ventilator capabilities. On the other hand, simple lung simulators are used basically for educational purposes; they are cheap and even easily constructed. Unfortunately, these simulators are not very precise or reliable to create standard clinical scenarios, so the professor sometimes faces simulation problems during hands-on sessions.
Project Brief: (Describe the project specifying the main objective and its outcomes, design specifications, etc…) Design a lung simulator for educational purposes able to create standard clinical situations like decrease of compliance, increase of resistance or leaks in neonatal and paediatric scenarios. The lung simulator has the following different parts: - Design of the mechanical device transportable in a small suitcase. Two sizes of lungs available. Neonatal (25-50 ml) and paediatric lungs (125-250ml) - Internal mechanism (resistance, etc) to generate pre-defined common clinical scenarios with several degrees of severity A concept prototype of the device has already been developed by students of the precedent IDPS. The challenge is to continue developing the project so as to deliver, test and validate a fully operational prototype that could eventually be used in a real-field environment. To meet this challenge, performance by the prototype should allow for: - Connection to different sizes of lungs - Generation of changes in compliance and resistance - Remote wireless operation by the instructor through an application running on a mobile device (smart phone or tablet) - Testing and validation in a real-field simulation environment
Company

Name: Children's Hospital Sant Joan de Déu
Address: Ps. Sant Joan de Déu, 2. 08950 Esplugues de Llobregat
Contact person: (name, e-mail, phone number) XXX

1.3 Six years' experience results

The IDPS program started in 2012, and we are now running its 6th edition. During the five years of the program 48 engineering design students from 12 nationalities have participated in the program (Figure 2), ensuring the internationality and inter-cultural learning of the program. Students have worked in 15 real projects related to all kind of sectors: ICT, furniture, robotics, domestic appliances, industrial machinery, buoys for marine industry, etc. (http://www.epsevg.upc.edu/idps/idps-course/projects-from-previous-idps-programmes)

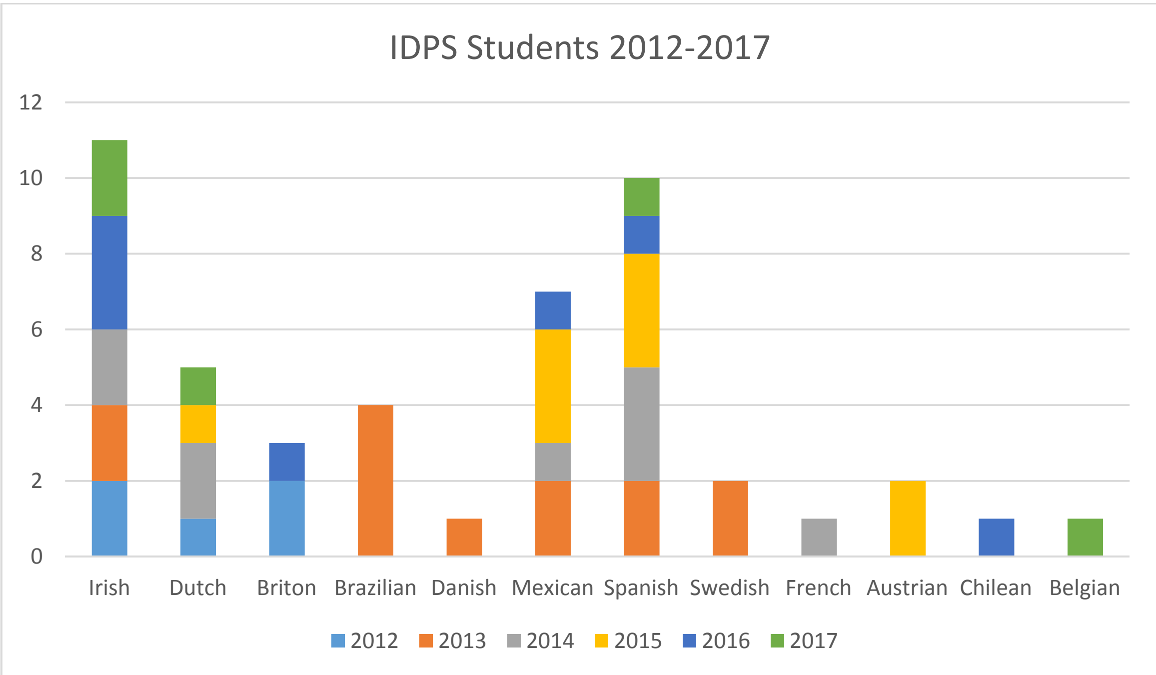

Fig. 2. Students participating in the IPDS program

Participating students were asked to complete questionnaires to provide the EPSEVG with feedback on the course and to show where improvements could be made. The questionnaire used is the Students' Evaluations of Educational Quality (SEEQ) questionnaire [2]. It measures nine distinct components of teaching effectiveness that have been identified in both student ratings and faculty self-evaluations of their own teaching. Figure 3 illustrates the results from these questionnaires, where we can see the high level of satisfaction of student for all courses.

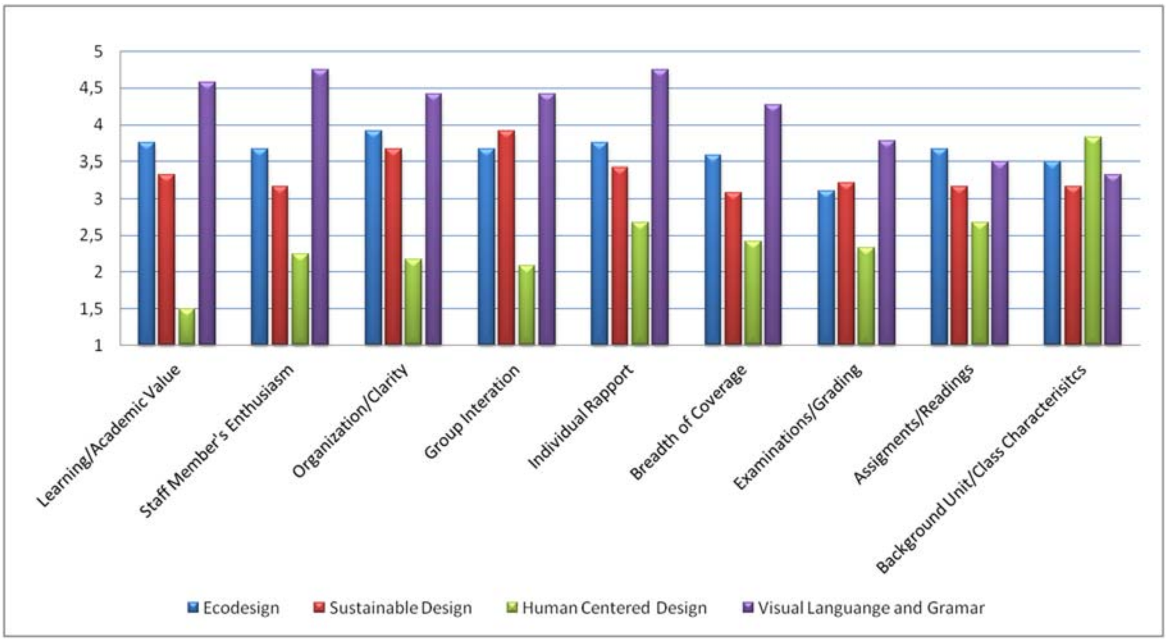

Fig. 3. SEEQ Courses evaluation by students

2 CONCLUSIONS

This paper has introduced an undergraduate example of engineering design for sustainability at UPC Barcelona Tech. The experience show a minor (30 ETCS) for final year Engineering Design students at bachelor level.

The author highlights that using community oriented and constructive learning approaches [3], where students work most of the time in real projects proposed by companies is crucial for sustainability education in general and specially in Sustainable Design education.

3 ACKNOWLEDGMENTS

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Teaching Energy Storages

by means of a Student Battery Cell Test System

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ABSTRACT

Energy storage systems are vital for success of electric mobility. Thus, knowledge of energy storage systems behaviours is essential for the development of electric vehicles. Universities and vocational training institutions are urgently required to educate specialists in electrical storage systems. A safe and easy-manageable battery test system was developed to improve the outcomes of student learning of battery storage systems and to allow practice for future employment through hands-on laboratory training. This test system supports temperature-dependent experiments with different cell types including lithium-ion cells, and incorporates a redundant safety shut-off module that protects students from being injured. Based on this system, a new energy storage laboratory course was developed. This course covers four main content areas of battery energy storage: (1) contact & isolation resistance, (2) open-circuit voltage, (3) internal resistance & power, and (4) energy of cells. This new laboratory course was introduced in summer 2016 and has already been conducted with several full-time and part-time student groups.

Conference Key Areas: Open and Online Engineering Education, Engineering Education Research, Sustainability and Engineering Education

Keywords: Student Experiments, Energy Storage Systems, Battery Test System

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INTRODUCTION

Transportation currently experiences a major period of change that is focused on minimizing the environmental impact associated with motor vehicles. Battery-powered electric vehicles play an important role in development of greener cars that minimize pollution in big cities. One of the central challenges for the design of these vehicles is the efficient storage and provision of power and energy by an energy storage system on board. As such, academic qualification in this area is essential for the mid- to long-term success of electric mobility [1]. Highly trained professionals are needed and universities as well as vocational training institutions have to find ways to meet this industry demand [2]. Thus, teaching modules on electrical energy storage systems are increasingly incorporated into existing and new study programs related to electric mobility. It has been reported that when practical training complements theoretical lectures, it significantly improves the outcomes of student learning [3]. In addition, laboratories provide valuable hands-on practice for future employment [4].

1 BATTERY TRAINING

The Technische Hochschule Ingolstadt (THI) offers a wide range of qualification programs in the field of electric mobility. Students may choose between various full-time and part-time bachelor and master degree programs, which include lectures on electrochemical energy storage systems. With a profile of a University of Applied Sciences, the consolidation of theoretical knowledge by means of practical experiments in the teaching laboratory is of particular importance for all of these study programs [5].

To prepare graduates for fieldwork with electrochemical cells, a new energy storage laboratory has been developed, which must meet conflicting framework conditions. On the one hand, laboratory space, financial resources, and the students' time are limited while on the other hand, science about electrochemical cells is a growing and rapidly evolving field, which gets increasingly complex to teach. Therefore it was decided to reduce the new laboratory to the most relevant knowledge of battery systems. Students should strengthen their basic understanding of electrochemical storage systems and learn about the practical behaviour of battery cells – building up universal knowledge for their future career. The focus was laid on practical knowledge of the most important parameters of battery cells. Students should be able to determine these parameters self-sufficiently by means of appropriate experimental setups – competencies that are necessary to design energy storage systems.

The identified learning objectives were grouped into four main content areas: (1) contact & isolation resistance, (2) open-circuit voltage, (3) internal resistance & power, and (4) energy & efficiency.

These content areas are taught during five discrete laboratory sessions, three hours in duration each. These laboratory sessions lead to a workshop in which the individual students' measurements are used to parameterize a simulation model and to design an energy storage system in Matlab/Simulink.

The initial plan to conduct a set of laboratory experiments on battery storage led to the specifications of the battery test system for such laboratories. Unfortunately, no fitting equipment, which would allow execution of the planned experiments within the abovementioned framework conditions could be found on the market. Ready-to-use industrial battery cell test benches and temperature cabinets are generally large, multichannel, and expensive devices, which are impractical for laboratory work in small learning groups. Thus, a small and flexible cell test system was developed, which allows safe and effective individual learning experiences for the students. The development was funded by the German Federal Government's Showcase Program “Academic Education Initiative on Electromobility”. The developed benchtop test system supports temperature-dependent experiments with lithium-ion cells and other types of energy storage cells, while a safety shut-off module ensures a high degree of safety during operation at all times. The combination of all functions required for an energy storage laboratory in a compact design is a unique feature of this test system.

Funding by the Faculty of Electrical Engineering and Computer Science allowed a complete teaching laboratory at THI to be equipped with 13 battery test systems. The hardware and the newly created laboratory experiments were tested in various study programs on electric mobility [6]. The students have evaluated practical experiments that utilized the new system more favourably then similar experiments conducted using computer simulations [7].

2 BATTERY TEST SYSTEM

The battery test system is based on a 19-inch table top case of three rack unit height. Its housing consists of three modules with standardized plug-in technology according to IEC 60297-3-101, and allows simple adaptation of the test system to the desired functional range or future developments through connectors according to IEC 60603-2.

The functions of the three modules that are shown in *Fig. 1* and *Fig. 2* cover all needs of the energy storage laboratory. Included are a potentiostat/galvanostat module for cell measuring operations, a thermostat module, and a safety module.

Fig. 1. Battery test system for hands-on laboratories. Students strengthen their basic understanding of electrochemical storage and learn about the behaviour of cells.

As even the production of the tester was used to educate students, the circuit boards were designed by the researcher in a way to enable easy manual assembly by student assistants in a separate project. Thus, most components are in the relatively large SMD format 0805. An ARM Cortex M4 processor was used as an arithmetic unit in all modules. The housing including all submodules and integrated power supply unit weighs 11.5 kg.

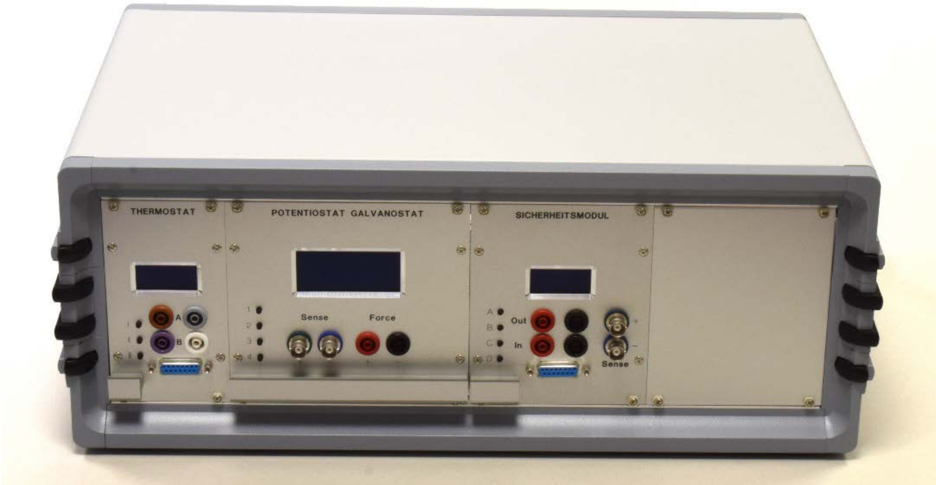

Fig. 2. Battery Test System, from left to right: thermostat, potentiostat/galvanostat, safety switch off module

2.1 Potentiostat/Galvanostat

The central element of the tester is a potentiostat/galvanostat. It allows to conduct experiments with small single cells with amp-hour capacity up to 600 mAh. Currents and voltages can be applied to the cell and may be measured time discrete. The voltage range is symmetrical for measurements up to ±12 V, with currents up to 8 A for discharging and 4 A for charging. In addition to the DC component, an AC voltage of lower amplitude can be overlaid for impedance measurements. In this case, the device determines the impedance's magnitude for frequencies up to 10 kHz and its phase for frequencies up to 5 kHz. The new test system offers a continuous frequency range with 1 Hz resolution.

Apart from technical implementation, finding a good compromise between cost/production efforts and measuring accuracy was challenging. A test system should be easy to build and to maintain, and at the same time should be accurate enough to provide a realistic test environment for the students. Therefore, focus was laid on optimized measuring accuracy and not on the exact analogous injection of current and voltage. If the system injects inaccurately, the resulting errors will automatically be corrected by the measured data (*Fig. 3*). For voltage measurements the error is below 10 mV, for current measurements the error stays below 5 mA in the specified temperature range (21 °C ±5 °C). The down sampled data rate for the time discrete transfer to the computer is adjusted automatically in the range between 312 Hz and 625 Hz.

The galvanostat/potentiostat is controlled from a laboratory computer via serial communication (USB) using C# and Java-based control programs as well as a LabVIEW driver. The Java program was used for the student laboratory, because it is similar to software used for industrial test equipment regarding architecture and user interface. The program was developed during a master's thesis and allows learners to freely program the steps and control structures to implement a certain experiment. Conformity to industrial test benches prepares the students for their later professional life.

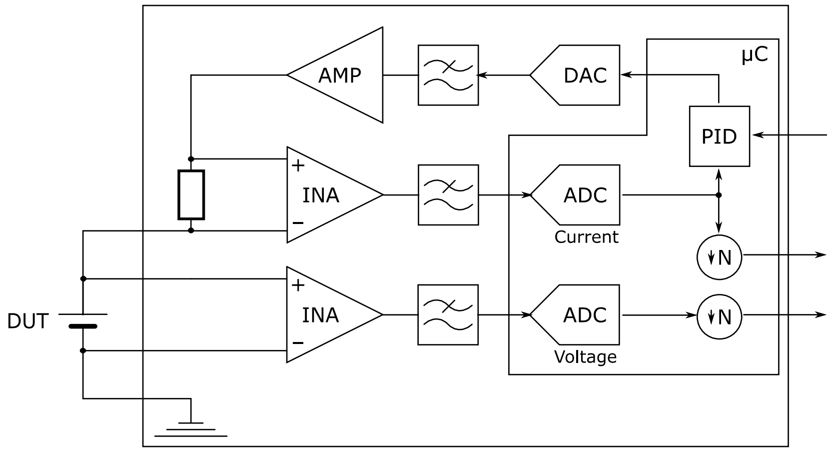

Fig. 3. Simplified working principle of the galvanostat. Actual current and voltage are converted to digital values using two synchronized ADCs. After downsampling the values are submitted to the controlling computer. The current is compared with the target current by software and controls the DAC.

2.2 Thermostat

A major challenge for electric mobility is the strong temperature dependence of parameters of electrochemical energy storage systems [8]. Thus, it is important that students can comprehend the effects of high and low temperatures on the performance of battery cells. Unfortunately, this cannot be achieved using industrial temperature cabinets, which are optimized for testing larger test objects. These cabinets are too big in size, expensive and don't allow changing temperature of small single cells quickly enough to conduct a laboratory within two to three hours.

Besides the requirements on the equipment, the waiting time for a homogenous temperature distribution within the cells must be considered for the lesson preparation. To be able to carry out various temperature-dependent measurements during a lesson, especially the cooling performance is essential. For example, to conduct several tests on the internal resistance of a cell according to ISO 12405-1 within a teaching unit of three hours, cooling from room temperature to -18 °C was required within 20 minutes.

To avoid the disadvantages of convection cooling or fluid thermostats and to solve the problem of minimal time, a small, cost-effective, and rapidly responding two-stage thermoelectric cooler as shown in *Fig. 4* was integrated into the battery test system. Cooling and heating are based on Peltier elements, which allow temperature control in a range from -25 °C to 50 °C. To achieve rapid cooling (*Fig. 5*), the test cell is in direct contact with the metal on four sides. The chamber is made for cells with maximum dimensions 90 mm x 34 mm x 30 mm. The cooling stages are driven by two modulated H-Bridges, providing up to 250 W of power. Heat flux losses are reduced by a foam cube, which isolates the cooling device from the environment. The chamber temperature is measured with an absolute error below 1 K. This external cooling system weighs 5.0 kg, its dimensions (26 cm x 26 cm x 20 cm) allow for easy storage while not in use.

The thermostat supports remote control, utilizing the galvanostat/potentiostat module as mediator between the USB-communication and the CAN-based bus between all the modules.

Fig. 4. External heating and cooling system

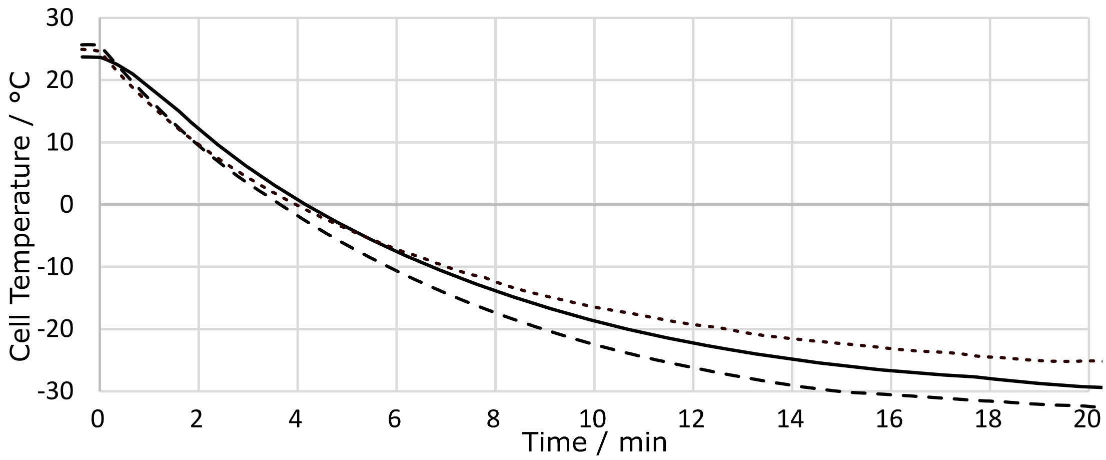

Fig. 5. Max. cooling performance of three exemplary external heating/cooling systems, T_{env}=25 °C

2.3 Safety switch off module

Lithium-ion battery cells are potentially dangerous. In case of mistreatment, they may burst or burn [8]. To ensure the safety of the students at all times, experiments must be either greatly simplified or prepared in step-by-step instructions, which the student has to follow without any degree of freedom. However, this style of instructions would preclude students from gaining skills of planning their experimental work, the skill that is at the core of the engineering profession.

To enable students gaining skills in planning experimental work, a special safety shut-off module is integrated into the test system. This shut-off module is pre-parameterized by the instructor and allows the students full autonomy in controlling the battery system, and minimizes the need for supervision. The module monitors three parameters of the test specimen: (i) current (±12 A), (ii) voltage (±12 V), and (iii) temperature. If the ranges of these parameters fell outside of the range permitted by the instructor, the module automatically disconnects the cell from the test system. It is important to note that the switch-off value may be configured to be pulse-length dependent, as most battery cells allow pulses outside the cell's specified range for a short time. Since this safety shut-off module can neither be influenced intentionally nor unintentionally by a student, he has full freedom to program the potentiostat/galvanostat and may gain valuable learning experience through trial and error.

3 EXPERIMENTS

The developed test instructions are not given in a step by step style. Through decision-making freedom, instructions encourage reflection on the new topic in an environment that stimulates hands-on learning from experimental errors.

The following student experiments have been tested and improved iteratively since summer 2016: (1) Charging/discharging of different individual accumulator cells to measure the cell voltage as a function of the state of charge, (2) Determination of the internal resistance according to ISO 12405-1, (3) Determination of maximum achievable power dependent upon temperature, (4) Capacity determination dependent upon the load profile, (5) Measurements under a load profile in order to parametrize a Matlab/Simulink model, (6) Determination of energy efficiency under various conditions. All laboratory instructions were written to encourage learning through trial and error. They were specifically tailored to support theoretical knowledge acquired from the accompanying theory-based lecture. The biggest challenge while creating the experiments was the limited time for a single student's laboratory (e.g. to cool a specimen down, discharge, charge a cell, and to wait for stable states is extremely time consuming). It was often necessary to divide the students into subgroups, who obtained differently parametrized experiments (e.g. discharge rate) and to let them consider the collected data from all groups for evaluation. The laboratory was piloted in summer 2016 and repeated with improvements in 2017.

The aforementioned experiments are a selection for the study programs at THI. Ideas for additional experiments using the battery test system are: (1) Observing the behavior of cells under load in driving cycles, (2) Development of SoC/SoH determination methods, (3) Impedance spectroscopy, (4) Use of two lithium cells in series connection to demonstrate experiments using battery management systems.

4 CONCLUSIONS AND RECOMMENDATIONS

The described battery test system allows students to easily conduct hands-on experiments in an energy storage laboratory. The students can carry out practical experiments on accumulator cells in a safe, flexible learning environment. Current focus lays on repeated evaluations of the practical training with different groups and types of students for stepwise improvements. The newly developed laboratory sessions and devices may give other educators a good starting point for battery laboratories. In addition to practical training at universities, the developed practical experiments and equipment can be used at other educational institutions as well as by training departments of industrial corporations. More than sixty percent of young people in Germany take part in the dual system of vocational training [9]. Practice-orientated vocational schools, technical colleges, or colleges for master craftspeople may use the hardware in combination with adjusted teaching material.

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Around the world in 36 hours -
Understanding the dynamics of the global product design relay marathon

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ABSTRACT

In this system paper we will present a learning experiment - a unique three-day global product design relay marathon organized by the Design Factory Global Network (DFGN). The experiment called Rat Relay simulates a real-world situation in product development where very often a person or team is only working on a project for a limited time and not from beginning to end, individuals work in multidisciplinary and multicultural teams around complex problems, and everything is done with a fast pace. Rat Relay is a learning experiment developed by the Design Factory Global Network, a network of innovation hubs in universities and research organizations in five continents of the world aiming to contribute to transformation of learning and research through a passion-based culture of interdisciplinary collaboration and effective problem solving.

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Conference Key Areas: Sustainability and Engineering Education, Open and Online Engineering Education, Skills and Engineering Education

Keywords: sustainability, global collaboration, product design, problem-based learning, project-based learning, challenge-based innovation

INTRODUCTION

In this paper we present the process and experiences gathered during the first official global product design relay marathon in the Design Factory Global Network, previously piloted in 2016 with four international hubs. The aim of this paper is to share learning outcomes and results of the exercise, and to further develop the approach for collaborative learning for the next round of Rat Relay.

1 THE SETTING

1.1 The concept of the experiment

The Rat Relay is focusing on finding novel ways to teaching product and service design in a global context and in distributed teams. The number of participating institutions is not limited or fixed. However, in this paper we will present how the experiment looked like with six participating institutions. The Rat Relay is an experiment about real-time global collaboration, and at the same time a local learning project where each institution offers for a local team a learning environment where the learning and working can take place. Further on, the institution representatives together with a company, start-up or NGO prepare a global, real-life challenge, and gather students to participate in teams of ca. five people, and invite teaching staff to act as coaches for the students.

This teaching and learning experiment is divided in six slots of six hours each, to complete a 36 hours' marathon in three days. Each slot represents a different phase of a design project. Each institution participating in the Rat Relay launches off their challenge during the first slot to their local team, which works on the given challenge for the first six hours. The challenge will then be passed on to a new country, just like runners pass on a baton in a relay, where a new interdisciplinary team works on the challenge in a next phase of the project for another six hours. In the end the challenges return back to the originating country for finalization of the outcomes. Table 1 presents an example of the schedule from Aalto Design Factory.

The six slots are distributed to three consecutive days, to morning and evening shifts by taking advantage of time zones to make a real-time relay between Europe and South America in this particular case. The distribution of the shifts in each location, according to the time zones, can be seen in Figure 1. In this experiment the teams did not work around the clock as the shifts took place only on mornings and evenings in each country. Besides, in Figure 2 there is the distribution of the teams of the Rat Relay 2017 and the sequence of the projects going from one institution to another one; in this Figure 2, the meaning for the letters in the right- and leftmost columns are: "n" goes for "night", "m" goes for morning and "e" goes for evening. The far most left column represents European and right side South American time zones. The participating teams of 2017 are denoted as FIN (Finland), NED (Netherlands), POR (Portugal), SAN (Santiago, Chile), CAL (Cali, Colombia), BOG (Bogotá, Colombia).

GMT	Finland	Holland	Portugal	Santiago	Cali	Bogota
	GMT +3	GMT +2	GMT +1	GMT -3	GMT -5	GMT -5
00-01	02-03	01-02	00-01	**20-21**	**18-19**	**18-19**
01-02	03-04	02-03	01-02	**21-22**	**18-19**	**18-19**
02-03	04-05	03-04	02-03	22-23	**20-21**	**20-21**
03-04	05-06	04-05	03-04	23-00	21-22	**21-22**
04-05	06-07	05-06	04-05	00-01	22-23	22-23
05-06	07-08	06-07	05-06	01-02	23-00	23-00
06-07	**08-09**	07-08	06-07	02-03	00-01	00-01
07-08	**09-10**	**08-09**	07-08	03-04	01-02	01-02
08-09	**10-11**	**09-10**	**08-09**	04-05	02-03	02-03
09-10	**11-12**	**10-11**	**09-10**	05-06	03-04	03-04
10-11	**12-13**	**11-12**	**10-11**	06-07	04-05	04-05
11-12	**13-14**	**12-13**	**11-12**	07-08	05-06	05-06
12-13	14-15	**13-14**	**12-13**	08-09	06-07	06-07
13-14	**15-16**	14-15	**13-14**	**09-10**	07-08	07-08
14-15	**16-17**	**15-16**	14-15	**10-11**	**08-09**	08-09
15-16	**17-18**	**16-17**	**15-16**	**11-12**	**09-10**	**09-10**
16-17	**18-19**	**17-18**	**16-17**	**12-13**	**10-11**	**10-11**
17-18	**19-20**	**18-19**	**17-18**	**13-14**	**11-12**	**11-12**
18-19	**20-21**	**19-20**	**18-19**	**14-15**	**12-13**	**12-13**
19-20	21-22	**20-21**	**19-20**	15-16	**13-14**	**13-14**
20-21	22-23	21-22	**20-21**	**16-17**	14-15	**14-15**
21-22	23-00	22-23	21-22	**17-18**	**15-16**	15-16
22-23	00-01	23-00	22-23	**18-19**	**16-17**	**16-17**
23-00	01-02	00-01	23-00	**19-20**	**17-18**	**17-18**

Fig. 1. Working hours according to time zones

	FIN	NED	POR	SAN	CAL	BOG	
n				**San**	**Cal**	**Bog**	e
n							n
m	**Fin**	**Ned**	**Por**				n
e	**Bog**	**Cal**	**San**	**Fin**	**Ned**	**Por**	m
n				**Cal**	**Bog**	**San**	e
n							n
m	**Ned**	**Por**	**Fin**				n
e	**San**	**Bog**	**Cal**	**Ned**	**Por**	**Fin**	m
n				**Bog**	**San**	**Cal**	e
n							n
m	**Por**	**Fin**	**Ned**				n
e	**Fin**	**Ned**	**Por**	**San**	**Cal**	**Bog**	m
							e

Fig. 2. Projects sequence among the six participating institutions

Altogether this resulted into 216 hours (i.e. six locations times 36 hours) of project-based learning in globally distributed teams. The Rat Relay experiment took place in April 2017 in Design Factory learning platforms in six different universities: Aalto University in Finland (ADF), NHL University of Applied Sciences in Netherlands (FDF), Porto Polytechnic in Portugal (PDF), Duoc UC in Chile (DDF), and in Pontificia Universidad Javeriana in Colombia in two different cities Bogotá and Cali (DFJ).

Table 1. Rat Relay schedule example from Aalto Design Factory, Finland

	DAY 1 / Wed 26 April	DAY 2 / Thu 27 April	DAY 3 / Fri 28 April
Morning slot 8:00 - 14:00	**SLOT 1** - Project owner: ADF - Brief: International Trade Centre - Send to: DDF	**SLOT 3** - Project owner: FDF - Brief: Red Cross - Comes from: DFJ Cali - Send to: DDF	**SLOT 5** - Project owner: PDF - Brief: The city of Porto - Comes from: DFJ Cali - Send to: PDF
Evening slot 15:00 - 21:00	**SLOT 2** - Project owner: DFJ Bogota - Brief: Intellectus Centro de Memoria y Cognicion - Comes from: DFJ Bogota - Send to: DFJ Cali	**SLOT 4** - Project owner: DDF - Brief: Liberty Sequros - Comes from: DFJ Bogota - Send to: DFJ Cali	**SLOT 6** - Project owner: ADF - Brief: International Trade Centre - Comes from: FDF

1.2. Learning objectives

For students, the main learning outcome of the Rat Relay is to understand the necessity of work distribution in design or product development projects in a real global context. The idea is that only clear and constructive communication about the work done in one phase by one team will enable the best possible progress for the next teams in the relay. In addition, the students get to handle time pressure, improve and increase their argumentation skills for decisions they have made, and learn to document their projects via videos, illustrations, presentations, and photos. Learning outcomes also include process planning, product development skills, teamwork skills, and application of design thinking process. The success of the exercise is assessed with the feedback that is gathered from the teams after each slot, and from the organization providing the challenge after the final results are presented to them.

In the same way, students are able to improve their conflict management skills when different situations take them out of their comfort zones. Students get to work with other students from different countries, disciplines, and languages, thus offering them an opportunity to gain practical information about different societies and communities. In this particular case, none of the participants was an English-speaking country. However, the official language of the Rat Relay was still English, which represented both a challenge and an opportunity for practicing and learning communication skills.

For faculty members or Design Factory representatives, in addition to the valuable experience of coaching the different phases of the project, there are many learning outcomes from the interactions between participating institutions. Essentially the rather short time window pushed participants and coaches to work in non-traditional ways finding ways to communicate ideas to next teams in the relay.

1.3. Six phases and slots

The Rat Relay process was roughly built on six phases of product design, each one developed in a six-hours slot.

- 1st slot: understanding the brief, background research & identifying the user.
- 2nd slot: problem definition & benchmarking.

- 3rd slot: diverging & ideation.
- 4th slot: converging, concept definition & prototyping.
- 5th slot: refining the concept, iterating the prototype & testing with users.
- 6th slot: final prototyping & presentation.

However, following the Design Factory approach to product development, the design processes are not linear and the emphasis is made on the problem or need rather than on the process itself. In that sense, the Rat Relay teams were encouraged to jump across phases if the logic of the problem demanded it. This iteration is central in concept level development projects (Ulrich & Eppinger, 2016), in the Design Thinking approach (Brown, 2008) and in the TRIZ approach (Cavallucci, 2002).

1.4 Grand challenges to be solved

All challenges in the Rat Relay had both a global aspect and a social benefit involved. The idea of the Triangle of Sustainability (Serageldin, 1995)—where all three aspects, economic, ecological and social need to be taken into account—was a key for both the organization of the Rat Relay and the development of the six different solutions to the challenges.

Firstly, the economic aspect was addressed by a symbolic fee for profit organizations participating from the Rat Relay and the fact that all the solutions needed to provide some level of market validation. Secondly, the ecological aspect was addressed in a way of work where the teams gained large global perspective to societal challenges and problems without the need to physical travel around the world thus reducing the carbon footprint related to transportation of the projects. Finally, the social aspect was addressed with the selection of the challenges, the alliance with organizations with a social conscience and the forming of diverse teams where every background and context was there to enrich the general capabilities of each local team.

In the Rat Relay experiment the six challenges were provided by the International Trade Centre based in Geneva, Liberty Seguros (insurance company in Chile), San Ignacio Hospital Memory and Cognition Center: Intellectus in Bogotá, Colombia, Social Foundation De Menos a Más for vulnerable population in Cali, Colombia, The International Red Cross in the Netherlands, and the City of Porto in Portugal.

The diversity of profiles and academic backgrounds of the participants makes this experiment particularly interesting. Due to the perceived nature of the product development marathon and the participating institutions, it could be more obvious to attract people from engineering, product design and business. However, the call for participants was open also for disciplines "at the border" such as arts, ethics or health sciences, and gathered also many of them to join. We argue that a global challenge will always need diverse points of view to be solved, thus calling for a collaborative environment beyond the boundaries of academic fields.

Table 2 depicts—as an example of the interdisciplinary nature of the Rat Relay—the background of the participants at the Aalto Design Factory in Finland. Of the 22 participants 18 were university students, one visiting scholar, one university faculty member and two junior high school students. The participants also represented 10 different schools and various disciplinary backgrounds. Similar interdisciplinary backgrounds were to be found also in other participating institutions. The majority of the participants in all six locations were BA and MA level students, but also many vocational students, industry professionals, university faculty, and even junior high school students participated the experience.

Table 2. Backgrounds of the participants in Aalto Design Factory, Finland

School	Number of Participants	Discipline
Aalto University of Arts, Design and Architecture	3	Industrial Design, Design, Collaborative and Industrial Design
Aalto University School of Science	2	Technical Physics, Computer Science
Aalto University School of Engineering	6	Production Engineering, Mechanical Engineering (3), Marine Technology, Product Development
Aalto University School of Business	3	International Design Business Management, Marketing, International Business
Aalto University School of Electrical Engineering	2	Microelectronics, Automation and Systems Technology
NHL University of Applied Sciences	1	Design
University of Helsinki	1	Finnish and Nordic History
Metropolia University of Applied Sciences	1	Digital Media
Arcada University of Applied Sciences	1	Media Management
Other	2	Junior High School

In the following sections, we will depict the Rat Relay as a unique learning method for global collaboration, present the data and experiences gathered in April 2017, analyse the process, and address future possibilities of research and next steps.

2. DATA GATHERING AND ANALYSIS

The data about the Rat Relay experiment was gathered through a survey taken by the participants after each time slot and through the reports of organizers in each Design Factory. The survey, which gathered 63 answers, looked into the diversity of the team, the previous design experience of the participants, the decisions made during the six hours' slot, interactions within teams, and the results of each round, accordingly. The intention was to support understanding the participant's attitudes and the dynamics within Rat Relay over the 36 hours' period. The analysis was done in a privacy-preserving and anonymous fashion. Table 3 presents the number of participants and coaches in each institution. The total number of participants in all six institutions was 166 with 30 coaches.

Table 3. Number of participants and coaches in each institution

Institution	DDF	ADF	FDF	DFJ Bogota	DFJ Cali	PDF
Participants in total	43	22	20	21	42	18
Slot 1	8	6	7	13	26	4
Slot 2	6	2	5	8	13	5
Slot 3	12	5	3	8	9	4
Slot 4	5	4	3	6	12	6
Slot 5	5	6	3	8	18	5
Slot 6	7	6	2	10	21	4
Coaches	8	5	3	3	7	4

2.1 Limitations and context

- The sign-up process was not restricted; everyone was able to sign up to the slot they wanted. This caused some unbalance to the teams.
- In some slots students participated only part of the time, however majority of the time the team participated for the whole six-hour slot. In Cali students worked also locally in parallel teams.
- The Rat Relay was a voluntary activity; students were not awarded ECTS credits.
- In Bogotá, the event took place at the Creative Room of the Ático Building, which was shared with other students who were working on their own activities, but were invited to participate mostly in the prototyping and validation slots.

2.2 Analysis of results

In order to support understanding of the Rat Relay experiment and its results we visualized the data gathered in the survey. Figure 3 depicts four core questions from the survey with answers in a five-point Likert scale, “1” being a strong disagreement and “5” meaning a strong agreement with the claim. Most participants (58%) found that their team’s goals were clear and shared by all team members. Interestingly, more participants (46 % compared to 16%) tend to reflect more because of their designerly attitude. Slightly more (40% vs. 21%) of the participants found that design-based approach helps to improve efficiency. However, there was no clear difference between how participants see they attitude helps to use their imagination outside the working environment.

Fig. 3. Answers to four core questions of the survey visualized.

In the survey our aim was to understand also relevant other aspects around these core questions. Figure 4 depicts answers to questions about the attitude of participants towards the society. As we can evidence, substantially more participants reported that their designerly attitude helps in different aspects to serve the society (inclusiveness, innovativeness, hopefulness, reflectiveness).

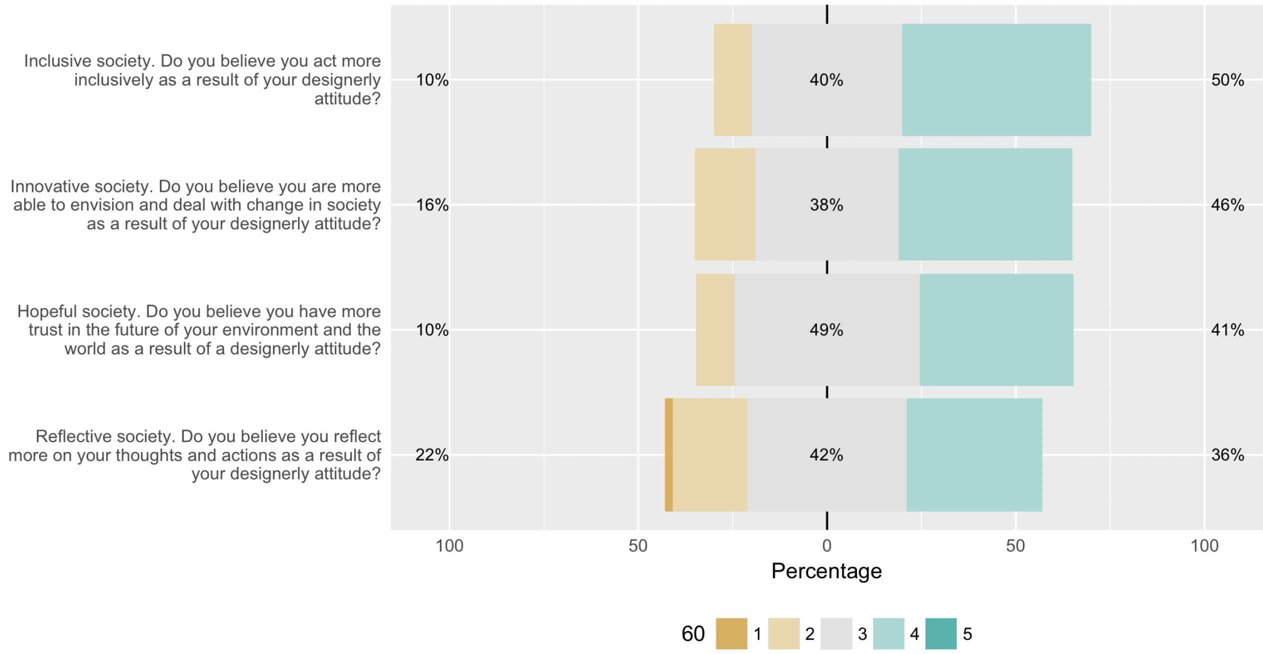

Fig.4. Participants' answers about their designerly attitude for the society.

3. LEARNING OUTCOMES & DISCUSSION

The Rat Relay marathon was organized for the first time with students and real company partners in April 26th to 28th 2017. The feedback gathered from the participants, company partners, and organizing institutions was crucial in analysing the success of the learning experiment and the next steps.

3.1 Student experience

The students reported that they especially enjoyed the intensive nature of the relay marathon to work against the clock and with real time with other Design Factories. They appreciated both the diversity of the teams, and the challenges. The participating students liked the unique approach to work only on a certain part of a project, and thus expected to build on others' ideas, and to send over their progress to the next team in an understandable and compact way. They felt that the communication between the different slots, without any face-to-face communication in between, was the biggest challenge but also the biggest learning experience.

Communication was perceived as one of the big challenges since English language was the main language of the Rat Relay amongst non-native English speakers. To convey ideas and thoughts better, students used drawings, visualizations, pictures, acting, body language, and even music and movie references to enable assertive communication between the slots.

3.2 Sponsor experience

Although the Rat Relay experiment was only a 36 hours' project, all the sponsors received a proper design solution for their challenges, making the six slots division a powerful methodology tool. The phases assigned to each slot were not fixed but worked perfectly as a guide to understand and achieve deliverables for each phase. The NGOs and industry partners providing the real-life challenges were all surprised of the amount of ideas and content students were able to produce in just three days.

Several partners reported afterwards how the Rat Relay was also a great learning experience for them to design and frame their challenges in a better way for student projects. Within the Rat Relay they were able to test an idea and a challenge very quickly and see the end results directly after 36 hours.

4. SUMMARY

In this paper we reported about the Rat Relay experiment, a 36 hours' marathon to provide design-based solutions to a variety of challenges provided by companies, universities and NGOs. We presented the setting, including the idea to have several locations around the world, and how draft designs were passed to following teams in other locations, thus creating a relay effect.

We provided the first analysis and visualization of results of the survey to support understanding the experiment, and also to see how participants think their designerly attitude can help in societal questions. We also presented and discussed the learning outcomes for students. As we evidenced, students found the creative communication between slots without any face-to-face communication to be both most challenging and most supportive for their learning. Organizations that provided the challenge-based tasks for the Rat Relay were both surprised and satisfied about the results.

As a part of the future work we plan to analyse and visualize all the data collected from the survey from this first official Rat Relay experiment. For instance, it will be interesting to look more closely into what influenced students' decisions and whether previous design experience of participants plays a role in the decision-making and final outcomes. The next round of the Rat Relay will take place in the first part of 2018, and we are looking to have more participating institutions, more students, and more coaches, and to use the experiences and results presented in this paper to create an even more engaging setting.

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Education for Sustainable Development through Service Learning in Engineering

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ABSTRACT

The Research Institute for Sustainability Science and Technology under the Master degree in Sustainability Science and Technology organises the course Action Research Workshop on Science and Technology for Sustainability (5 ECTS). The purpose of the course is to put together civil society organisations, local administrations, students and educators to collaboratively undertake responsible research, using transdisciplinary Action-Research methodologies through service learning.

Students work on service learning real projects, related to local sustainability problems, represented by a community entity. Action research methodology is used with a two-cycle approach. After finalising three editions a relevant conclusion is that during the process students faced conflict and frustration situations, within their team and with stakeholders. To face that, an Emotional Intelligence module was introduced in the course and helped students to solve some paralyzing situations. Therefore we suggest that engineering students need specific training in transdisciplinary learning and conflict resolution, otherwise they could collapse in frustration when dealing with real sustainability challenges.

Conference Key Areas: Sustainability and Engineering Education, “I want to contribute to solve local problems”, Engineering Skills

Keywords: Sustainability education, Service Learning, Emotional Intelligence

INTRODUCTION

Sustainability issues are widely recognized as wicked problems [1], which should not be considered as problems to be solved, but as conditions to be governed [2]. There is a general agreement on the need to reform scientific expertise, as it is required to deal with sustainability challenges, by developing new ways of knowledge production and decision-making. In that sense, Stephen Sterling [3] maintains that the nature of sustainability requires a fundamental change of epistemology, and therefore, of education. In relation to engineering education, the Barcelona Declaration [4] highlight the sustainability competences that engineering students should master when graduating.

The Universitat Politècnica de Catalunya (UPC Barcelona Tech), aware of the new sustainability competences that engineers should have, offers a master degree in Sustainability Science and Technology that trains students to become entrepreneurial professionals and agents of change for sustainability. Service learning is one of the pedagogical approaches applied in the master. The following sections explain the learning environment and the challenges and lessons learnt when applying such learning approach.

1 SERVICE LEARNING APROACH

Service-learning is an innovative teaching and learning method with experiential character that integrates service to the community and critical reflection with the academic learning, personal growth and civic responsibility. It is powerful tool for learning and for social transformation, which responds to the ultimate goal of education: to form competent citizens capable of transforming society.

Service-learning is the necessary response to an educational system that is alienated to social needs [5].

There are two main mechanisms that make service-learning an effective educational tool: the process and results. Firstly, it causes a mental process that improves learning. Research shows that complex facts and ideas are best retained when knowledge is linked to Experience [6] and facilitates the transfer of skills and knowledge to real situations [7]. Therefore, when teachers create a reflective learning-service environment, it is likely to improve the understanding and remembering of complex material. Secondly, service-learning produces results of great interest to higher education. Studies show that service-learning contributes to develop critical thinking and problem-solving skills [8] [9], citizen participation, social responsibility and development of values and self-efficacy and self-confidence [8].

Service-learning increases awareness of social justice [10], teaches students to question society from a point of view critical and emphasizes social change rather than charity [11].

Through learning-service, students can develop a vision of the social justice and learn to analyse the issues that are encountered in your life with a critical look at injustices [12].

2 SERVICE LEARNING COURSE

The service learning pedagogical approach is applied in The Action Research Workshop on Sustainability Science and Technologies a course within the Master of Sustainability Science and Technology. It is a 5 ECTS (European Credit transfer System) course, which uses constructive and community oriented learning which has shown to be the most efficient way to train students in sustainability science competences [13], [14].

2.1 Learning outcomes

When finishing the course students will have been trained in the following competences.

- To understand how their work interacts with society and the environment, locally and globally, in order to identify potential challenges, risks and impacts
- To reflect on the results of the service learning process in order to understand the social dynamics that appear when applying engineering approaches in real sustainability challenges

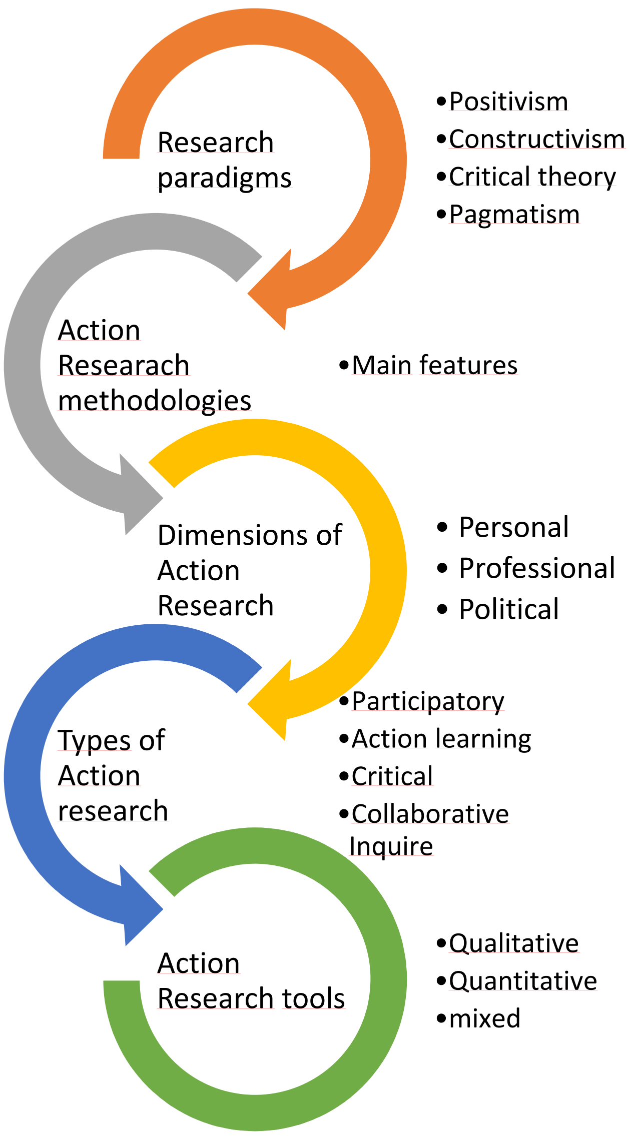

Fig. 1. Action research theoretical framework of the course

2.2 Course structure

The course is organized (Figure 1) around five areas: Research paradigms, Action research methodologies, Dimensions of Action Research, Research tools and Real projects. First students are faced with different research paradigms: Positivism, Constructivism, Critical theory, Pragmatism and their features in order to facilitate their reflection on the research that they may apply in their future work as engineers. Next, students are trained in the main features of Action Research methodologies. Once students are familiar with the main characteristics of action research, they learn about the main types of action research: i) Participatory action research [15]; ii) Action learning [16] [17]; iii) Critical action research [18] and iv) Collaborative inquiry [19]. Students study their main features, pros and cons, methodological approaches and examples. Finally, students are trained in qualitative, quantitative and mixed research tools and methods typically used in action research: Conceptual maps, questionnaires, interviews, backcasting, complexity and network analysis, etc

They apply all their learning in Action Research in real sustainability projects under Service Learning paradigm [20] [21].

3 THE EXPERIENCE AT UPC

The course has been run for three years (2014, 2015 and 2016). We are currently running the 2017 experience. The course is organized around current sustainability relevant topics, broadly related to unsustainability aspects which are analysed in study real-life projects in local real situations, needs or challenges. Table 1 show the general topics for each course, organisations who lead their own real-life projects and the research question for each of them.

Table 1.Service learning projects ran at UPC

Topic	Stakeholder	Real-life projects	Research question
2014			
Sustainable clothing and slow fashion	Clean Clothes Campaign	Spanish fashion in Morocco	What a local clothing company can do to minimize labour exploitation risk, when pushed to find suppliers in Morocco?
	Slow Fashion Spain	A local booming sustainable clothing market	What are barriers and challenges faced by sustainable fashion initiatives in current market?
2015			
Energy poverty in Catalonia	Energy Bank Association BE - Municipalities Premià/Sabadell	Detection of motivations to participate in the BE in Premià	What are the factors that influence the decision to join or not the driver group of BE?
		Phase 1 of implementation of the Energy Bank in Sabadell	What key factors that encouraged real participation in a local energy program can be used for BE?
2016			
Energy poverty in Catalonia	Energy BE – Premià	Phase 2 of BE implementation in Premià: private sector	What affordable and sustainable offer could facilitate the organizations involvement to BE?
Gas Geopolitics	OdG- Debt Observatory in Globalization	MIDCAT, huge construction of a mega- pipeline for gas interconnection France-Spain	What is the capacity of this civil organized campaign facing to maximize transparency and public accountability?
		Gas imports of the Port of Barcelona	What is the city responsibility on the perpetuation of fuel energy model based on natural gas?
UPC's water management teaching	EWB- Engineers Without Borders	What kind of water management is promoted at UPC?	Does the curriculum and UPC research respond to ensuring the human right to water?

3.1 Assessment of the course

In order to evaluate the course, two explicit reflexive questions are asked to the students: *What have I learned in this course?* And, *What do I think about the course* *(structure, organization, timing, projects, etc.)?* The results of the students' reflexions have been clustered in tables 2 and 3.

Table 2. Reflections of students about their learning

Topic	Relevant comments from students
Research methodologies	- *Qualitative and quantitative approaches are needed to see beyond the numbers.* - *I learned the relevance of qualitative aspects as we learned more from direct interaction with people than with quantitative data obtained by "R software".* - *The management of relations with qualitative research, which is not usually taught in tech universities, has been very stimulating* - *Qualitative data from interviews is a very inspiring process*
Transdisciplinarity	- *I have learned the relevance of stakeholders and the role they play.*
Real-life projects	- *To participate in a real project and to be in touch with real stakeholders has been very interesting* - *I liked to work in real projects*
Mutual learning	- *We learn to work with people from different disciplines and to improve our communication skills when working with professionals with different project management schemes* - *We learn to be more tolerant with our group mates that have different backgrounds and ways of working.* - *The most valuable point was the interaction with stakeholders from other disciplines, listening to their points of view and experiences in the topic.*
Robust knowledge	- *To realise that the different needs and concerns of stakeholders may shake the project process.*

Table 3. Reflections of students about the course

Topic	Relevant comments from students
Discussions in class	- *What I liked the most was the organization and group work in class, allowing us to listen and learn from each other*
Low directedness	- *There were many expectations at the beginning from all stakeholders and we felt a bit lost* - *The goal of the research should have been defined between the stakeholders which delayed the project, and was time consuming* - *The planning was confused and it took time to our self-organization with the stakeholders* - *I think that this course gives us too much freedom to make our choices, depending on which stakeholders we were discussing the topic with, the goal were changing…*

The main criticisms were related to the low degree of directedness at the beginning that for some was very frustrating, (the low directedness was deliberate in order to train students in dealing with stakeholders' different interests in real settings). In order to decrease the frustration among students, the course coordinators introduced an emotional intelligence workshop in the course

3.2 Emotional intelligence workshop

The module aims to allow students to obtain some experiential knowledge related to emotional intelligence and what the related competences are. These interpersonal competences, related to emotional intelligence are rarely included in curricula, although they have been widely studied and claimed [21] [22].

The workshop (2.5 hours) it starts with a framing theoretical introduction about emotional intelligence [23], multiple intelligences theory and related competences, always within the framework of sustainability [24] [25]. After that they participate in some exercises or dynamics proper to therapeutic theatre. The module follows the thread of the 5 domains of emotional competence: emotional awareness, emotional regulation, emotional autonomy, social competence, skills for life and well-being.

Participants recognize in an experiential way what the emotions involved in each of these domains of Emotional intelligence are, self-competence in all of them and how emotions can be perceived and expressed, understood, regulated and facilitated.

4 CONCLUSIONS

After the three years of the service learning programme, we have observed that students set out the importance of some topics and the difficulty they have to maintain them. Difficulties appeared at different points in the process, starting from the very beginning, when the problem formulation proved to be one of the most arduous task in the process. Another challenge arose with the accompaniment of stakeholders and the recognition of their role, during the whole process, because engineering students are not usually trained to work in wicked problems and moreover to work together with stakeholders. In this sense collaboration and communication with stakeholders was also challenging.

Finally, it is relevant to highlight that during the process students faced conflict and frustration within their team and with stakeholders. To face that, an Emotional Intelligence workshop was introduced which helped students to solve some paralyzing situations, which could have stopped the progress of the project. Therefore we suggest that engineering students need specific training in action research and conflict resolution. If not, they could collapse in frustration when dealing with real sustainability challenges.

5 ACKNOWLEDGMENTS

We would like to thank the students, faculty and stakeholders that has participated in our experience. We also thank the Municipality of Barcelona who this year is financing one of services in which students are participating under the framework of *Grants to institutions dedicated to the field of justice and the global international cooperation 2016*.

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Opportunities To Share Ideas & Practice Among Engineering Education Initiatives

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ABSTRACT

Globally there are a significant number of engineering and STEM related initiatives and organisations with each organisation having a particular emphasis, audience or approach regarding development of education in these fields.

All however aim to share ideas and best-practice among engineering educators so improving the overall learning experience of their students. By analysing the nature of the organisations it is hoped synergies can be found to more formally encourage organisations to share ideas while still retaining distinct identities and focuses.

At the SEFI 2016 conference in Tampere the issue of exploring and developing links between SEFI and CDIO (Conceive, Design, Implement and Operate) was raised.

This paper will share work being done towards a SEFI (European Engineering Education Society) position paper to improve the links between it and the CDIO initiative.

Conference Key Areas: Curriculum Development, Engineering Education Research, Attractiveness of Engineering Education

Keywords: SEFI, CDIO, Collaboration

INTRODUCTION

Around the globe there are a number of organisations and initiatives focussed around supporting and developing engineering education at which recognise the distinct demands, expectations and goals of the discipline.

Each organisation will have its own particular remit which may be focussed around specific branches of engineering, may be geographically focussed or may have particular emphasis such as engineering education research, practical implementation or focus on aspects such as technology to support education.

With pressures on academic staff to often focus their personal development around scientific and technical research, Engineering Education innovation is often characterised by small numbers of individuals working in the field in their own institution. The involvement of particular universities in these organisations is often dependent on key individual academic's personal contacts, capacity and aspirations.

While this is understandable, there could therefore be a tendency for parallel communities to develop which miss some potential synergies to support their members.

At the 2016 SEFI conference in Tampere there were a number of discussions regarding opportunities for closer collaboration between the European Society for Engineering Education (SEFI) and Conceive, Design, Implement and Operate (CDIO) with a view to developing a corresponding SEFI position paper.

This paper looks at these two organisations and draws together some thoughts on opportunities for collaboration.

1 ENGINEERING EDUCATION ORGANISATIONS

1.1 The global landscape

Globally there are a number of engineering education initiatives including the American Society for Engineering Education (ASEE), European Society for Engineering Education (SEFI), International Society for Engineering Pedagogy (IGIP) and Conceive, Design, Implement & Operate (CDIO).

For the purposes of this paper, the focus will be on the relationship and synergies between SEFI and CDIO.

The reason for focussing on these initiatives relates to overlapping but distinct educational and geographical focuses which offer potential synergies while still acknowledging the different strengths and objectives of each initiative.

2 SEFI AND CDIO

2.1 SEFI

SEFI (Société Européenne pour la Formation des Ingénieurs / European Society for Engineering Education) was established in 1973 in Belgium by a consortium of 21 European Universities from 6 countries with a mission *"To contribute to the development and improvement of engineering education in Europe and to the enhancement of the image of both engineering education and engineering professionals in Society"*. [1]

It lists a number of objectives including acting as a networking organisation among academics, industry and international bodies, serving as a forum to develop and influence policies related to engineering education and to contribute to the development and the improvement of higher engineering education.

SEFI offers membership as an individual, an institution, on a corporate basis or an associate basis – typically professional bodies, non-European organisations, student groups etc. At present SEFI has around 130 institutional members who pay an annual subscription to support the upkeep of the organisation.

SEFI runs an annual conference and is also responsible for the European Journal of Engineering Education. Organisationally SEFI is run by a council with responsibility for specific themes devolved to 11 working groups. These thematic groups have a range of responsibilities such as subject area (Mathematics, Physics, Sustainability, Ethics), operational aspects (Curriculum development, Quality, Online education) together with a range of other areas (Gender & Diversity, Education Research, Lifelong Learning).

These groups are then charged with developing their respective fields through projects, position papers and through the support and review of papers to the annual conference. Recent position papers emerging from SEFI include those on skills (2015/16) and those on the accreditation of engineering education (2012).

2.2 CDIO

CDIO emerged toward the end of the 1990s following thinking at the Massachusetts Institute of Technology's (MIT's) aerospace group which showed concerns among engineering employers that graduates emerging from Universities were often strong in engineering science but tended to lack many of the practical and personal qualities required by industry. While voiced at MIT, this was quickly seen as a global issue and a reflection of the culture of Universities moving toward a research driven agenda which in turn informed staff appointment and other strategic decisions.

By the turn of millennia a consortium involving MIT and a number of Scandinavian Universities began to develop the CDIO approach centred initially around a syllabus focussing on "what to teach" based on consulatation with stakeholders. Later 12 standards were created which tended to focus on "how to teach" with the focus being on active and project based approaches and continuous improvement of provision in an effort to draw out many of the perceived deficiencies in conventional graduates. The Conceive, Design, Implement and Operate (CDIO) was coined to reflect the sort of stages a student or graduate engineer might go through in the holistic solving of a typical engineering problem. [2]

At the time of writing, the initiative has grown to around 130 institutions globally, organised into 7 geographical regions. The initiative annually organises a main summer conference, a Fall (Autumn) meeting together with at least one meeting held by each region per annum.

Membership is at institutional level and carries no subscription cost. Potential new members are expected to benchmark themselves using a 0-5 rubric on each of the CDIO standards and present their plans at a regional or international meeting. There is no requirement to score any particular number of points against the standards however the CDIO organising council expect to see commitment to the CDIO approach, senior management support from their institution and a clear indication of how they would hope to participate in CDIO activities going forward.

For a typical CDIO member, initial involvement may often be triggered by a desire for their institution to make a step-change away from relatively traditional programmes to ones with a more holistic, active and project based approach. The CDIO standards and networks can then be used to help manage, measure and inform this change process.

For more established members, CDIO perhaps takes on a more conventional form, acting as a network for sharing best practice and innovation. In recent years a stronger focus has been made in regard to developing stronger engineering education research rigour and methodologies with the aim to provide continuing benefits to more long standing members.

Table 1 : A comparison between SEFI and CDIO

	CDIO	**SEFI**
Established	2001	1973
Institutional Members (Global/Europe)	~130/~75	~133/~133
Membership	• Institutional only (No fee, elected following successful presentation showing commitment to CDIO principles)	• Institutional • Individual • Industrial • Associate (eg. Professional Body, Industrial Organisation) • All by subscription
Organisation	• CDIO Council • 2 Co-chairs • 6 Members at Large • 7 Regional leadership teams	• SEFI Board of Directors • 21 members plus President & 2 Vice-Presidents
Devolved Responsibility	7 Regions	11 Working Groups
Events	• Main Summer Conference (June) • Fall Meeting (November) 1-2 Regional Meetings per region / per year • Regular TELECONS	• Main Summer Conference (September) • Working group events • Board meetings
Publications	• CDIO Conference Proceedings • Fall and Regional Meeting Documentation	• SEFI Conference Proceedings • Annual Report • EJEE (6 issues pa)

3 MEMBERSHIP AND FOCUS

3.1 Membership

SEFI has around 130 institutional members in Europe, while CDIO has around 80 members within its European and UK & Ireland regions, with a further 50 or so institutional members around the globe. The memberships of both of these organisations has grown organically over the years since their respective launches.

More detailed analysis of the breakdown of the memberships shows some interesting patterns and opportunities. [3], [4]

Fig. 1 shows the membership breakdown for some of the most heavily involved nations. It can be seen that there are a number of observations which can be made.

- Institutions typically belong to one or other but not necessarily both despite the possible overlapping and complementary opportunities afforded by this.
- There can be an apparent geographical bias toward SEFI (eg. France), or CDIO (Russia) which is likely due to history or local influences in each case.
- The membership levels of both institutions do not necessarily correlate to the number of engineering education providers in each country. Thus Finland and Sweden have a similar number of members of SEFI and/or CDIO as much larger countries such as France, Germany and the UK.

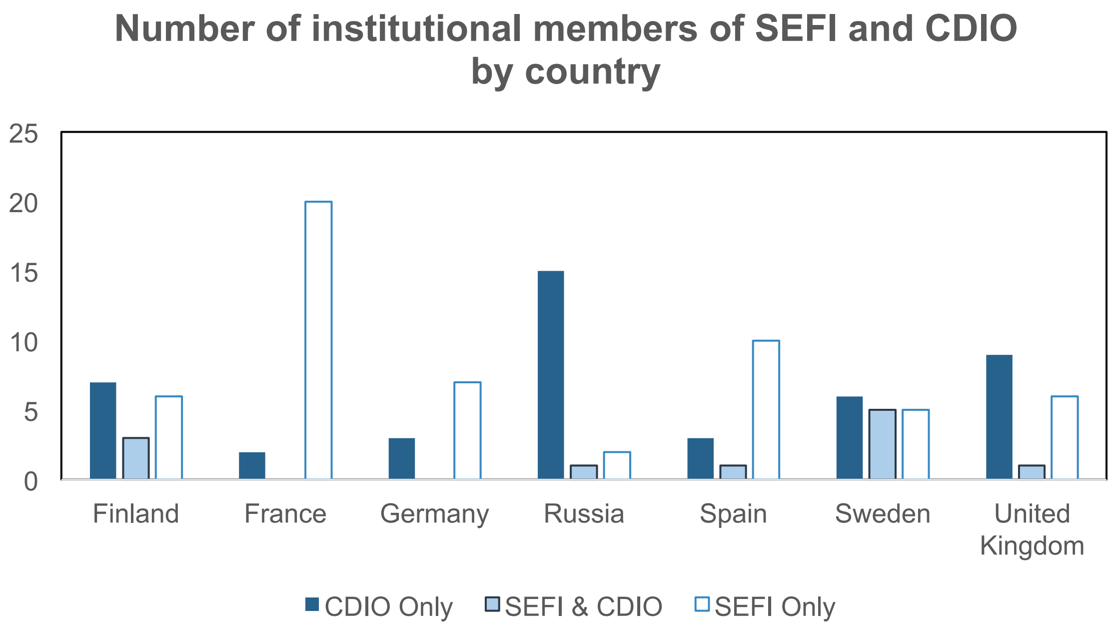


Fig. 1 . Number of institutional members of SEFI and CDIO by country

To reinforce the independence of the two organisations, *Fig. 2* shows the degree of overlap between the two organisations within Europe. It is notable that only around 10% or institutions holding membership of either organisation formally participate in both.

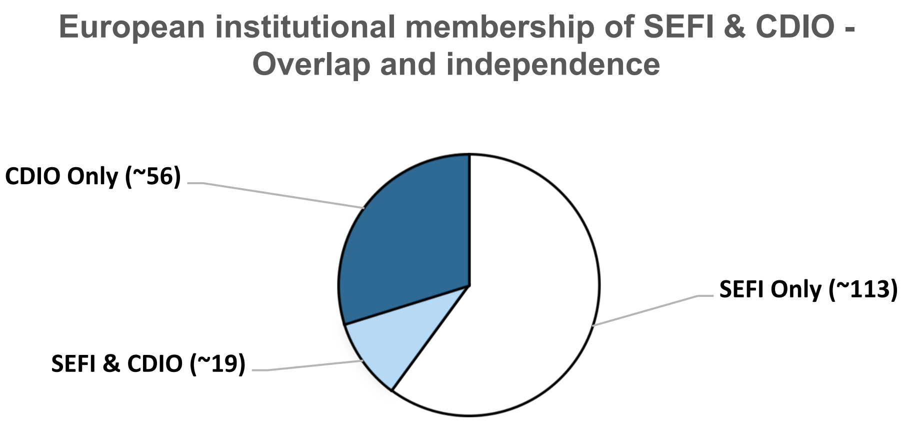


Fig. 2. European institutional membership of SEFI & CDIO - Overlap and independence.

It is also observable that both organisations have scope for growth in some of the larger markets should they choose to. As an example *Fig 3.* shows the extent of CDIO and SEFI membership within the UK market showing only around 10% of institutions awarding engineering degrees are members of either organisation. In the UK market, there may be particular appetite for growth with the introduction of the "Teaching Excellence Framework" (TEF) which has put some pressure on Higher Education providers to develop their approaches to learning and teaching. [5],[6]

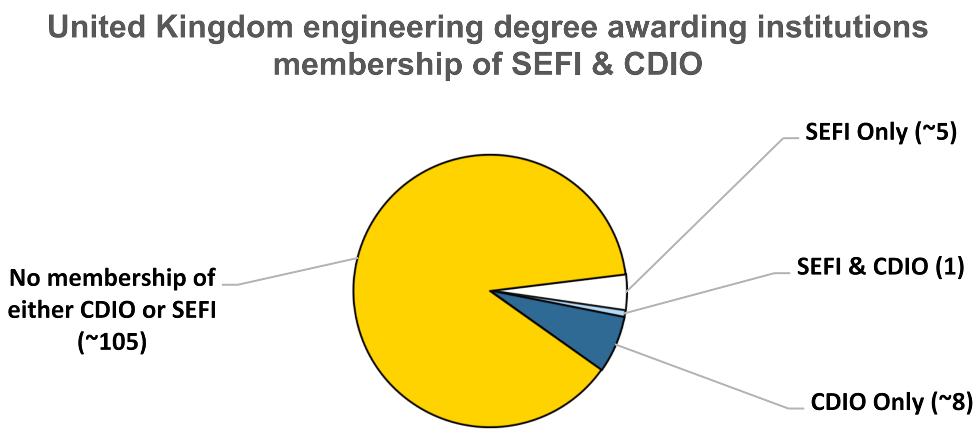
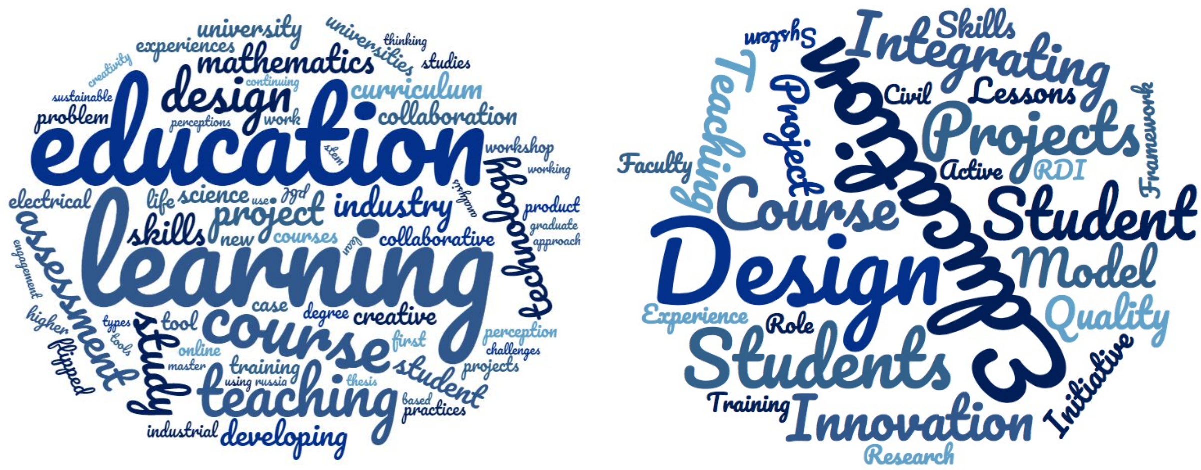


Fig. 3 . United Kingdom engineering degree awarding institutions by membership of SEFI & CDIO

3.2 Focus

Both SEFI and CDIO have annual conferences where they invite members and any other interested partners to share their latest ideas, findings and research. In 2016 both conferences were held in Finland. In June the CDIO conference was held at Turku University of Applied Science where just under 100 papers were presented, while SEFI had their annual gathering at Tampere University of Applied Science in September with around 150 papers.

As a means of assessing the interests and directions of the participants of the two initiatives a survey of the titles of the papers and posters was carried out. [7], [8]. *Fig. 4* shows word clouds generated by the paper tiles from the two conferences. Words appearing only once or twice in the conference titles were omitted for clarity.



(a) : SEFI 2016 *(b) : CDIO 2016*

Fig. 4 . SEFI and CDIO 2016 conference paper title comparison

While CDIO was removed from its cloud it can be seen that the emphasis of the papers presented at both conferences were along similar lines and almost certainly would be of interest to each other's audiences.

4 POSSIBLE WORKING ARRANGEMENT & POSITION STATEMENT

Engineering education is a highly dynamic field and it is both challenging and rewarding to develop students who are not only encouraged and engaged in their studies of the discipline but once graduated, do so with not only the underpinning skills and knowledge required of a new engineer but do so with the ability to continue to evolve and develop through their career. Both SEFI and CDIO share these ambitions and so, while recognizing each as a distinct organisation, a greater awareness of what each has to offer, gives the chance to strengthen both. The following proposals are suggested as the basis of a SEFI working paper on their relationship with CDIO.

- SEFI recognises the approach of CDIO and that the framework of the CDIO standards and syllabus is a strong but flexible framework on which to transform programmes to ones which better meet the needs of industry.

- That both organisations have a strong history and ongoing innovation in engineering education research and that by sharing practice and developing initiatives in this area can only be positive. This is exemplified by a special edition of the SEFI run European Journal of Engineering Education focussed on "Scholarly Development of Engineering Education – the CDIO approach".

- That by sharing engineering education research proposals across the joint SEFI and CDIO networks, there is a much greater chance of finding like-minded partners, giving stronger overall partnerships, greater likelihood of securing funding and better overall project outcomes.

- That all engineering education specialists face a range of common practical pressures related to demands on staff time, expectations and budgetary and resource concerns. By working together SEFI and CDIO have greater critical mass to help influence the decision makers at institutional and governmental level to recognise the value and importance of engineering education.

- That both organisations have their own distinctive profiles and objectives and while sharing many core values, each offers the practising academic, support and tools to help them achieve their personal and institutional objectives.

- That, as exemplified by the 20 or so institutions holding memberships in both SEFI and CDIO, involvement in both institutions is a positive experience.

- That to make such interactions possible both CDIO and SEFI should be open to joint initiatives and offer platforms to raise awareness of each others activities both among existing members but also to the sizable engineering education

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Sustainable energies – the beauty and the beast

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ABSTRACT

Energy consumption has been essential for Nations' development. Developing countries are highly populated and growing at a faster pace than already developed ones. Their willingness to reach a higher state of development is natural, which will inevitably mean the need for huge amounts of energy and resources. Moreover, they will generate huge amounts of gaseous and liquid effluents, and of wastes, triggering a need for much more efficient and cleaner technologies. Developed countries, however, face other problems, as they have established technologies, strategies and policies that are hard to change. Therefore, changing attitudes and strategic planning is vital to achieve a sustainable world. This change of attitudes is hard, and extremely dependent on the existence of a new kind of professionals who can, not only understand the diversity of problems and their implications, but also act as the link between the several *specialists* who can solve only particular problems. This calls for a multidisciplinary training at the higher education level, which has not been favoured. In this paper it will be discussed how to introduce in the engineering curricula the tools to educate such professionals, and how this strategy can be used to distinguish this

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new generation of technicians.

Conference Key Areas: Sustainability and Engineering Education, Curriculum Development, Skills and Engineering Education

Keywords: Curriculum Development, Engineering Education, Environmental protection, Renewable Energy, Sustainable development, Sustainability

INTRODUCTION

The energy-based development has driven Nations to an exponential growth in energy consumption. The fossil derived energy is becoming scarce to fulfil all the energy needs. Besides, the associated emissions and environmental impacts are driving scientists and decision makers towards both a new model of development based on renewable energy systems, as well as on more efficient energy systems. However, both have brought new challenges: a significant part of renewable energies is intrinsically unpredictable and presently only can be used in a low percentage, as the electric paradigm is based in control. New appliances are now not only more efficient but also nonlinear loads, because of the introduction of electronic controllers, which brought negative impact on the electric energy quality.

These evidences show that not everything that is renewable will be sustainable. *The Beauty* of being apparently more environmentally friend also causes problems that need solution. On the other hand, the non-renewable energies cannot be considered as *The Beast*, as their total elimination from the actual energy system cannot be achieved without a deep change of both human behaviour and of the energy system. The whole system has to be analysed in a life cycle thinking perspective, where non-renewable energy sources must be considered as one essential piece to supply the failures of the renewable sources, and all the appliances that are developed to reduce the energy consumption are submitted to deep analysis of their impacts.

To analyse such problems, two different approaches can be used, though, any of them is based on the existence of professionals who are multidisciplinar in nature. The first approach is to build teams that are leaded by senior experienced engineers (SEE), used to work in large teams of specialists; the second approach is to form teams that are leaded by junior multidisciplinary engineers (JME), used to analyse and discuss problems in multidisciplinary teams, including in their analysis not only the direct impacts but also the impacts that occur in different dimensions, and to anticipate potential problems. SEE have high associated costs and may have tendency to overestimate or underestimate potential problems. JME have lower associated costs and a natural willingness to let specialists present the advantages, whereas they can themselves anticipate the drawbacks.

Thus, multidisciplinarity is now an advantage to solve problems such as the storage of surplus renewable energy produced for later use, or its immediate distribution to where it is needed by using smart grids, the mobility and transportation in modern mega cities, the integrated waste and effluents treatment with energy and/or biofuel production, or even the construction of Zero net Energy Buildings (ZEB), among others.

Therefore, this new model of development relies on a new class of environment and energy professionals, who are able to relate their particular expertise with all the other areas involved, and to understand the impacts of such systems. The time to explore concepts and emerging technologies in a collaborative way has just started, bringing together engineers, researchers, decision makers and professionals from different areas. In fact, we can perceive that new and tighter targets towards sustainable development have been set by several countries, as from the Paris Agreement in December 2015. However, the path to reach them is a sensitive matter concerning to each country and no rules were set. Thus, more than ever, in this very moment it is critical to educate professionals who are able to plan truly sustainable systems.

We will discuss how to introduce in the engineering curricula the tools to educate such professionals, and how this strategy can be used to distinguish this new generation of technicians.

1 DEVELOPING AN ENGINEERING CURRICULUM

According to Feisel and Rosa [1] "*Engineering is a practicing profession, a profession devoted to harnessing and modifying the three fundamental resources that humankind has available for the creation of all technology: energy, materials, and information*".

The Bologna Declaration on Higher Education (HE) [2] was the turning point when all the Portuguese HE Universities and Polytechnics had to change the model of their engineering curricula to a 3+2 years plan of studies. Up to then, different models co-existed, with 3+2 years in the Polytechnic and 5 years in the Universities. Nowadays, the 3 years graduation as a Bachelor in Engineering (*Licenciado em Engenharia*) allows one to develop a professional activity as an engineer with limited intervention, if the graduate comes from a Polytechnic. However, Universities that essentially have adopted and integrated model offering a 5 years course with an intermediate graduation as Bachelor in Sciences of Engineering (*Licenciado em Ciências de Engenharia*) in the 3rd year, do not recognize that these graduates have any engineering skills. The last 2 years are part of the graduation as MSc in Engineering, including a Master Thesis corresponding to at least 30 ECTS.

1.1 Graduation in Engineering

It has been a matter of discussion, if engineering curricula should start with a focused or with a comprehensive plan. The main advantage of the comprehensive plan, where students must contact with several matters, is that graduates learn, from a very early stage of their lives, how to interact and consider the different problems. However, they do not have enough time to deepen the knowledge, and therefore they may not really have the tools to understand the impacts of their decisions. This partially explains the relatively high rate of Dropouts in such courses.

On the other hand, the focused plan has the advantage of providing the students with enough tools to start a professional activity in a particular field of engineering, such as mechanical engineering, electrical engineering, civil engineering, geotechnical engineering, chemical engineering, etc. Being focused, students may not be aware of the need for interaction with other specialities, and therefore they may not develop the necessary skills for teamwork (not group work).

However, in our experience, we believe that younger students have generally much lower degree of autonomy and maturity that is needed for succeeding in graduation under the comprehensive plan.

1.2 Post-graduation: the MSc in Engineering

Depending on the HE system, the number of students who already are developing (or have developed) professional activity when they are studying in the MSc program can be substantially different, whereas in the Polytechnic system this number can reach up to 90% [3], in the University system it is usually much below 25%.

This not only affects the *style of learning*, but also the motivation, the time available to attend classes and to study, and specially, the matters of interest. In fact, professionally active students often pose questions intrinsically linked with *problems* from real cases in their own jobs. This is not only important because the school acts as a trigger for the *solution* but also because the remaining students in class recognise the global *importance* of a given subject and increase their *trust* on the educator.

Additionally, having developed professional activity can be used as case study, or as a source of interaction between Academy and Industry, helping the creation of strong and long lasting ties between them.

The higher degree of maturity of the students in this 2nd cycle of studies allows one to address bigger challenges, as those that are derived from multidisciplinary problems. This is the reason why it should be preferred to organize the HE courses in engineering in such a way that the 1st cycle is focused in a particular field of engineering and the 2nd cycle can be more comprehensive.

2 EDUCATING ENGINEERS FOR SUSTAINABLE ENERGY SYSTEMS

Having decided that it is preferred to use the focused+generic plan in the 1st+2nd cycle, it was thus decided to plan a MSc in Sustainable Energies. This MSc program [4] receives graduates from any 1st cycle in Engineering, as well as graduates from other fields of sciences. However, the later may have to acquire skills in particular areas, such as Thermodynamics, Physics, etc.

2.1 Designing the course plan

The course plan was built upon multidepartamental teamwork. Representatives from all engineering departments at ISEP were involved in the design of this course, bringing their expertise in the particular scientific area of engineering as well as their knowledge on the scientific problems under study in the energy field. Already at this time, it was privileged the participation of those who were able (or who were willing to make an effort) to address and discuss mustidisciplinary problems.

The result was a set of 8 mandatory plus a set of 5 out of 19 elective disciplines, each accounting for 6 ECTS, followed by a final Master Thesis (42 ECTS) [4].

2.2 Mandatory courses

The objectives of the mandatory courses is to provide all the students with the basic knowledge and skills in the energy sector, with a particular focus in the Environment and Natural Resources; Renewable Energy sources; Transfer Phenomena; Dynamic Control Systems; Management and Evaluation of Environmental Impacts; Energy Conversion Systems, and finally, Economical Analysis of Environment and Energy Projects. As the MSc receives students from different backgrounds, sometimes this means that the mandatory courses start with a kind of brief revision of basic concepts, and then they deepen the necessary disciplines.

2.3 Elective courses

These are the courses that allow each student to build his own professional profile, according to his preferences and style. Therefore, it is possible that a student chooses courses more oriented to higher energy efficiency, to sustainable buildings, to combustion systems, to biofuels production and characterization, to emissions treatment and minimization, air conditioning, distributed energy systems, energy markets, or even entrepreneurship, among others. The electives are focused courses, usually appealing to previously acquired base knowledge.

3 DISCUSSION

It should be emphasized the high acceptance of this course and the enthusiasm of the students who attend it. Partly this is due to the fact that energy and sustainability are current and modern themes, for some, they are really a hot topic. However, students realize that there is still much to be developed in several areas of work and they genuinely intend to contribute with their attitude, efforts and skills.

In fact, it is motivating to develop solutions that contribute to a more sustainable world (The Beauty) but an intervention in an area has a chain effect in the system (The Beast), being only possible to solve the problems stepwiselly.

When we take the example of public lighting using LED-based lamps, we know that the replacement of conventional lamps with LEDs resulted in a lower energy consumption. However, LED lamp power supply has a highly non-linear behaviour, causing harmonic distortion and greatly increasing electric power distribution losses [5]. Public lighting is an Electric Energy System area, whereas the lighting power supply belongs to the Electronics Engineering area. Furthermore, other problems arise from the extensive use of LED lamps, as is the case of the quality of light and the effects of single wavelength on human visual comfort (Electric Energy Systems), the problem of natural resources needed to supply the required amount of lamps (Mining, Geotechnical and Environmental Engineering), or last but not least important, the problem of the disposal and elimination of the spent LEDs when their end-of-life is reached (Environmental planning and management).

When we take such a kind of approach to the Electronical appliances, we notice that it is mandatory to apply a Life Cycle Analysis (LCA) methodology to the production of any new equipment in a large scale. The solution to this problem can only be designed through the collaborative work of professionals of all involved areas.

As referred in section 2 of this paper, the Master in Sustainable Energies was carefully designed in order to develop the technical and interpersonal skills, with a broad scope of disciplines taught by professors from six engineering departments of ISEP, who have succeeded in working together in the same collaborative path.

As an example of the success of this MSc, we can point out a geotechnical engineer who is working today with Bosch, a mechanical engineer who is working in a biofuels plant supplier or a civil engineer who is working in the wind energy sector, all of them as Master graduates.

4 CONCLUSION

The Master in Sustainable Energies has graduated professionals in the Energy sector with a focus in the engineering aspects, from 2011. The course has a comprehensive structure, and has received growing interest, not only at a National but also at an International level – Brazilian, Indian, Polish, German, Latvian, French, Spanish, Italian, Syrian, Nigerian, etc., students. Its graduates are all developing professional activity, regardless of their primary 1st cycle graduation program, in the energy sector.

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What is a Sustainable Curriculum?

Re-thinking the Modes of Curricular Existence

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ABSTRACT

The following intervention proposes an alternative way of thinking about curricula. It argues that current theorizing about curricula tends to confuse sustainable course contents with a sustainable curriculum. Drawing on object-oriented ontology and actor network theory it offers a way of rethinking curricula to better attend to the real challenge of sustainability.

Conference Key Areas: Curriculum Development, Sustainability and Engineering Education, Ethics and Engineering Education

Keywords: Sustainability, Curriculum Theory, Object Oriented Ontology

INTRODUCTION

Rethinking curricula from an ecological point of view demands much more than merely adding courses on sustainability-related themes. It requires a revision of the way that we think about the nature of curricula, an open reconceptualization of what a curriculum might be.

Almost all thinking on curricula, like so much else that is inherited from the western tradition, is rooted in an idealized conception of the human being which sees minds as separate from the world that surrounds them. Humans are not entangled in things, they are not part of the world or an ecosystem. They are radically separated into mind and body, or, at another level, into society and nature, or the study of discourse and the study of things. This mode of thinking supports what might be called superficially sustainable curricular reform. The superficially sustainable engineering school has modules on sustainable manufacturing, it has researchers working on producing green energy, classes on sustainable cities, and so forth. In accordance with broadly accepted ideas about how to form a sustainable curriculum, the teachers at this school work across disciplines, making a consistent effort to make students aware of environmental problems. [1] In addition to course work, students at this school find themselves immersed in a culture which reinforces and generates sustainable values. The school conforms to the definition of a sustainable curriculum offered by the UK Engineering Council and other such organizations. In other words, it fosters an “understanding of the requirement for engineering activities to promote sustainable development”. [2] We should be happy such schools exist. However, if this is our paradigm for a sustainable curriculum, then we have a major sustainability problem. Why?

One can intend to teach about sustainability, without that curriculum being sustainable. Between the intention to teach something and its enactment, **there are always material conditions that intervene to make that happening of the curriculum possible. These conditions, despite the strain that it may place on our traditional ways of thinking, need to be seen as part of the curriculum.** *Rather than asking whether the courses are about sustainability, we need to explore whether the entire network of material parts and multi-agent interactions making those courses possible is consistent with sustaining life on earth.* Every sustainable development curriculum implies classrooms, books, computers, and other supports proximate and distant, including connections to various infrastructures and networks—including intercontinental fiber optic cables, highway systems, global markets, and power grids. This is true for brick and mortar institutions and for digital classrooms. These supports form part of the indispensable conditions of existence for any curriculum; these material networks *are also the curriculum*.

Reflecting on curricular sustainability in this broader sense is challenging, because it undercuts the legitimacy of the model of sustainability thinking presented above. Our superficially sustainable curriculum involved lessons transmitted by textbooks. Books are made of paper, and that paper comes from trees, which in turn come from forests. These forests might be managed sustainably… or they might not be. In most cases, neither of these things will be transparently evident to students reading about the benefits of reducing, reusing, and recycling. Say we replace books with computers or digitized documents of some kind. We often think that digital documents are more sustainable than paper ones, we feel like we are doing something environmentally virtuous when we do not print out a document but rather consult it electronically. But also means that we overlook the material reality of computing. What is a computer? It is rare that we think deeply about this question, because most of the time we do not look at or into our computers, but rather through them, considering only the information that they contain. [3] Yet as anyone who has ever seen Edward Burtynsky's photos of e-waste recycling sites in China would know, computers are much more than streams of information. They are generally made of plastic (a petroleum by-product) filled with various pieces of silicon and rare metals, some of which are non-toxic and recyclable, others of which are toxic, non-recyclable, and frankly dangerous for human health. [4] Many of these materials are sourced or disposed of in ways that are neither sustainable nor humane (consider the case of coltan, one of the key materials employed in the making of smartphones, and the cause of a great deal of violence against both human beings and the environment). [5] A computer is always either immediately or via radio waves attached to two cable systems, one of which brings it power (the source of which may well be combusting coal), another one distant information. This latter implies links to fiber optic systems and server farms world-wide, all of which once again consume potentially non-sustainable energy sources, while potentially (in the case of undersea cables) interfering in marine ecosystems. [6] To these considerations we can also include reflections on the sources of heat and light in the classroom, or the means of transportation by which students come to and from their homes or dorms to the classrooms.

Wholly other sets of connections also inflect the real sustainability of a classroom and ought to be taken into account. These connections are not primarily material like the ones mentioned about, but include socio-material networks like the economy.

Everyone knows that schooling is expensive. Top schools need to have significant funds to enact their curricula (and to compete for places on the Shanghai ranking). But where does this money come from? We can safely assume that the sustainability of the tuition money in elite schools will roughly mirror the sustainability of the sources of high-income employment within society. It is mostly the parents' jobs or the student's downstream employments which will generate the revenues that cover tuition fees. Given that so many of the world's largest and richest corporations are unsustainable (four out of the top five grossing corporations worldwide are petroleum or energy companies) we can conclude that at least part of the money paying for the happening of any curriculum is unsustainable (the case is only slightly altered in the case of public school systems, since the wealthiest corporations pay the most taxes.) Aside from student tuitions, most major universities derive their funds from endowments and research contracts with corporations and governments. Are these funds sustainable? The recent student movements protesting the high percentage of fossil fuel stocks in the portfolios of many top American universities show that this not yet the case. [7] What about the research contracts? It is more than likely that any top engineering school with some courses on sustainable development will also have researchers working on projects funded by the fossil fuel industry, with it being no stretch of the imagination that these are *the same researchers* teaching courses on sustainability. As Naomi Klein and others have shown, highly visible investing in sustainability research has been one of the most frequently used greenwashing strategies deployed by major companies in the petroleum and transport industries. [8] Of course, one can reply to this analysis that the material contribution of unsustainable industry to increasing sustainability actually amounts to a net demonstration that the curriculum is sustainable, since investments are flowing from the unsustainable to the sustainable. But what one cannot do is disregard this level of complexity when considering curricula.

The economic does note exhaust the complexity of curricula, however, particularly if we are thinking about engineering schools. Unlike liberal arts institutions, engineering students spend a great deal of time interacting with technological devices. Whether these be robots, computers, or nanoscale microscopes, engineering schools would not exist without technologies. Based on the above we might be tempted to analyze the sustainability of these technologies via purely material considerations. But if we did so, we would miss out on what might be called their architectural telos. This is a twofold category, one with respect to how technologies condition us, and one with respect to how the current design of a technology conditions future redesigns of the same. Both aspects come into play when we consider the direction in which any curriculum is likely to evolve, and both aspects can to be considered part of the sustainability of an engineering curriculum. *The design of current technologies impacts the design of future technologies and so plays a role in the sustainability of a curriculum.*

It turns out that assessing or even describing sustainable curriculum is harder than making up a curriculum about sustainability. The examples that I have given are not exhaustive but rather suggestive of the real complexity of curricula. Serious attempts to think about the sustainability of engineering curricula must not flee from this complexity but rather embrace it. Doing so poses conceptual and methodological challenges, may leave us feeling lost or confused, may seem to alienate us from what we thought was reasonable and certain. But failing to even attempt to rise to the challenge or brushing aside the concerns raised by deeper questions are sure recipes for failure.

1 RETHINKING CURRICULA

1.1 A Curriculum as an Enacted Ecosystem

A sustainable curriculum possesses the long-term means for its perpetuation. A curriculum that is sustainable is sustainable on all levels, not just sufficiently sustainable to reassure us that we are trying to do something at the level of ideas. Thinking about curriculum that overlooks the question of long-term means by focusing only on ideas and pedagogical intentions is endemic, and this is precisely what we have criticized in the standard model conception of ecological curricula. In order to avoid shallow thinking, we must *view curricula from the point of view of their enactment as opposed to their content*. By enactment we intent the broader coming into being of a curriculum. This means that we abandon the subject-centered intentional understanding of curriculum that is and has been the norm. We must now consider the interactions between all of the things involved in making happen a curriculum as we normally intend the word. Material things, and not just human intenders are now actors. A curriculum is a particular kind of complex ecosystem, and it can be studied as one studies other ecosystems, albeit with an addition of the additional complexity introduced by the importance of intention and discourse in human interactions.

This is obviously a heterodox interpretation of the meaning of curriculum, though it is not an abusive one, even from the viewpoint of etymology. According to the *Oxford Latin Dictionary*, the word *curriculum* (a 2nd declension neuter noun) has the following definitions: the “act of running,” the “chariot,” the “course of action/heavenly bodies”, “lap, track,” and “race.” [9] Roughly half of these meanings refer to the aspect of the curriculum that interests us, namely the material conditions or the ecosystem in which the race occurs—the chariot and the track—and their influence on the happening of the race.

1.2 Anti-Anthropocentrism

Recent work philosophy in the philosophy of the social sciences, has suggested that we must move away from understanding society anthropocentrically. [10,11] Anti-anthropocentrism in this sense implies that we must not overly privilege what social actors think that they are doing when we analyze what happens in social groups. Our ideas and intentions are merely one level in the complex tangle of interactions that make up any kind of social happening. A computer, a test bench, or the geographic location of a school, can thus be thought of as equally important to the happening of a curriculum as the ideas of a pedagogical visionary like MIT’s William Barton Rogers. A curriculum is thus not just the sequence in which ideas and values are impressed upon human minds, nor any accounting that might be made of those ideas and values, but something much more complex and indeed ambiguous. Our example above illustrates this perfectly: is our curriculum sustainable or not? Yes and no, depending upon which perspective we privilege. One is tempted to eliminate one or the other aspects just to get a clear response. Yet a better reaction is to think about a way to create a meaningful discourse about this complexity, to find out a way of making sense of and attending to the complex and conflicting aspects and actors at work within the unfolding of curricula.

1.3 Theory versus Topography

We tend not to appreciate the complexity of things in part because so much of human practice is aimed at reducing complexity. Theories attempt to reduce complex happenings to simpler structures or essences that are taken to be the real of what initially appeared complex. They are intrinsically reductive. But what we need is not reduction but orientation. We need tools that encourage us to look a bit farther, to find out what is around the next bend, to prompt us to fill in details and aspects of curricula that we might otherwise miss. One method of preserving complexity while orienting ourselves within this complexity is cartographical or topographical. Topographies do

simplify to provide orientation, but they in no way suggest that the map is more real than the territory. The rewards for employing this kind of topographical approach
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involve greater sensitivity to difference and complexity, as well as a heightened understanding of the mereological relations between the curriculum and its constituent elements.

Because a curriculum is highly complex, involving mind-mind interactions, mind-object interactions, and object-object interactions, as well as variable dimensions of expression and latency, multiple degrees of conscious and unconscious awareness, fairly complicated metaphysical notions are necessary for its description. I therefore introduce the notion of the mode of existence. A mode of existence is a way of being that is complete but not total or exclusive. By this I mean that that mind-object interactions exist on a different plane than mind-mind interactions, that these interactions have play out along what seem to be independent lines of temporality, spatiality, and causality, and that both interactional nexuses are to be treated as equally real, precisely because the interactions between these two modes must both exist, and exist ambiguously. Understanding a curriculum involves elaborating its topography across multiple modes of existence.

In order to illustrate my point, we can consider abstractly the idea of the sustainable curriculum and its material reality. In terms of mind-mind interactions, all of the teachers and students might well believe that a curriculum is sustainable, without that curriculum being as sustainable as they think in object-object terms. As Etienne Souriau has pointed out, a typical theoretical gesture is to attempt to assign degrees of reality to the varying existential modes, essentially claiming that some are less real than others. [12] Yet just as it would be violent and even absurd to say to a depressed person that their perceived causes of their sadness were unreal, and that the real source of their depression is their serotonin levels, it is violent and absurd to claim any aspect of the curriculum as the real. Every mode of existence is characterized by a specific articulation of how actants can relate meaningfully with one another. It would be wholly possible (if contrafactual) to imagine that a curriculum was materially sustainable without anyone having ever intended this to be the case, just as it was the case that the curriculum that we initially imagined sustainable turned out not to be so, though the long-term evolution of both curricula would be different (but that would depend upon more factors than just the intention to make a sustainable curriculum).

2 FOUR MODES OF EXISTENCE

Contemporary philosopher Graham Harman has introduced a fourfold existential topography that can help us to direct our attention to the broad modal outlines of curricular existence. [13] I say broad outlines, because as we will see, every fundamental mereological framework (and that is to say every science, be it chemistry, physics, or curriculum studies) establishes a novel mode of existence as it codes meaningful elements within its discursive system. Nevertheless, Harman's work is interesting because of its relatively high level of ontological abstraction allows us to rediscover its broad outlines in other, more local, existential ontologies.

Harman calls the four primary modes of existence the "fourfold." According to Harman the fourfold is made up of two pairs, each of which is in tension with its other. [14] The first pair of modes he calls real objects and their qualities, and the second pair are sensual objects and their qualities. Rather than adumbrating the sense that he attributes to these terms, it seems more useful to introduce and explain the versions of these notions adapted to the study of curriculum. In what follows, I equate the

Harman's distinction between the real object and its qualities with the metaphysical and the material curriculum, while the distinction between the sensual object and its qualities are equated with the social and the subjective curriculum.

2.1 Metaphysical Curriculum

The **metaphysical curriculum** exists in a state that Harman describes as "withdrawn." It is primarily to be understood as a group of objects subtracted from their relations. These objects include both human beings and material things like buildings or books. No subject experiences or perceives this curriculum directly, no two objects interact with one another. No science or discourse about this curriculum is possible. The metaphysical curriculum in this sense is latent and remains latent, but it is the site from which all radical curricular becomings originate. It is at once a pure idea and the bedrock of material reality.

If we thus have nothing to say about the metaphysical curriculum, why then should we even mention it here? Most importantly, claiming that there is such a metaphysical curriculum affirms that there is a reality out there, a reality wholly independent from the human mind and the constructions of discourse, and that beings have a reality apart from those expressed in their relations. Stipulating an outside allows also for us to theoretically leave space for becoming, and to recognize non-human material agency. It can also, and likewise, be thought provide a metaphysical justification for the exercise of the principle of precaution as it is elaborated in the philosophy of Hans Jonas. [15]

2.2 The Material Curriculum

The material curriculum corresponds, in Harman's thought, to what he calls the real qualities of an object, and we can understand this to be the curriculum insofar as it is expressed in object/object interactions. Contrary to the metaphysical curriculum, the material curriculum is expressed (if it is not necessarily expressed to human observers). We might thus speak of it as available to science, but not necessarily present to science, and of course never present to science in precisely the same form that any discourse about this science might take. In fact, any account of the material mode will only be partial, only offered to knowing subjects through the mediation of a system of discourse and practices. Actor Network Theory-influenced science studies scholars have often—and with good reason—discussed material modes of existence as multiple. As Anne Marie Mol has illustrated, after having carefully studied production of knowledge and discourse around the material aspects of the patient's bodies within a hospital, via the study of blood chemistry, or cell cultures, or radiographic images, we end up having multiple bodies, since each technically assisted process offers insight into an aspect of the material that can only with difficulty be translated into terms equivalent with another. [16] This is because each mode of making discourse implies different material connections relative to the coming to discourse among objects. Let us note also that human bodies are also deeply entangled in the material curriculum. This is true in the sense that human bodies are involved in making sense of matter, but also in the sense that human bodies are affected by matter in ways that oftentimes elude or challenge sense making. It has been shown, for example, that chemicals emitted into the air by automobiles affect the development of children's cognitive functioning, leading to higher incidences of learning disorders and including ADHD. [17] As is evident, having affected children in the classroom, or, considering a larger time frame—affected teachers behind the lecterns—will affect the contents and the rhythm of the courses taught within an institution. But making sense of these changes, at least from a first-person point of view, must remain obscure. None of the people that are affected know what life would be like outside of their being affected. All would be affected differently by this differently were they aware of these material interactions. How they understand their being affected happens through a process of translation, via a making sense of one regime of signs (reflective personal experience) in terms of another regime of signs (scientific knowledge about brain chemistry). In a practical sense, describing a curriculum in terms of the material curriculum involves looking for spaces that can be measured, but which stands outside any accounting of human social actors regarding either their individual or collective intentions and understandings.

2.3 The Social Curriculum

The social curriculum is the curriculum as it exists in mental, social, or inter-subjective space. It is not necessarily the curriculum as it is consciously articulated by actors, but rather the unconscious within the discourses produced by conscious actors, or at least between actors interacting via sign systems. Within the social curriculum we can situate what some have called the “invisible” or “hidden” curriculum, we can also situate many of the dimensions of the curriculum brought out by Structuralist curriculum scholars such as Bernstein. [18] The social curriculum does not exclude the material, but includes the socio-material tangle that is the economy, as well as what Bruno Latour has called the Parliament of Things, namely the articulate results of human-non-human interactions such as scientific disciplines, as well as various phenomena associated with material signification. [19, 20] It can also include the symbolic, but unintentional meaning of various object dispositions, such as the meaning of chairs in a room or departments within campus buildings. The key feature of this curricular mode from the point of view of scholars striving to establish curricular topographies is its distance from the intentions of the actors involved in articulating it, it is thus available to what systems theorist and sociologist Niklas Luhmann calls second order observers. [21] For many, this is the most interesting dimension in curricular studies. Within this framework can discuss elements such as the effects of an environmental studies professor’s gas guzzling car on the lessons that he or she teaches, or study the ways in which Judeo-Christian ideas about the natural world structure the environmental values conveyed by an institution. It should be noted that just as in the case of the modes of material existence, each of these networks of connections within the social curricular mode of existence appears ontologically discrete, since they can only come to subjectivity through a specific process of enactment and translation. This means that we can look at the same social curriculum from the point of view of economic relations or gender relations, and both will yield insights into the sustainability of a curriculum, but neither will articulate in the same way the elements within the social curriculum. A topographic approach allows these various perspectives to co-exist and to co-inform our understanding of curricular sustainability.

2.4 The Subjective Curriculum

It may seem almost unnecessary to discuss the subjective curriculum, because it is this curriculum that has historically almost always been the subject of discussions on curriculum. The subjective curriculum is the *content* of a curriculum as it is articulated by a conscious subject aiming to construct a plan for teaching students. The subjective curriculum includes the visions of curriculum articulated by educators and administrators, not in their textuality or material reality, but as they themselves believe that they understand them. It also includes the signification of all the curricular supports and events—books, exams, even the symbolic importance of campus monuments—but seen only from the viewpoint of the educator’s intentions. More broadly speaking, and this is crucial for understanding the interest of the multi-modal model presented here, the subjective curriculum is any version of the curriculum that any subject—a teacher, a student, or a curriculum scholar—articulates. In the final instance, this therefore also includes any account of an institution's curriculum articulated by a scholar, including one using the methods here. That said, there is obviously a radical practical difference between considering the subjective curriculum as the total extent of the curriculum—i.e. speaking of a curricular vision or an intent to articulate a specific curricular vision—and recognizing that it is just the tip of the curricular iceberg.

3 Towards a Conclusion

The elements presented here prompt us to more fully describe the elements in existing curricula, but they do not explain how to form a sustainable curriculum. What then is the point of this exercise?

3.1 Studying Curricula

The general topographical oriented presented is really aimed at those seeking to carefully and scientifically describe curricula. This is important, since to a certain degree we cannot understand what our curricula are without carefully applying ourselves to this task. Considering each mode of existence in turn it forces us to explore the potential importance of that which may not appear to have meaning to the traditional curriculum theorist. This brings about a second benefit, namely the fact that a multimodal approach offers a richer sense of the meaning and lessons enacted by a particular curriculum. The key here is to note that unlike traditional thinking on curriculum, where one supposes that each institution has a single curriculum, this approach allows us to envision multiple and sometimes apparently contradictory curricula existing within the same institution. While paying attention to these additional levels of complexity may seem frustrating, it is crucial to note that it is only by acknowledging complexity can we hope to improve curricular sustainability.

3.2 Pedagogy for Sustainable Innovations

Assuming that we have taken the time to appreciate curriculum in all of its complexity, what do we do next? The first thing to do is recognize that we have already undergone an essential re-orientation—we are now operating not from ideas down, but from material signs on up. Deeply engaging with the material curriculum in all of its levels will yield ecological awareness, but it may also yield innovations. Solutions to environmental problems do not come out of thin air, but rather out of an everyday entanglement with environmental problems. The more profoundly our curricula set in motion processes of co-creation in which actors human and non-human engage with one another, the greater the likelihood that our curriculum actually tends towards being sustainable and producing sustainability innovators.

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Sustainable design of products and services course: designing through materials' sustainability lenses

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ABSTRACT

"Sustainability" in design is not a simple constrain that can be quantified and optimized in an engineering design. Issues of sustainability are inherently complex and wicked; their assessment requires acceptance of this complexity and working with it. Each aspect (e.g. environment, society, regulations, design, materials…) can be explored in a systematic way but the integration of the aspects to give a final assessment needs judgment and reflection, as there is no one single sustainable solution to a problem. Integrating the different articulations of Sustainable Development needs a holistic approach and stakeholder participation. How can we teach this to engineering design students in an efficient and effective way?

This paper presents the scheme of the Sustainable design of products and services master course and the ideas behind new teaching resources for Sustainable Development, designed for engineering design and materials science courses. These resources identify the complexity and transdisciplinary issues of sustainability and new methodologies and tools to help student understand and analyse them. This paper describes the course and the reasoning behind the resources, which include a method and a database of background information. The outcome is, inevitably, subjective, influenced by social, cultural and political background and therefore one requiring debate, but the method creates a common background of accepted facts on which an informed debate can be based. Since 2013, the course has been run at the Master in Sustainability Science and Technology at the Universitat Politècnica de Catalunya, providing experiences in a real educational setting. This paper summarises some of their outcomes in terms of learning, course design and participatory approaches in education.

Conference Key Areas: Sustainability and Engineering Education, Engineering Skills

Keywords: Engineering Design, Sustainable Design Education, Design Education

INTRODUCTION

Since 1991, the Universitat Politecnica de Catalunya (UPC) has focused on introducing Sustainability education in all its engineering and architectural programs through two environmental plans and currently through the UPC Sustainable 2015 [1] plan.

Since 2013 the course Sustainable design of products and services has been run in the Master in Sustainability Science and Technology at the Universitat Politècnica de

Catalunya. Next sections will present the experience which may help when introducing new teaching for Sustainable Development, designed for engineering design and materials science courses.

1 SUSTAINABLE DESIGN OF PRODUCTS AND SERVICES COURSE

The Sustainable Design of Products and services (SDPS) is a 5 ECTS course offered at the third semester (out of four) of the master degree in Sustainability Science and Technology at UPC.

2 COURSE STRUCTURE

The course uses constructive and community oriented learning for sustainable design. It is organized around three axes (Figure 1): Strategies, Tools and Projects. First, students are introduced to sustainable design strategies principles (Eco-design, Cradle 2 Cradle, Biomimicry, Product Service Systems, Design for Sustainable Behavior, Human Centered Design, Social design, etc.). Second, students use CES-Edupack software using the Advanced SUSTAINABILITY database tool and finally, students apply the tool to a contextualized project taking into consideration the sustainable strategies available. Students spent approx. 50-60% of the course time on the group project. They presented the progress after each project phase. Next paragraph focus in this methodological approach.

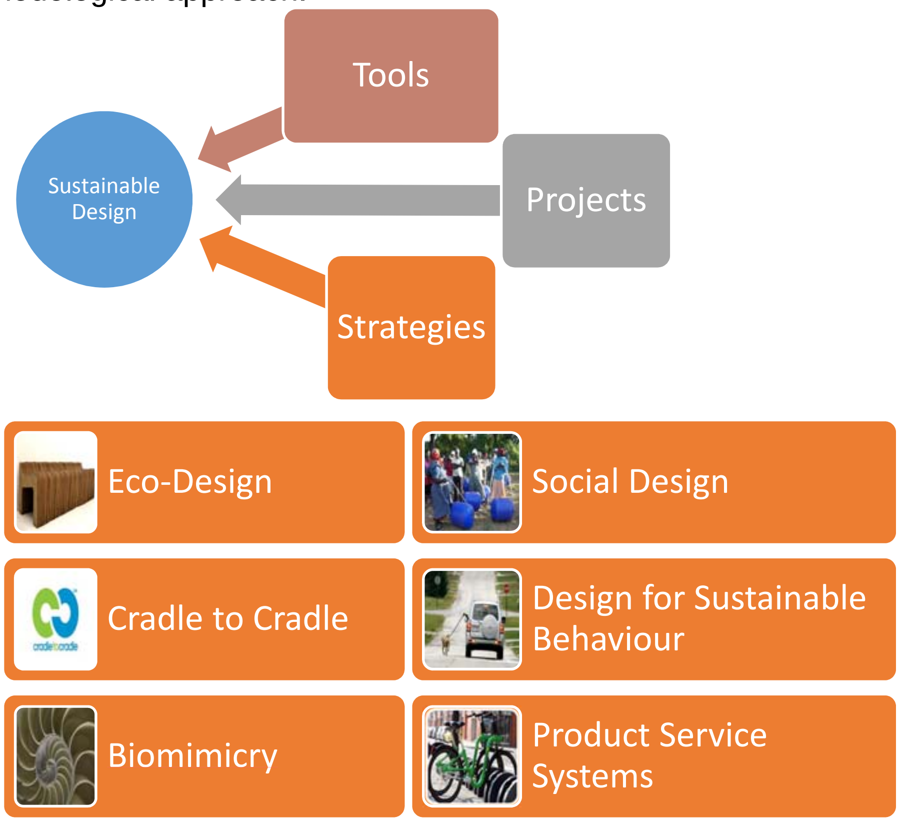

Figure 1. Main features of the course with sustainability design strategies.

3 METHODOLOGY

A “Sustainable Development” is one that contributes in an equitable way to human welfare and does so in a way that minimizes the drain on natural resources. Many academic, civil, commercial and legislative projects claim to do this – promoting biopolymers, carbon taxes, design for recycling are examples. Following Mulder et al.

[2] we shall refer to them as “articulations” of sustainable development. But how are they to be assessed? There is no simple, “right” answer to questions of sustainable development – instead, there is a thoughtful, well-researched response that recognizes the concerns of stakeholders, the conflicting priorities and the economic, legal and social constraints of a design as well as its environmental legacy. How can students be introduced to this complexity and equipped to assess the viability of designs that claim to be sustainable? The aim of the method described here is not to define a single metric of index of sustainability; rather it is to improve the quality of discussion by providing a reasoning-path and guided access to relevant data [3].

“Wealth” is a generic term for all that we value. Global or national “wealth” can be seen as the sum of three components: the net manufactured capital, the net human capital and the net natural capital [4]. Sustainable development is as a development that takes in account the evolution of the three capitals, and aims at the increase of all of them. Examination of many articulations of sustainable development suggests the following picture. Each articulation has a motivating target that we will refer to as its “Prime Objective”. Each involves a set of Stakeholders. In assessing the sustainability of project the first step is to identify these: if the Prime Objective is not achievable or major Stakeholders are left dissatisfied, the project is unlikely to be sustainable. Further examination suggests that the central issues might be grouped under the six broad headings:

- Materials and Manufacture: supply-chain risk, life-cycle demands and recycle potential.
- Design: product function, performance and safety.
- Environment: energy efficiency, resource conservation, preserving clean air, water and land.
- Regulation: awareness of, and compliance with, National and International Agreements, Legislation, Directives, Restrictions and Agreements.
- Society: individual health, education, shelter, employment, equity and happiness.
- Economics: the cost of the project, and the benefits that it might provide.

This suggests the following way of analysing articulations of sustainable development. It has 5 steps (Figure 2). The first is a statement of Prime Objective, its scale and time envisage to achieve it (Step 1). Stakeholders are identified and their concerns listed (Step 2). These concerns are mapped onto a Fact-Finding search (Step 3) assembling data relevant to each of the headings listed above. This provides the background for a debate or discussion of the impact of these facts on Human, Natural and Manufactured capital (Step 4). The analysis ends with reflection on possible priority changes (Step 5). The first three steps are objective and deterministic; the last two are subjective, and therefore open to debate and creative thinking.

The methodology is applied during the course and it is articulated in order to facilitate discussion and debate about the interim and final results at class with stakeholders, faculty and other students. See figure 3 and table 1.

Table 1 shows de distribution of the five step methodology during the 12 weeks of the course. The table schedules the introduction of sustainable design strategies, the work related to the project that is realized in the classroom, the task to fulfil each week and finally the outcomes expected after the task are performed.

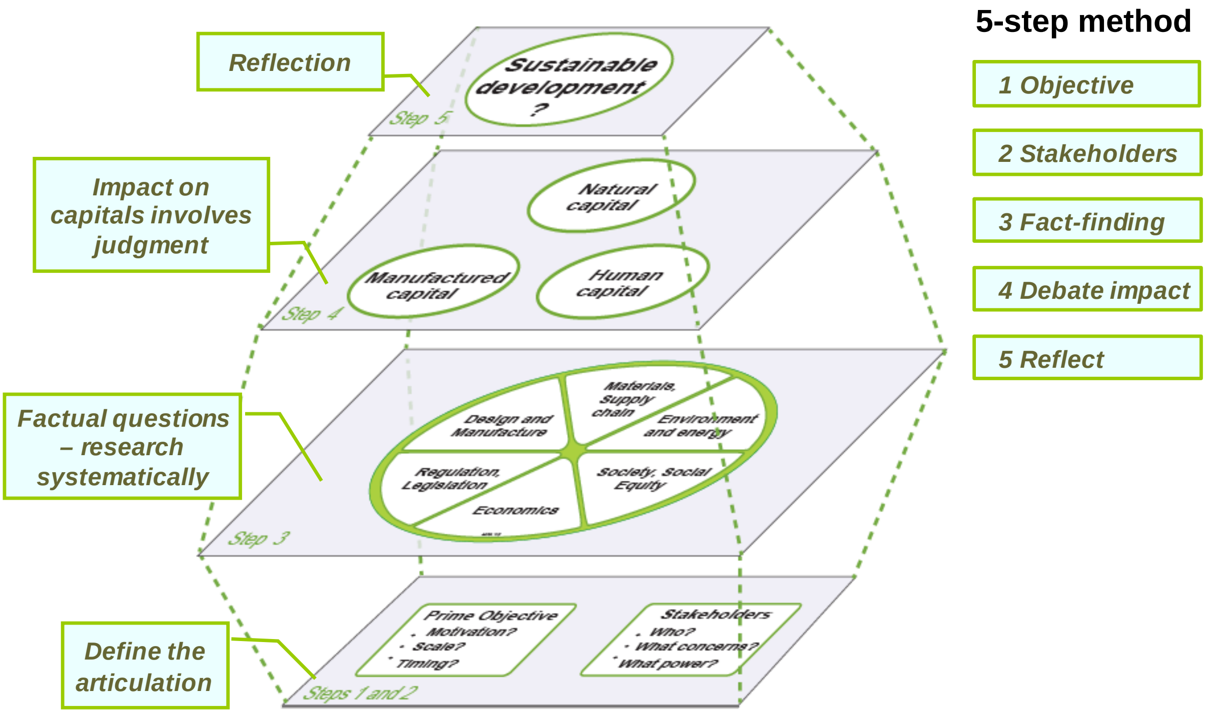

Figure 2. Methodology applied at Sustainable Design of Products and services course [3].

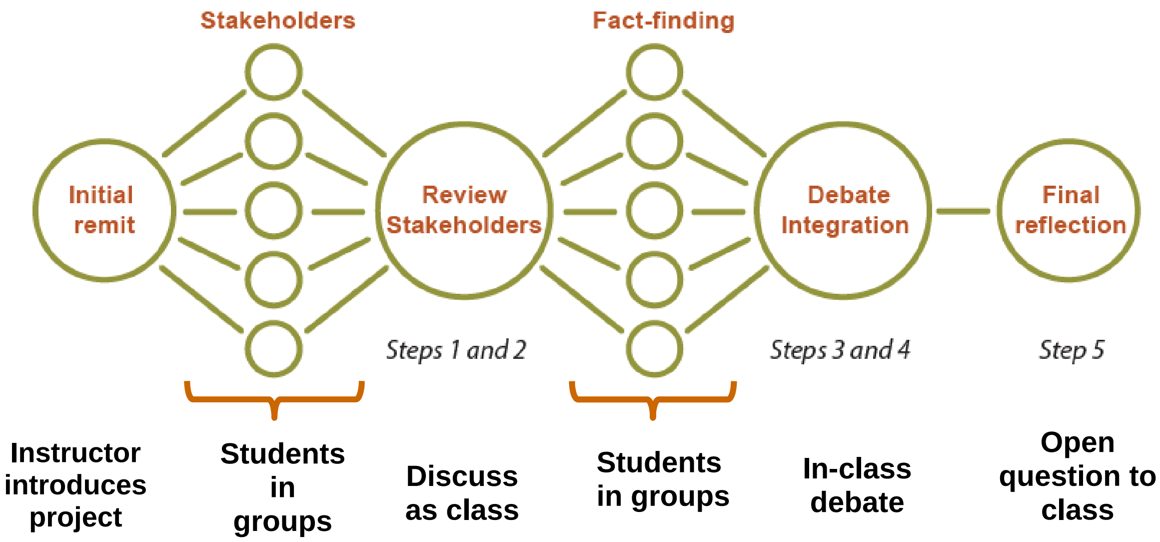

Figure 3. Articulation of the methodology facilitating discussion and debate [3].

To help with the fact finding step the sustainability database have been jointly designed with Granta Design [6]. The CES EduPack Sustainability Database is designed to support the teaching of sustainability at all levels of study. The database consists of seven interlinked data-tables. They provide the data needed for engineering design and for the eco-audit of products. The Sustainability Database allows materials to be traced back to their countries of origin and enables exploration of possible supply constraints. The data includes relevant legislation and regulations that bear on the use and disposal of materials. The information on price allows cost comparison of alternative design choices. Finally, the database allows the investigation of the economic, environmental and social profiles of the countries from which materials are sourced or in which manufacturing takes place. (Figure 4).

Table 1. Distribution in time of the methodology

WEEK	Strategies	Project	Tasks	Outcome
W1		Sustainable Design Project Methodology	Grouping + Project selection	
W2	Eco-design	Presentation of Campus Lab CE projects		Project Selection
W3		Grand objective	Discuss the grand Objective	Definition of the Grand Objective
W4	Cradle to cradle + Biomimicry	Stakeholders	Stakeholders Definition and strategy for their assessment	Definition stakeholders and stakeholders analysis strategy
W5		CES SUST. DB	Discuss Stakeholders	Stakeholder analysis
W6	Product-Service systems		Fact finding with CES-SUST DB or other sources	
W7	Social design		Fact finding with CES-SUST DB or other sources	
W8		Fact finding	Discuss fact finding	Fact Finding analysis
W9	Design for sustainable behaviour		Integration: Grand Objective + Stakeholders analysis + Fact finding	
W10		Integration > Sustainability analysis	Discuss integration	Integration > Sustainability analysis
W11		Alternatives and Redesign proposals	Discuss alternatives / Prepare defence of the project	Sustainable analysis and alternatives.
W12		Project Presentations	Project defence	Sustainable design report and presentation.

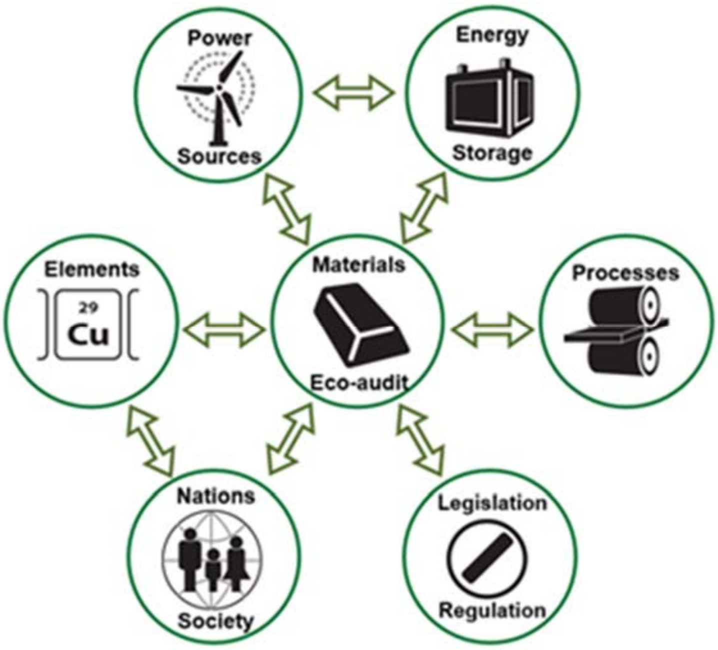

Figure 4. Interlinked data-tables of CES EduPack Sustainability Database tool [3].

The 5-step method and the SUSTAINABILITY database described here are contributions towards the difficult task of introducing students to the multi-dimensional aspects of Sustainable Development. It can be used for individual or for group projects. As a group activity, the role of a stakeholder and the responsibility for one fact-finding task can be assigned to each member of the group, the individuals research their assignation and report back to the group as a whole. This is then followed by a group “debate” seeking consensus on the impact of each of the fact-finding searches on the three capitals. The analysis as whole has a purpose and conclusions: while the underlying problem may be complex, it is important to report the result in a simple manner, making them accessible to non-experts.

At the end of the course, students were asked to give their opinion about the teaching method, the tools and their learning progress. The students appreciated the methodology as a holistic and practical approach to exploring sustainability. They commented that it gives guidance and focus while tackling the complexity of the task. They greatly appreciated the continuous feed-back from the teachers after each phase.

4 CONCLUSIONS

This paper has introduced a specific course in Sustainable Design of Products and Services (5 ECTS) at Master level at UPC Barcelona Tech. The author highlights that using community oriented and constructive learning approaches [3], where students work most of the time in real projects proposed by companies is crucial for sustainability education in general and specially in Sustainable Design education. Moreover, the five steps methodology here introduced, facilitates the sustainable holistic and systematic analysis of engineering projects where materials are relevant.

5 ACKNOWLEDGMENTS

We would like to thank the students, faculty and stakeholders that have participated in our experience.

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SPECIFIC LEARNING ENVIRONMENTS FOR FOSTERING STUDENTS' SUSTAINABILITY MINDSET

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ABSTRACT

One of the core and fundamental principles of sustainable development is responsible consuming of natural resources in order to maintain and better to increase them for future generations.The implementation of this principle is not possible without formation of a special world outlook of each member of society - the mindset of responsibility for the expenditure of resources and conditions regulating the use of resources.

Transformation of modern society from industrial into knowledge-based society requires a substantial increase of the role of the universities because they are just those organizations where the knowledge is gathered and disseminated. Today it is more common for universities to focus their efforts on developing competences rather than mindsets of future engineers. Apart of other considerations, another important issue is proposed for discussion in this article: a need to form/change students' mindsets, a need to develop specific learning environments at HEIs.

Conference Key Areas: Sustainability and Engineering Education

Keywords: Sustainability, specific learning environment, sustainability mindset, engineering education.

INTRODUCTION

Currently, global environmental challenges in conjunction with the issues of social responsibility are recognized as extremely important for all mankind. The search for ways to solve them has led to the development of the concept of sustainable

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development in the 1980s and then to the first steps towards its implementation. The meaning of the concept of sustainable development is to identify the prerequisites and conditions for harmonizing socio-economic and environmental development and the lifestyle of every person on our planet. According to this concept, people must satisfy their needs in such a way that fundamental measures of the biosphere processes established over the millions of years are not violated and life of the next generations is not jeopardized [1]. In general, it is assumed that sustainable development should be characterized by the economic efficiency, biosphere compatibility, social justice, and comprehensive security through the harmonious development of the personality, society and nation as well as through the well-considered interaction with the nature [2].

On September 25, 2015, the States Members of the United Nations adopted the Agenda for Sustainable Development until 2030. It contains a number of goals aimed at eradicating poverty, conserving resources of the planet, and ensuring well-being for all. Each of the 17 Goals contains a number of indicators to be achieved by 2030. To achieve the Goals in the field of sustainable development, shared efforts of the governments, private sector, and civil society are needed.

Education is recognized as the most important mechanism for ensuring sustainable social and economic and spiritual (intellectual) development. This statement is also emphasized in the materials of the World Summit on Sustainable Development (Johannesburg, 2002). The key role in achieving the goals of sustainable development has to be played by the education system, which is called "a decisive factor for changes" in many UN documents. The wide recognition of the education and closely related upbringing and enlightenment as a decisive factor has made it necessary not only to consider the main issues related to the ecology and social responsibility in the process of training of engineers, but also foster the sustainability mindset of the students.

1 SUSTAINABILITY MINDSET

Currently, the world community is paying even more attention to sustainable development of our society: moderate consumption, greening and environmentalization of professional activities, responsible resource management, and other aspects that affect nature and society as a whole, as well as the ability to conserve resources for future generations. Considering of sustainable development principles is an integral part of training specialists in the field of engineering and technology. Graduates should build their professional activities in accordance with ethical, social, environmental standards, be responsible for the technical decisions they make, be able to forecast and reduce/prevent damage from the technologies they develop. The modern educational process requires adjustments in order to introduce the principles of sustainable development into the training process of engineers.

One of the core and fundamental principles of sustainable development is responsible consuming of natural resources in order to maintain and better to increase them for future generations. The implementation of this principle is not possible without formation of a special world outlook of each member of society - the mindset of responsibility for the expenditure of resources and conditions regulating the use of resources. Essentially, it involves social responsibility of each member of our society and communities at large (companies, enterprises, public organizations and others). This personal and corporate responsibility includes social consequences of all their activities and all kinds of their decisions concerning not only consuming exhaustible resources and resource saving, but also measures taken to create conditions necessary for this [3,4]. It is not a coincidence that that in the modern world exist and develop such trends as Responsible Research and Innovations, Responsible Industry, Technology Assessment, etc [5].

We can assume that an integrating condition for the realization of any of these trends is not only the formation of the competences of each person (specialist), participating in the decision-making process. It is important to manage development of sustainability mindset and social responsibility competence. These conditions cannot be met without active and decisive contribution of the education system at all stages. New models for sustainable education must be aimed at changing the mindsets of future generations beginning at an early age then fostered through formal education at undergraduate, graduate and professional levels.

To the credit of modern Russian engineering education, it is worth mentioning that training of socially responsible graduates became a notable trend. This ongoing trend is enhanced and supported by the requirements of Federal State Educational Standards, real academic activities within development and implementation of educational programs, curriculum requirements of several courses and disciplines, and, rarely, in scientific research. The process of developing competences among future graduates is realized along a study program and requires from students acquisition of fundamental knowledge and skills to be applied in practice. Usually it implies to provide ordinary and well-known conditions: qualified scientific and pedagogical staff, modern facilities, good connections with employers (cooperation with industry). To form any outlook in general, in addition to the above conditions, it is necessary to create a specific environment that forms the appropriate mindset of students.

2 SPECIFIC ENVIRONMENT AT UNIVERSITIES

Engineering influences directly the quality of life of the mankind; therefore, the actions of engineers require honesty, impartiality, justice, and efficiency. Their actions have to be aims at health protection, safety, and wellbeing of people. Fostering a socially-oriented mindset and behavior of future engineers requires from the educational organizations and educational process to implement adjustments in order to introduce the principles of sustainable development into the training process of engineers.

Analysis of the current state of implementation of the concept of sustainable development in the system of higher professional education shows that the most common approach is the introduction of a number of new disciplines in the field of sustainable development in the curriculum, particularly ecology, resourceefficiency management, etc. [6,7] However, those measures are not enough to develop a culture of sustainable development among the academic and management staff and students. This paper introduces a new holistic approach that aims to create a specific environment within a university for fostering sustainable development and social responsibility mindset that allows future engineers to take managerial, project, economic, social, and political decisions that are adequate to the crisis situations and trends faced in all spheres of life of the nation and the world community at large.

Despite the application of competence-based approach to the process of educational programs' development, the contents of the programs and teaching and learning methods used, as a rule, do not allow fostering future specialists' skills, attitudes and knowledge on a level needed for winning in a competitive battle. At this, it is necessary to mention that representatives of industry confirm a good level of basic knowledge and theoretical background on certain disciplines. However, they point out as an evident drawback a low level of key competences' formation (professional skills and soft skills), as well as a low level of practical skills needed for solving real engineering tasks and problems.

Introduction of the competence-based approach to the designing of educational programs is a necessary, but not sufficient condition required for guarantee the expected level of future specialists' competences of social responsibility within the educational process. The pivotal factors ensuring the formation of required competences within the educational process are the teaching and learning methods and conditions for their implementation (including the potential and qualification of faculty) and the specific university environments that support fostering of competences.

The analysis of world's best practices in identifying and developing specific learning environments allowed to select most challenging and vital types of environments listed below:

1. Environment for sustainable development, including
    a. Ecological (greening) environment
    b. Social responsibility environment
    c. Lean production environment
2. Creative environment
3. Entrepreneurial environment
4. Project based learning environment.

As mentioned above today it is more common for universities to focus their efforts on developing competences rather than mindsets of future engineers. Apart of other considerations a necessary condition to form/change students' mindsets is that higher education institutions need to develop specific learning environments, as shown in the Fig. 1 [8].

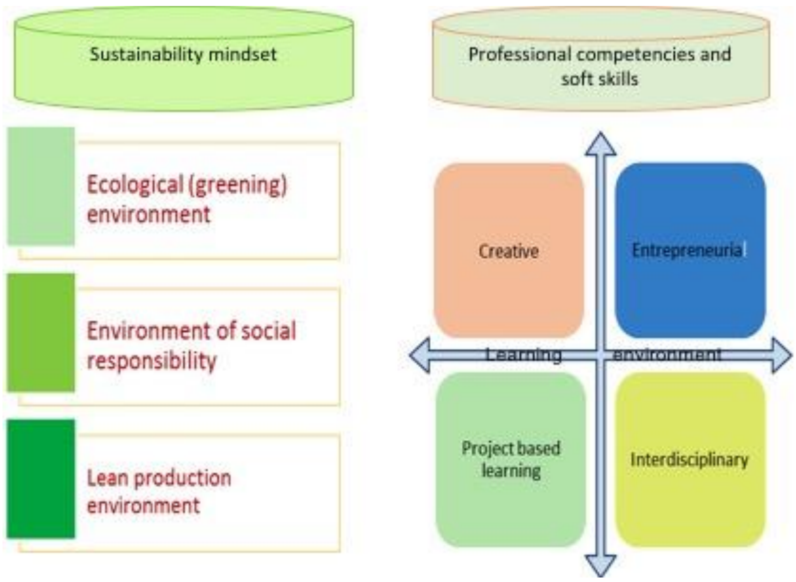

Fig. 1. Specific learning environment

Specific environments such as "ecological environment", "environment forming responsibility", "creative (innovative) environment", etc., create the basis for the development of relevant competencies at university, both for students and teachers, and for managerial staff. Orientation of the university on purposeful formation of specific environments will allow in a more successful way and in a shorter period of time to implement qualified training of graduates in the field of engineering and technology that meet the requirements of the labor market and the modern society as a whole.

The paper presents an ongoing reserach at Tomsk Polytechnic University with the support of Association for Engineering Education of Russia. The key direction of the research is changing the paradigm of thinking and professional activity of the future engineer, fostering new students' mindset, aimed at understanding the responsibility for resource endowment of the next generations, changing consumption patterns, forming a new lifestyle. The priority is given to the development of tools for the implementation of (scientific, theoretical, informative, pedagogical, technological, organizational) aspects of sustainable development concept in the system of training students in the field of engineering and technology.

The main objective of the research is the development and pilot testing of methods, tools and actions for creating specific university environments that contribute to fostering sustainable development and social responsibility mindset.

We assume that creation of such university environment will allow to transform the mindset of all stakeholders involved in the educational process (students, academic staff and administration of the university). It will ensure more sustainable development of students' competences, facilitate their employability and will become one of the most important steps how the educational process could respond the big challenges.

The toolkit proposed for the development is universal in nature and can be applied in different types of universities (technical, classical, medical, etc.) in order to promote creation of specific environments of any type. The complex of actions for the development of specific environments can be adapted to the needs of the country, region and the university itself. The actions should be continuously pursued, thus contributing not only to the initial creation of the environment, but also to its maintenance and development.

3 SUMMARY AND ACKNOWLEDGMENTS

Revealing the new paradigm of education in the interests of sustainable development, it is necessary to point out the main aspect of the orientation of any moral teaching. It involves formation of a new mindset. In the available nowadays research studies this issue is not highlighted enough when talking about training of future engineers. Nevertheless, in our opinion, mindset development is an essential and fundamental element in the structure of professional engineering activity. Despite the recognition of the importance of reforming education systems for ensuring sustainable development, the efforts are not successful enough. This is partly due to the fact that pedagogical traditions are based on the transfer of existing knowledge, the reproduction of real connections and attitudes reflected in the public consciousness. The future is always more or less uncertain. This fact determines, in essence, the establishment of fundamentally new pedagogical and management tasks related to the formation of a sustainable development mindset.

The necessary fundamental basis needed by every graduate for systemic and holistic solving of real-life problems is fostered through the prism of professional competency. A universal, creative, developing personality of a future professional can be formed only if there is a continuous pedagogical process and each stage of it is based on integrated principles and methods and has a core aim – professional competency of an engineer, who will be able to ensure sustainable development.

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ISMEP-Supmeca: an example of recognition of training on sustainable development and social responsibility through the awarding of the new French “Label DD&RS”

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ABSTRACT

In December 2016, ISMEP-Supmeca, a French public engineering school, obtained a SD&SR (Sustainable Development and Social Responsibility) label for a period of 4 years.

Launched in France in 2015, this "SD&SR label” (“label DD&RS” in French) is the result of the work of many stakeholders: higher education institutions, ministries, associations... Carried out by CIRSES (French higher education SD&SR collective), it is organized around five themes and allows to:

- Promote the best SD&SR initiatives of French higher education and research institutions,
- Upgrade skills within a group of committed institutions.

ISMEP-Supmeca chose to respond to this labeling approach. In this paper, we will first focus on the SD&SR label. Then, we will present the approach of ISMEP-

Supmeca and detail the strategic variables of the education axis of the label through the sustainable development education policy developed at ISMEP-Supméca:

- Train and prepare engineering students for tomorrow's issues, problems and jobs, emphasizing the initiatives and opportunities presented by SD&SR,
- Continue to gradually integrate SD&SR as tied approach, knowledge and skills in all modules, projects and courses offered in the curriculum.

We will conclude with a focus on one specific action undertaken at ISMEP-Supmeca, the “SD&SR days”.

Conference Key Areas: Sustainability and Engineering Education, Ethics in Engineering Education, Engineering Skills

Keywords: Sustainable development and social responsibility, Engineering Education, Labeling

INTRODUCTION

ISMEP-Supmeca is a human-sized French public engineering school, located in a rapid-changing part in the north of the Great Paris area and engaged in sustainable development and social responsibility policies for many years.

In 2016, the institution decided to engage into the recognition of this engagement and the result was obtained quickly: ISMEP-Supmeca was awarded a SD&SR (Sustainable Development and Social Responsibility) label for a period of 4 years.

In the first part, we will present this "SD&SR label” (“label DD&RS” in French), launched in 2015 and the result of the work of many stakeholders: higher education institutions, ministries, associations...

Then, in the second part, we will present ISMEP-Supmeca and especially focus on the approach of the institution towards SD&SR in general and the education axis in particular, with references to the specific SD&SR education policy and to the so-called “SD&SR days”.

1 THE FRENCH SD&SR LABELING SYSTEM

1.1 Some words and facts about the French SD&SR label and its operator

France has a higher education system involving two main kinds of institutions providing education: universities and Grandes Ecoles (engineering schools and business schools). It has also bodies playing a great role like the Conference of Grandes Ecoles and the Conference of University Presidents. Finally, it has a strong accreditation history, with, for example, the CTI (Commission des Titres d’Ingénieur), engineering accreditation institution, which introduced high-level standards and is now paying a lot of attention to topics like SD&SR.

Created and launched in France in 2015, the "SD&SR label” (label DD&RS in French) labeling system is the result of the collective work of a dozen universities and so-called “Grandes Ecoles”, the Conference of Grandes Ecoles, the Conference of University Presidents, the Ministry in charge of Sustainable Development, the Ministry in charge of Higher Education and the French Network of Students for Sustainable Development.

It meets the implicit demand of a growing number of institutions developing initiatives and it is fully in line with the article #55 of the first so-called “Grenelle environnement” (open multi-party debate in France that brings together representatives of national and local government and organizations).

The label, based on a self-assessment tool “SD&SR framework”, is carried out by CIRSES (French acronym for Collective for the Integration of Corporate Social Responsibility and Sustainable Development in Higher Education), the latter being an association with three main objectives:

- To support the persons in charge of the SD&SR mission in the higher education institutions,
- To contribute to the influence of the SD&SR initiatives of the higher education institutions,
- To be the reference in terms of SD&SR practices in the French higher education and research area.

Concretely, the SD&SR label is accompanying the objectives presented above. Its main aims are to:

- Promote nationally and internationally the best SD&SR initiatives of the French higher education and research institutions,
- Upgrade skills in the framework of a group of committed institutions.

Labelling sessions took place, under a process and with first results presented hereafter.

1.2 How it works and first results

Two labelling sessions have already taken place since the label began to work: the 2015-2016 winter session (from October 2015 to May 2016) and the 2016 summer session (from March 2016 to December 2016). Each session starts with the application period, followed by the assessment by auditors, then by a direct audit and is closed by a meeting of the labelling committee, officially awarding or not the label.

The whole evaluation process is based on a SD&SR assessment grid organised around 5 main axes:

- 1. Strategy and governance,
- 2. Education,
- 3. Research,
- 4. Environmental management,
- 5. Social policy and territorial rooting.

These axes and more generally the grid are referring to the axes defined in the so-called Green plan constructed by the stakeholders of the higher education and research area and already tested with success by more than 100 institutions since 2012.

Each institution aiming to apply has to provide a self-assessment of its SD&SR policy by filling in the assessment grid, each axis containing sub-topics and then each sub-topic containing sub-items. This has to be completed by supporting documents.

The first assessment, done on these documents, is completed by an assessment meeting with representatives of the applicant institution. Both parts of the assessment process result in awarding the label or not.

A total of fourteen institutions was awarded during the two first labelling sessions: ten engineering schools, two business schools and two universities. More institutions have already applied, will apply and will be awarded the label in the coming months.

ISMEP-Supmeca is one of these first fourteen institutions, which responded to the second application wave at a moment corresponding to its wish to see its actions recognised. Hereafter we will focus on the institution SD&SR actions and policy.

2 ISMEP-SUPMECA: AN INSTITUTION WITH A RECOGNIZED SD&SR POLICY

2.1 From the first actions to the SD&SR label award

ISMEP-Supmeca is French public engineering school, giving to its students a three-year engineering education (1/3 of internships; 1/3 of projects and experimentation; 1/3 of courses and supervised practical work), making them specialists in modelling, conception and production systems, who will mainly join large industrial companies. The school hosts globally around 600 students on these three levels (for example, in 2016-2017: 490 students in a classic engineer curricula, 140 students in an apprenticeship engineer curricula and 16 students in a specialized or advanced master on lean management), making in a human-sized school. It also has a global staff of around 200 people (permanent and non-permanent).

ISMEP-Supmeca is located in Saint-Ouen, in Seine-Saint-Denis department, i.e. in a rapid-changing part of the north of the Great Paris area. Being one of the only two public engineering schools of this department, ISMEP-Supmeca also faces challenges due to its location in a dense residential and post-industrial urban area.

Taking all these aspects into account, ISMEP-Supmeca engaged step-by-step into a real SD&SR approach in 2010, the SD&SR label obtained being the concretization of both the engagement and the strategy.

The first actions in favor of the development of a SD&SR were taken in 2010 and were from the beginning placed in the larger framework of a real strategy. Indeed, a SD&SR officer started working in June 2010 and this was followed by the first steering committee until the design and writing of the first SD&SR charger of the institution in November 2010.

From that date and under the supervision of different persons in charge of the management of the SD&SR policy (in addition to their initial tasks at ISMEP-Supmeca), this policy grew, with many particular actions. We can quote among others the following ones:

- Development of an apiary,
- Writing of a monthly SD&SR info-flash,
- Provision of electrical bikes to ISMEP-Supmeca staff members,
- Student association doing remedial courses for children from Saint-Ouen and neighbouring municipalities,
- Formalisation and co-building of the professional training for the staff,
- Diagnostic of psycho-social risks.

All these actions are integrated into five axes defined previously in this article and also integrated into the SD&SR strategy of the institution. Revised in 2016, this strategy defines two main SD&SR wishes for ISMEP-Supmeca:

- Acting with students, who will be the main SD&SR vectors in the context of their future professional life,

- Training all the students so that they can be ready and able to make an energy balance, a carbon assessment and a lifecycle analysis.

The secondary wishes of the school defined in the SD&SR strategy are the following:

- Promote SD&SR through concrete actions,
- Use the family size of the school in order to conduct projects involving staff, students and graduates,
- Be a pioneer in its territory and be more open towards its territory.

This global SD&SR strategy is completed by a specific SD&SR educational strategy, linked to the “Education” axis of the Green plan or SD&SR label assessment grid.

Beyond the actions and the formalisation into the strategy, there is the third very important point: the involvement of the stakeholders. There is a core group of people, both staff and students, who make SD&SR a reality at ISMEP-Supmeca. Several student associations (Soutien Scolaire Supmeca, involved in remedial courses, Ecostudent or New Defi) and a small group of key staff members are very involved in these issues, being pro-active and available.

After six years of actions, it was decided to try to gain a recognition for the work done and to apply for the SD&SR label in order to receive this recognition.

As presented in figure 1 hereafter, the institution was assessed 3 out of 5 in four of five axes (Strategy and governance, Education, Environmental management, Social policy and territorial rooting), and received 2 out of 5 in the Research axis, which is, according to CIRSES, the most difficult to get a good mark.

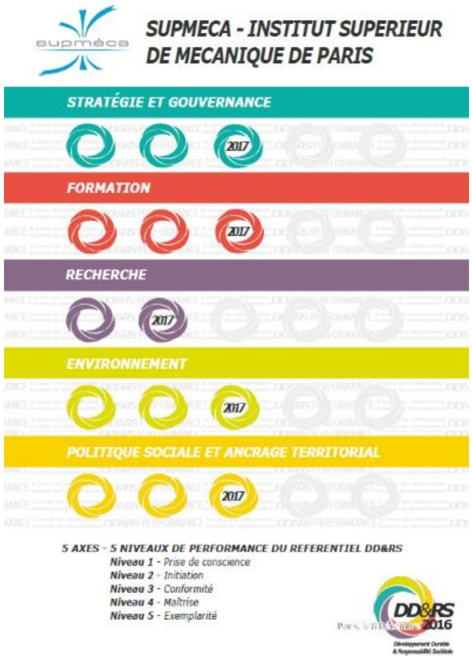

Fig. 1. Performance summary of ISMEP-Supmeca at the SD&SR (“DD&RS” in French) labelling session

The awarding of the label for a period of four years (with mid-period self-assessment to provide) and the 3 out of 5 marks obtained on four axes reflect the work done and could have been even better with a better formalisation of the actions, especially in the Education axis, where more and more is being done.

2.2 Education first: responsible engineers for the twenty-first century

The specific SD&SR educational strategy developed at ISMEP-Supmeca is linked to the "Education" axis of the Green plan or SD&SR label assessment grid and makes the integration of SD&SR possible at different levels and different moments of the curricula, in order to make the future engineers responsible engineers able to work and behave like ducks in the water in the twenty-first century. The main elements resulting from this strategy and present in the curricula are:

- Integration of SD&SR issues into the internship reports (4-week operator internship in the first year, 18-week assistant-engineer internship in the second year, 24-week engineer internship in the third year),
- Integration of SD&SR issues in the framework of problem- and project-based pedagogy: PRIM module (Mechanical Engineering project / 26 half-days per student in the first year), PLACIS project (5-month project for incoming students in the second year), Design office project (25 half-days per student in the second year), Synthesis project (48 half-days per student in the third year), PLACIS project (48 additional half-days to the synthesis project in the third year),
- Core course on Ecological footprint of the systems / 24-hour course for second-year students (20 hours for apprenticeship students) corresponding to 2 ECTS,
- Elective course on Ecodesign of Systems / 32-hour course in the second year corresponding to 2 ECTS,
- SD&SR days, developed in the next part of this paper.

This list can be divided into four parts: internships, projects, classical courses and special days. The projects are very interested here as they already share common values with SD&SR, especially the PRIM module and the PLACIS projects.

PRIM module is a full multidisciplinary problem-based module using topics like wind turbine conception in order to teach a bench of mechanical courses and associated skills.

PLACIS projects are multidisciplinary and systems-oriented projects, most of them being multi-semester, international, industrial and addressing direct SD&SR issues, like electrical and hybrid vehicles, biomimicry, eco-planes of the future… One of the important added-value of these projects is that they teach students how to work collaboratively, at-a-distance, on real long-term projects.

Also, the two classical courses presented above lead to specific SD&SR skills and competencies, but they are not the only ones. Courses linked to systems engineering and systems analysis or linked to materials also lead to SD&SR skills. For this reason, responding to a demand from both the CTI and the SD&SR label auditors, SD&SR issues are being clarified or introduced in a growing number of courses and under new formats, which tend to be successful, as proven by the SD&SR days presented in-depth at a recent congress in France [1] and briefly presented hereafter.

2.3 The SD&SR days: an example of training initiative

There are two SD&SR days: a half SD&SR day for first-year students and a SD&SR day for third-year students. Set up for several years, the DD & RS days were initially in a classic format of conferences by experts in topics like wind energy or cooperative companies. These conferences met limited success and students asked for an evolution towards a less passive format, both agreed and pushed by the staff.

These days have therefore evolved into a participatory format allowing to better capture their students' attention, as well as stimulating imagination and exchanges. This evolution was carried out in a progressive way: a transition to a participative format for the half-day for first-year students in 2015-2016, and then, regarding the success, a transition to the same participative format for both days in 2016-2017.

Concretely, the half-day for first-year students takes place in the following way: the students, divided into two rooms, work in groups by brainstorming method and then perform a pooling and restitution by room before one or more professional(s), who comment on the renditions and then present their experiences. For example, in 2015-2016 and 2016-2017, the objectives of the students were to: 1. define the SD&SR and imagine themes, missions, objectives, skills, interlocutors, problems of a SD&SR manager in a SME or a large group; 2. Imagine interactions and constraints related to the SD&SR of an engineer when he is in office.

The SD&SR day for students of the third year has also been participatory since 2016-2017: the morning is devoted to brainstorming and pooling; the afternoon to presentations and interventions. This day proposed for its first edition a prospective reflection around seven themes (passenger and freight transport, management of nuisances, well-being at work, circular economy ...), each of which treated by two groups, which later pooled and presented their results in the form of mental maps.

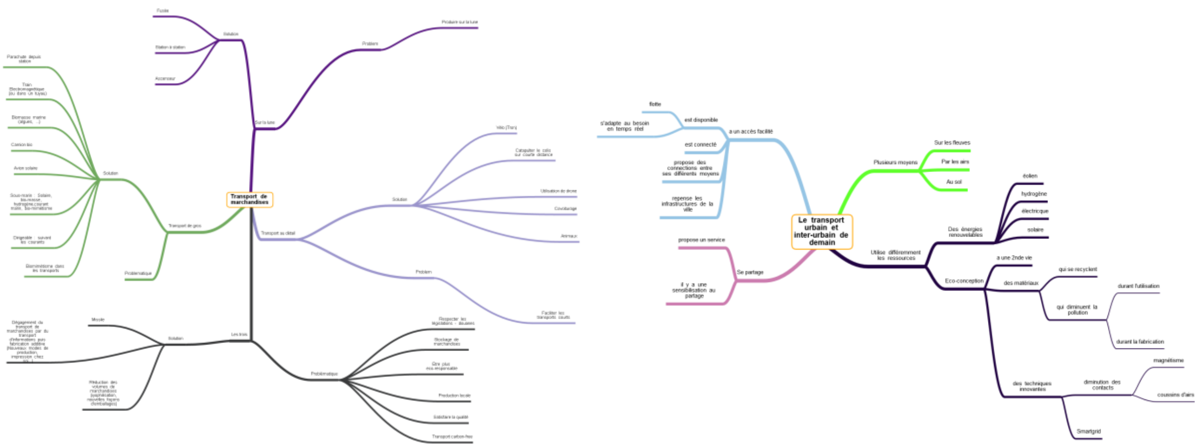

Fig. 2. Examples of mental maps produced by the students (in order to see the diversity of paths followed)

Not only the SD&SR topics were an added value for the students, but also the tools: both mental map and brainstorming were new for most of them. Even if not fully appropriately used by everyone, these tools brought positive results about their use by the persons attending these days, including professional ones.

One very positive point is that professionals highly rated their involvement in these days, but also students highly valuated the participation of the professionals, who had the opportunity to present concrete experiences and engage the debate on some issues. High-rank persons from Kering, Alstom and SNCF Reseau already participated, the two latter ones based in Seine-Saint-Denis department and enforcing the local rooting of ISMEP-Supmeca.

The feedback to these events is very positive. Satisfaction surveys (questions on the principle of the day, the program, the participative format, the interventions, and the presentations for third year students) conducted after each event indicate for example that first-year students endorse very much the participative format and third-year students also attach great importance to the presence of an enthusiastic external professional commentator. If we convert the evaluations to a score of 20, for the academic year 2016-2017, the half-day for first-year students was rated 14.7/20 and the day for third-year students was rated 13.9/20.

There are three categories of comments enclosed to the answers to the surveys:

- The positive ones, being the large majority, for example:
  - "extremely interesting, to be renewed absolutely for future promotions, this day reinforced me in the idea of wanting to work in SD&SR",
  - “format more interesting than the usual conferences",
  - "well to do a brainstorming",
  - “Interaction with professional stakeholders: ++".
- The ones asking for changes or expressing proposals, like the following ones:
  - "to be done in September or October",
  - "more actions are needed: garbage collection in parks".
- The sceptical or negative ones, like the following ones:
  - "concept rehashed for nearly 20 years",
  - "we are sensitized on themes on which we have no influence".

We took very much into account the two last categories of comments. For example, these events will take place earlier in the calendar from 2017-2018. Also, we think that resignation or criticism are linked to the fact that for some students, SD&SR is reduced to its environmental aspect. In order to counter that, we will focus more on economic and societal issues in the monthly SD&SR info-flashes. We will also try to make sure that as many students as possible are aware of the possibility, as engineers, of influencing a certain number of choices and conducting a systemic reflection integrating all the SD&SR parameters, despite various constraints which they will confront.

3 GOING FURTHER

Empowering the students and making them aware of the possibilities and limits they will have in their jobs and lives join the main SD&SR wishes of ISMEP-Supmeca. Linking SD&SR with project-based learning is already done and linking it with entrepreneurship is on the to-do list of of the institution, the latter aiming to go further in terms of actions and formalization.

Moreover, following both the continuous improvement approach promoted by CIRSES and the need for transdisciplinary approaches, more and more courses will be featured with references to SD&SR issues will lead to the gain of SD&SR-linked skills. The ongoing improvement and lifting of the syllabus of the institution will fasten this process, which will also need to be discussed with all the teachers involved, in order to enjoy the best understanding of the place of SD&SR issues in the different courses and taking into account the main learning outcomes and pedagogy approaches of these courses.

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Developing Creativity among Engineering Design Students

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ABSTRACT

As one of key drivers to solve real-life problems in practice of sustainable innovation, creativity has been argued as an important skill that engineering graduates have to master. This paper will mainly focus on 1) how to understand the concept of creativity and its relevance with sustainability in engineering design, and 2) as the educators, how we can provide basic conditions to recognise, develop, and assess creativity among engineering design students. The two focuses will further drive us to discuss a case of an education program of Medialogy at Aalborg University (AAU) in Denmark. Briefly, this paper contributes to bringing together with areas of creativity, engineering design, and engineering education, which also indicate that it has both theoretical and practical significances.

Conference Key Areas: Sustainability and Engineering Education, Engineering Skills

Keywords: creativity, engineering design, engineering education, sustainability, creativity assessment

INTRODUCTION

Recently, creativity has become a crucial issue for human-resource management in both academic research and industry. It is increasingly recognised that creativity and innovation are required to deal with changing circumstances in education and society as a whole [1]. So, the universities are increasingly expected to provide more opportunities that foster and nurture creativity in engineering students. Engineering students need creative minds to meet the advancing goal of engineering profession, design new products or systems and improve existing ones for the benefit of humankind [2]

The arguments that engineering design students require creativity also involve the consideration of developing sustainability [3]. In engineering design, it is necessary to add customers' requirements related to sustainability. Both the development of a product and making it sustainable requires the involvement of creativity into product design. So during the product lifecycle, the engineers must be able to be creative in all areas of the process. The creativity not only makes them more competitive than before but also favours more sustainability with innovation for possible solutions to many of the problems [4].

Following the above, this paper emphasises the necessity of developing creativity among engineering students and deepens the understanding of creativity and its assessment methods. This further implies us to show the plan of curriculum design in an educational program of Mediaology at Aalborg University (AAU) in Denmark. Therefore, this paper not only contributes to a theoretical bridging creativity and engineering design education in one framework, but also provide practical implications to educators for recognising and assessing creativity among engineering design students.

1 WHAT IS CREATIVITY?

The creativity has many perspectives of seeing. Creativity can be defined simply as a generation of a new and useful idea [5], [6]. In other words, Creativity is the conceptualization, the schematization and the execution of ideas [7], [8].

Therefore, the meaning is subjective to be measured at different cultures and backgrounds. According to Zhou [9], creativity has to see in an integral mode, as the integration of knowledge and skills. It could be effective to assess people to selection, management or classification purposes. The interaction between persons could see at the interpersonal, the group, and the socio-cultural level. Both individual and group can produce a tangible product, material or immaterial that is useful according to with the social contexts [10], [11]. Consequently, creativity could recognise by the people, the product, the process and the environment. That approach to assessing creativity is known as the 4P's of creativity, which means Person, Process, Product and Place.

2 CREATIVITY AND SUSTIANABILITY IN ENGINEERING DESIGN

In engineering design, creativity has its significances of developing sustainability. A new idea always has to be tested or use to be a real "idea" that is also useful. In a broad sense, we may view creativity as a pathway to develop sustainability. While sustainability refers to the design of human and industrial systems "to ensure that humankind's use of natural resources and cycles do not lead to diminished quality of life due either to losses in future economic opportunities or adverse impacts on social conditions, health and the environment"[12, p. 5315].

Furthermore, we can use the principles of precautionary and the prevention when to assess sustainability that also has effects on creativity. The precautionary principle is a strategy to address uncertainties in risk management [13]. This principle establishes that uncertainty determines the measures that must be taken to avoid damages to society and the environment. Therefore, engineers must take actions before damage can occur. Therefore, cautions include wider assumptions, recognise weaknesses and points where there is not knowledge, uncertainty, advantages and disadvantages, stakeholder recommendations, use of specialists, documents, and the real operating conditions. Also, engineers have to think of short- and long-term monitoring programs [14], [15]. The principle of prevention states that if the consequences and probability or occurrence of any activity is known, measures should be taken to avoid further damage to the environment or society.

According to Cucuzzella [4], the precautionary mode is typical of the stages of the formulation of the problem and involve reflection in action. The prevention mode is for stages involves technical knowledge while developing the solution of the problem. At the stage of a problem, the setting should appear requirements that include uncertainty. The way of the problem is addressed, and the different alternatives of presenting it are related to creativity. Furthermore, creativity promotes the search for various alternatives. The preventionary approach is oriented toward various action alternatives, reconstructing existing social and cultural elements; while the precautionary approach uses both instrumental models and critically constructed models. So the two principles have opposite effects on creativity in problem-solving and problem-setting contexts.

However, to Cucuzzella [4], also argued that the two principles of precaution and prevention coexist within a problem-solving and problem-setting model of thinking. That makes it possible to reveal at least four tensions that help to understand how creativity is impacted in the context of designing for sustainability. The four tensions are: (1) analogical/logical conceptualization, (2) epistemological/methodological uncertainty, (3) interpretive/analytic comparability, and (4) universal/contextual relevance of proposal. These four tensions comprise a system for judgment as they each address a major element of design thinking.

3 ASSESSING CREATIVITY IN ENGINEERING DESIGN EDUCATION

According to the literature [16], there is a great deal of controversy about the meaning of the word creativity, particularly in a university setting. It shows that some disciplines have been involved:

1) Psychology has focused on the individual’s creativity and tried to identify the cognitive capacities and traits of personality that make up a creative person.
2) Social psychology has studied the process of creativity as an interaction within a given context.
3) Sociology (and organisation theory) has emphasised creativity as an environmental process and studied efficient communication networks made up of prominent personalities with broad and deep knowledge.

Törnkvist [16] also argued it is important to recognise which approach mentioned in the above when we develop and assess students’ creativity in engineering education. For example, if one believes that creativity is constituted by a set of traits of personality only, testing for those traits of personality only, testing for those traits at entry level would seem to be a necessary and sufficient means of ensuring future creativity. If one believes that the social context has influences on creativity, as suggested by Amabile and Pillemer [17], creativity could be taught, learned, practised and developed, and everyone has potential to be more creative than before through positive influences of educational environments on developing creative ideas and learning methods of developing creativity. So, in educational methods based on collaboration, the assessing of creativity is view as a result of a process, at the end of an individual or group work.

In engineering design, assessing creativity has been focused on from a product perspective [18]–[21]. Creative engineering designers are those who can explore and scrutinise the available data or information and generate novel solutions to specific engineering problems or the production of a unique product are demanded in work places and markets [21]–[23]. The following four aspects of defining a creative product should be considered [23]

1) Relevance and effectiveness: the product solves the problem it was intended to solve.
2) Novelty: the product is original and ‘surprising’.
3) Elegance: the product is ‘beautiful’ or pleasing, and goes beyond a simple mechanical solution. And
4) Generalizability: the product is broadly applicable - it can be transferred to situations other than the present one and opens up perspectives for solving other problems.

Furthermore, as little engineering work is solitary, it is increasingly being recognised as a collaborative problem-solving process where is also the main context of creativity among engineers [23]. Also, ‘responsibility’ should be involved, which highlights the designers must be able and willing to think about their ethical liability for the consequences when the creative products are applied in practice [24]. For example, the relevance of sustainability with engineering design has been emphasised in this paper.

Also, to better assess creativity from the perspective of the product, observers have to review both the process explanation for the developing the product and the final product. There could involve many aspects, such as the problem formulation, user requirements and preliminary, and final specifications. Furthermore, the observers have to deal with accidental aspects (e.g., unintentional solutions). A student was tacitly explaining in a special session on a report facilitating the observation process.

4 DEVELOPING CREATIVITY IN ENGINEERING DESIGN EDUCATION

In the following, we take an example of the curriculum plan in a student programme of Medialogy at Aalborg University (AAU) in Denmark to show how engineering design education may provide necessary conditions for creativity. It should be noted here that AAU has a long tradition of an educational model of Problem-Based Learning (PBL). Students in Medialogy will have a ten-semester study period. Every semester, each student group should finish a project report which indicates their design processes and design products in solving real-life problems.

The Bachelor's degree in Medialogy at AAU begins with the students getting an insight into basic Information technology, Communication, New Media, Programming and the completion of a problem-oriented project. In the first year, the students in project teams analyse and solve a problem within the area Human-Computer Interaction. They draw up a problem formation and qualify a research question where they will be able to apply their knowledge and skills in mathematics, programming and interaction design. *Fig. 1* shows the detailed description of learning objectives of student projects.

Title: **Human-computer interaction**
15 ECT
Objectives: After completing the Project module, the student shall be able to demonstrate knowledge, skills and competencies in how design, develop and evaluate and artefact.
Knowledge • Describe new form of interaction with the real word, data sources, and/or physical/virtual models (understanding) • Explain how human computer confluence can enhance the foundations for future applications of societal value (understanding) • Explain the methods for planning and developing and IT application (understanding) • Explain the iterative nature of interaction design (understanding)
Skills • Applied the human center design approach in the contest of use, design, development and evaluation of a new interface (understanding) • Design, plan, organise and conduct user needs study of a target group (synthesis) • Analyse how a chosen target group interacts in a real world context of use with similar media products or artefacts and apply this to novel designs through, e.g., scenarios and storyboards, and later with early prototypes • Apply methods, tools and theories to allow people to explore and augment human interaction capabilities and awareness in action and interaction. • Synthesize technical requirements specifications as a basis for developing a media technology project • Design and implement a simple artefact based on fundamental object-oriented programming (COP) strategies, models and development environments (application) • Prepare and perform standarised testing of an artefact with the target user group (not a convenience sample) or domain experts and analyse and discuss the findings (application)
Competencies • Apply the gained experiences with project management to the future course of study (evaluation) • Evaluate the ethical perspective of engineering and science and discuss implications of a responsible professional practice (analysis) • Explain basic quantitative results with descriptive statistics in writing and in figures (application)

Fig. 1. Learning Objectives in Medialogy

So the students must create a model of the problem and include relevant concepts, theory and methods for analysis and assessment of possible sustainable solutions. As part of the solution, the students must develop an artefact, which has to be documented in the project report.

For example, The Intelligent Ashtray shown in *Fig. 2* is one of the students' projects in the 2nd semester. The overall theme of the semester is garbage in Denmark. The students first look at a lot of different areas to work their way towards finding a solvable problem in regards to garbage and dogged into which matters could be resolved. Then one group of students are very interested in issues of smokers. The issue is not merely that people throw the cigarette butts to irritate other persons, but rather another issue in finding places to dispose of it. Some people state that they do not recognise cigarette butts as litter, while others state that most ashtrays are full. Whatever the reason may be for not disposing of the cigarette butts correctly, the students decided to try and count this problem Based on the problem analysis. Finally, a problem formation was created by the students:

How do we motivate our primary group, the smokers, to reduce their littering of cigarette butts and in turn create awareness for our secondary group, the non-smokers, in the city of Aalborg?

This project aims to solve the problem formation with an interactive ashtray, with a design that would make it easy to spot. The ashtray has an info-screen, which seeks to change the user's perspectives in littering through information printed on-screen.

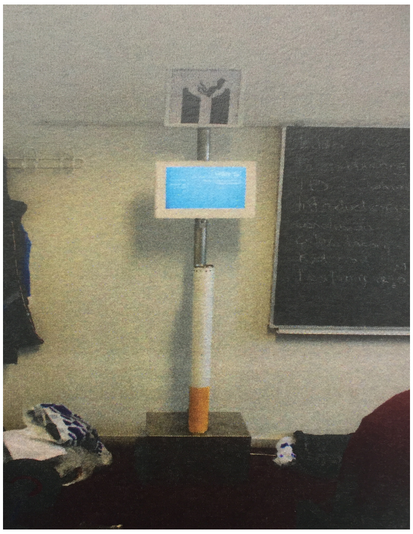

Fig. 2. The Intelligent Ashtray

The project includes a full implementation and product test. It showed, that "The Intelligent Astray" in the city of Aalborg had an impact on both the primary and the secondary target groups, in that it changed the motivations of the smokers to use the ashtray and made the non-smokers aware of the issues surrounding cigarette littering.

From the above case, we can learn that in Medialogy, sustainability has been an important element embedded in the curriculum design. Meanwhile, the product perspective creativity has been highlighted when the students are required to solve real-life problems; the criteria for assessing creativity discussed previously including relevance and effectiveness, novelty, elegance, and generalizability have also been encouraged to be reached among the students in the process of their design. Also, AAU is a supportive educational environment to develop creativity, as it has core principles such as group work, student-centered learning, and the shift from teaching to facilitation, which meets the requirements of fostering a creative learning atmosphere and students' active participation in creative activities.

5 CONCLUSIONS

This paper addresses the issues of developing creativity among engineering design students. These issues involve how to rethink what the concept of creativity means in the field of engineering design and its relevance with sustainability, and how to recognise and assess creativity among engineering design students. It is clear that only when educators have the strong awareness of developing creative teaching and learning, and when they can understand and recognise the needs and the particular characteristics of creativity in engineering design, the supportive curriculum design and educational environment can be accordingly developed. So a case of a student programme of Medialogy at AAU discussed may provide a practical example of how to integrate creativity into curriculums in engineering design education, which also provide implications for other engineering institutions around the world.

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Transforming Engineering Education: DESIGN must be the Core

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ABSTRACT

There have been many reviews of engineering education over the last 15 years, yet most engineering curricula remain traditionally focused on the development of technical outcomes, with a small emphasis on design. This paper reviews many of the international reviews, to seek the common themes that need to be addressed. Examples of new curricula are provided. Although the design of new curricula is difficult enough, it is the implementation of change within our existing academic structures that is really the difficult problem to be solved.

Conference Key Areas: Curriculum Development, Quality Assurance and Accreditation, Skills and Engineering Education

Keywords: engineering education transformation, engineering curricula, project-based learning, graduate outcomes, accreditation

INTRODUCTION

There have been numerous international reviews calling for changes to engineering education [1-9]. The key recommendations are enlightening and complementary. However, the sense of urgency for change seems curiously absent, despite many such reports over the last 15 years.

This paper first seeks the common recommendations from several international reviews. It then considers the gaps between these recommendations and typical engineering curricula. Primarily, there is a lack of engineering practice in most programs. The paper then considers required graduate outcomes as expressed in accreditation criteria and how these might be reorganised to provide a different emphasis, focusing on design rather than the technical knowledge that supports it. Examples are provided of design-oriented or project-oriented curricula, which are gradually becoming more common in Australia. However, space precludes discussion of these in detail. Nevertheless, the references provide enough information to seek out more information about, and evaluation of, these programs. Finally, the conclusions encourage all engineering educators to rethink their curricula from one based on engineering science to one based on engineering design.

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1 INTERNATIONAL REVIEWS OF ENGINEERING EDUCATION

The US National Academy of Engineering's *Engineer of 2020* report [1] presented a vision for future engineering (my emphasis):

1. … profound impact of the engineering profession on **sociocultural systems**, …
2. … engineers competent to address the **world's complex and changing challenges**.
3. We aspire to engineers in 2020 who will … **expand their vision of design**
4. … an engineering profession that will rapidly embrace the potentialities offered by **creativity, invention, and crossdisciplinary fertilization**
5. … engineers who will assume **leadership positions**
6. … an engineering profession that will welcome **underrepresented groups** to its ranks
7. … engineers will continue to be leaders in the movement toward … **sustainable development**
8. … engineers are prepared to adapt to changes in global forces and trends and to **ethically assist the world**

Further, the report adds:

> *With appropriate thought and consideration, and using new strategic planning tools, we should* ***reconstitute engineering curricula*** *and related educational programs to prepare today's engineers for the careers of the future*

Recommendations from the follow-on report, Educating the Engineer of 2020 [2] are surprisingly non-specific:

1. … students should be introduced to the **"essence" of engineering early** in their undergraduate careers.
2. Colleges and universities should **endorse research in engineering education** as a valued and rewarded activity for engineering faculty
3. … institutions must teach students how to be **lifelong learners**.
4. Engineering educators should introduce **interdisciplinary learning** in the undergraduate curriculum
5. … and explore the use of case studies of engineering **successes and failures** as a learning tool.
6. The engineering education establishment should participate in efforts to **improve public understanding of engineering** and the technology literacy of the public and efforts to improve math, science, and engineering education at the K-12 level.

Perhaps it is not surprising that change has been slow given these non-specific recommendations.

The UK Henley Report [3] highlights the need for three kinds of engineers:

1. The engineer as **specialist** recognises the continued need for engineers who are technical experts of world-class standing.
2. The engineer as **integrator** reflects the need for engineers who can operate and manage across boundaries, be they technical or organisational in a complex business environment.
3. The engineer as **change agent** highlights the critical role engineers must play in providing the creativity, innovation and leadership to shape the industry in an uncertain future.

The engineer as change agent is in tune with recent calls for greater innovation in engineering and many other disciplines, innovation being seen as the underpinning of the future world economy, e.g. [10, 11].

Sheppard, Macatangay et al. [4] concluded that:

1. "… the **tradition of putting theory before practice** and the effort to cover technical knowledge comprehensively allow little opportunity for students to have the kind of deep learning experiences that mirror professional practice and problem solving.
2. The **lab** is a missed opportunity: ... **Design projects** offer opportunities to approximate professional practice, … However, these opportunities are **typically provided late in the undergraduate program**.
3. Concerns with **ethics and professionalism**, …, have long had difficulty finding meaningful places within this historical model
4. Further, the dominant curricular model, …, with its attendant **deductive teaching strategies**, … does not reflect what the … research on learning suggests about how students learn and develop
5. The central lesson that emerged from the study is the imperative of **teaching for professional practice**"

The authors articulate **four principles of curriculum design**:

1. *Provide a professional spine*
2. *Teach key concepts for use and connection*
3. *Integrate identity, knowledge, and skills through approximations to practice*
4. *Place engineering in the world: encourage students to draw connections*

Robin King [6] examined engineering and engineering education in the Australian context and made six recommendations:

1. increase the **public understanding** of engineering … particularly in schools;
2. **clarify educational outcomes and standards**;
3. **develop best-practice engineering education**;
4. attract a **higher proportion of women** and other under-represented groups;
5. **increase staffing and material resources**; and
6. **promote stronger collaborative links with industry**.

In *A Whole New Engineer*, Goldberg, Somerville et al. [8] trace the innovation that has emerged from Olin College in Boston and the on-going collaboration with the iFoundry at the University of Illinois. They describe the six minds that engineers need to develop: the **analytical** mind, the **design** mind, the **linguistic** mind, the **people** mind, the **body** mind, and the **mindful** mind. However, when we look at curricula, it is the first that gets by far the most attention.

Interestingly, Trevelyan [9] reinforces the need for the *linguistic* mind – his research (and that of others) shows that engineers spend 60% of their time communicating. The *people* mind has a couple of dimensions; engineering is inherently a team activity and it works in the service of humanity. *People* dominate engineering, although this is sometimes not obvious from the curricula.

Goldsmith, Reidsema et al. [12] in *Designing the Future,* report on an industry-academic workshop at the culmination of a project that investigated design-oriented curricula. The **top six trends** affecting engineering practice were identified as: impacts of globalisation, environmental awareness, breadth of knowledge base, engineering systems, rapid changes in technology, and the research/teaching dilemma. The **top six capabilities** were: personal and professional skills and attitudes, communication, design, teamwork, systems thinking, and design of engineering systems.

Despite all these calls for educational innovation, change in traditional curricula, departments and faculties is hard. Ruth Graham [5] interviewed more than 100 change agents from around the world and identified four key attributes of successful change:

1. Change is often initiated by a **significant threat**, e.g. falling retention, recruitment and employability of graduates. Interestingly, such change is often driven by those with **industry experience** and/or new hires.
2. Change needs to be **systematic and connected**, bringing a new wholeness to the curriculum. In the process, it creates a **new brand**, which is easy to sell to others.
3. Change happens at the **Departmental level**, driven by the Departmental Head. Trust in this person's judgement is key, e.g. in future promotion applications that might flow from leadership of change activities.
4. **Change is difficult to maintain**. Successful programs involve most staff, involve systematic evaluation of the program that encourages sustained innovation and reinvention.

Reidsema, Hadgraft et al. [13] identified a structure for systematic change at national level in Australia, involving a partnership between industry, Engineers Australia, the Australian Council of Engineering Deans and the Australasian Association for Engineering Education. Unfortunately, little progress has been made.

Beanland and Hadgraft [7] reviewed the opportunities for transformation of engineering education from a global perspective. Key conclusions include:

1. engineering education must be exciting, relevant and socially responsible, particularly to attract more women
2. the curriculum should be focused on personal transformation based on student-centred learning
3. graduates must become creative, informed, capable and responsible
4. use the extensive literature to inform the transformation of curricula
5. improving curricula will increase completion rates and provide better graduates
6. engineering employers, governments, accrediting authorities and professional engineering associations, must support the universities to achieve transformation
7. changes required are significant – structure, content, delivery modes, objectives, student experiences, staff responsibilities and roles, assessment, etc
8. changes to how universities operate will be necessary – policies, practices, facilities
9. transformation needs to be part of each Faculty's strategic plan

It is also worth reminding ourselves of the context in which engineers work, which is neatly summarised by the Code of Ethics, in this case from Engineers Australia [14].

Demonstrate Integrity, Practise Competently, Exercise Leadership, Promote Sustainability

If these behaviours are to be developed in graduates, then we need a curriculum that is much more complex than teaching applied science and mathematics.

1.1 Summary

It is clear that we need new engineering curricula, ones built around the 'whole engineer' rather than the idea that if an engineer knows enough applied science, the rest is simply application.

Curricula need to expose students early to the complex and challenging problems emerging in the world. Not only will these problems help them to learn design and problem solving, but they will naturally integrate the full set of professional skills: teamwork, communication, ethics, sustainability, etc. – the people-oriented skills that have been shown to be the heart of good engineering.

This is not to argue that mathematics and science are not essential skills for an engineer. However, they need to be seen as analysis tools that serve design in the same way that prototyping does: engineering analysis is simply numerical prototyping. However, design must usually satisfy a complex set of requirements, not all of which are resolvable into neat scientific equations.

2 TYPICAL CURRICULA

When we examine most curricula, they remain reliant on lecture driven subjects covering traditional topics – statics, dynamics, solid mechanics, thermodynamics, fluid mechanics, materials, circuits, control, etc. Many of these subjects last well into third year, giving students in four year programs little time to develop engineering problem solving skills for a world where sustainability considerations are essential – less material and energy use over the product's lifecycle.

For example, an analysis of the civil engineering program at my own university shows the following breakdown:

Table 1. Breakdown of Civil Engineering program at the University of Technology Sydney

Category	**Units**
General purpose modelling (mathematics and computing)	3
Physical and chemical science	2
Professional skills (communication, design, economics, project management, business)	5
Basics of civil engineering (surveying, construction, materials)	4
Structures	6
Water, hydrology, environment	3
Geotechnics	2
Transport	1
Research and Project	2
Elective	4
Total	**32**

Of these 32 units, there is a design element in 6 units, accounting for perhaps 50% of each unit, which means that around 10% of the entire program is design. This is not unusual in my experience, having been involved in accreditation panels at a number of universities.

2.1 What are the alternatives?

There are now many universities that have moved to problem and project driven curricula, in whole or in part. Aalborg University in Denmark led the way (since 1974), with 50% of each semester devoted to project-organised problem-based based learning (POPBL) [15]. Other variations have been adopted at the University of Queensland in Chemical Engineering [16], Olin College, the University of Illinois's iFoundry [8], the Royal Melbourne Institute of Technology (RMIT) [17], Monash University in Civil Engineering [18], Central Queensland University [19], Victoria University in Melbourne, Deakin University [20], and many others around the world.

These curricula implement the recommendation from [4], namely a project-driven spine, typically in each semester of the program, beginning in the first. This project subject is usually 25% or 50% of each semester's work, sometimes expanding to 100% of the final semester of a program.

Two recent innovations in Australia are worth noting: Charles Sturt University (CSU) [21] and Swinburne University [22] are both using 100% project-based curricula supported by industry mentors and online learning. Students are immersed in engineering from day one, effectively providing an on-campus apprenticeship model. In the case of

CSU, students take 3 semesters on-campus before spending 4 x one year work placements, supported by online learning materials and summer schools for upskilling.

Oddly, unlike the medical discipline, engineering has not widely embraced problem/project-based learning, even though engineering is fundamentally a project-driven profession.

The following section takes a deeper look at how program outcomes are represented in accreditation criteria and in some of the research that has examined what it is that engineers do.

3 ENGINEERING OUTCOMES

First of all, what is the nature of engineering? The Define Your Discipline project [23] in Australia conducted more than 20 meetings with more than 200 engineers and asked them one simple question: what *do* graduate engineers do in your company? Participants were encouraged to write as many tasks as they could think of and then to organise them into meaningful clusters.

These meetings revealed *three* sets of interlocking skills: *process or problem-solving skills* such as investigation, modelling, design, management, impact assessment; *technical skills*, which define each engineering discipline, and *generic skills* such as communication, teamwork and collaboration, ethics, innovation, etc.

The *generic* skills are common across every discipline at the university, the *process* skills define engineering, as opposed to other disciplines, and the *technical* skills define the particular discipline of engineering, e.g. distinguishing a civil engineer from a mechanical engineer.

These three sets of skills should come as no surprise since they are easily found in the accreditation guidelines around the world: The International Engineering Alliance (the Washington Accord), ABET, EURACE, Engineers Australia, etc.

However, the three skill sets are rarely articulated in quite this way. Rather we are given a long list of competencies that begin by emphasising an understanding of mathematics and physics. The research shows that *design, investigation and modelling* are the core of engineering practice. Rewriting the accreditation guidelines to put design first could shift our thinking on engineering curricula. The professional skills have also been given greater importance, since this is where engineers spend most of their time, as shown above.

In Table 2, the Engineers Australia competencies have been reorganised, while preserving the original numbering, which demonstrates which elements have been moved to new places. The design criteria have been placed first, since these are what engineers do, supported by the people-oriented skills and the technical skills. This presentation should spark new ideas for curriculum designers beyond ‘let’s start with more mathematics and physics’.

Table 2. Engineers Australia Stage 1 Competencies (reorganised)

Engineering Design Ability	
2.3.	Application of systematic engineering synthesis and design processes.
2.1.	Application of established engineering methods to complex engineering problem solving.
2.2.	Fluent application of engineering techniques, tools and resources.
2.4.	Application of systematic approaches to the conduct and management of engineering projects.

Professional and Personal Attributes

3.1. **Ethical** conduct and professional accountability.
3.2. Effective oral and written **communication** in professional and lay domains.
3.3. **Creative**, innovative and pro-active demeanour.
3.4. Professional use and management of **information**.
3.5. Orderly **management of self**, and professional conduct.
3.6. Effective **team** membership and team leadership.

Knowledge and Skill Base

1.1. Comprehensive, theory based understanding of the underpinning **natural and physical sciences**
1.2. Conceptual understanding of the **mathematics**, numerical analysis, statistics, and computer and information sciences.
1.3. In-depth understanding of **specialist bodies of knowledge** within the engineering discipline.
1.4. Discernment of knowledge development and **research** directions within the discipline.
1.5. Knowledge of engineering design practice and **contextual factors** impacting the discipline.
1.6. Understanding of the scope, principles, norms, accountabilities and bounds of **sustainable engineering practice** in the specific discipline.

This ordering makes a little more sense, by focusing on design and professional practice. However, the wording does not capture the essence of engineering in my opinion. Describing engineering as the 'application of design processes' makes it sound like a recipe-following exercise, which design rarely is [24].

The Australian *Threshold Learning Outcomes* for Engineering and ICT [25] also begin with 'identify the problem':

Graduates will have the knowledge and skills to:

1. Identify, interpret and analyse *stakeholder needs, …*, using *systems thinking,* while recognising *ethical implications* of professional practice.
2. Apply *problem solving, design and decision-making methodologies* … to meet specified *requirements*, including *innovative approaches* …, while demonstrating *information skills* and *research methods.*
3. Apply *abstraction, mathematics and discipline fundamentals* to analysis, design and operation, …
4. *Communicate and coordinate* proficiently …, working as an *effective member* or *leader* of diverse teams, using basic tools and practices of formal *project management.*
5. Manage own time and processes effectively by *prioritising competing demands* to achieve *personal* and *team goals, with regular review* of personal *performance* …

These five statements capture what it means to do engineering and are complementary to Engineers Australia's Stage 1 Competencies listed above.

4 NEW CURRICULA

So, the first step in transforming curricula is rethinking the centrepiece of engineering from technical skills to identifying stakeholder needs and requirements, using design thinking and decision making. Engineering is not merely 'the application of science'.

The second step is to investigate a range of project-centred curricula from the 100% projects at Swinburne and CSU to 50% (Aalborg University, VU, CQU, Deakin) or even 25% models (UQ, RMIT) as referenced above.

The University of Technology Sydney is currently engaged in remaking engineering curricula in just this way using Studios as the focus of student learning [26]. In fact, a key transformation is not just the curriculum but each student's engagement with it, through a portfolio of career development, beginning in the first semester. Studios focus on student learning through a learning contract. Students become reflective practitioners in their own personal development – EA's point *3.5: Orderly management of self, and professional conduct*.

However, the real challenges are in shifting academics' thinking about how students learn their discipline, a topic for another paper.

5 CONCLUSIONS

The literature demonstrates that there is an urgent need to redesign engineering curricula, with design and problem solving at the heart of the student experience; this should also be reflected in the way that accreditation guidelines are articulated.

There are many examples from around the world to show how this can be done. However, the evidence is that it is difficult and the main impediment is the academic system, which emphasises technically-focused research as the most important academic activity. A lack of industry experience in the academic workforce is also a serious issue [27].

As the 21st century develops, we see a greater emphasis on innovation and the creation of new enterprises. A recent study showed 40% of my university's students expect or desire to start their own businesses.

So, our engineering curricula need to be sufficiently flexible to develop those three types of engineers identified in the UK Henley Report: the technical specialist, the integrator and the change agent.

We academics need to take up this challenge, to demonstrate our own capacity for change and innovation.

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2.
University-Business Cooperation

A Project-Based ICT Education by Citizen Support System Development

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ABSTRACT

One of the difficulties in ICT education in regular lessons is that educators must teach all the techniques for developing systems within a limited time frame, despite the fact that students cannot learn without actually experiencing the various techniques. This paper introduces an educational method of software development that is collaboration between the industry and the community. The method is based on the principles of Project-Based Learning (PBL). The proposed method features learning software development technology by incorporating an actual citizen support system using the Spiral model [1]. The project was supported as one of the Ministry of Internal Affairs and Communications IoT Service Creation Support Project. The purpose of the IoT Service Creation Support Project is to identify specific problems that should be overcome when creating and deploying IoT services through demonstration projects, build a reference model that will help solve the issues, and promote data utilization etc. In addition, it is to play a leading the role lead to the development and maintenance of the necessary rules for the IoT service. Students developed a citizen support system. Through this activity students learned about the idea of entrepreneurship. By use of the developing system and prototype system for citizens, as well as from the results of responses to a questionnaire survey, we found that the method developed is effective for improving citizen life.

Conference Key Areas: University-Business cooperation, “I want to contribute to solve local problems”, Engineering Education Research

Keywords: ICT, Industry-academia collaboration, Software engineering, Project-Based-Learning

INTRODUCTION

ICT education is difficult to deliver in a regular classroom setting because of the need to introduce all the techniques for developing systems in a limited amount of time. In addition, it is impossible to teach students practical requirements analysis, architectural design, etc., in such a limited time frame. The primary reason this is not possible is the inability to teach such techniques without actually having experienced them.

This paper introduces an educational method of software development that collaborates with industry and community. The method is based on Project-Based Learning (PBL) and applied to the students of the Department of Information and Computer Science in Kanazawa Institute of Technology (KIT). The method features a learning software development technology by creating an actual citizen support system using the Spiral model [1]. The software development method, using the Spiral model, is compatible with the Project Design Program in KIT [2].

The project was supported as one of the Ministry of Internal Affairs and Communications IoT Service Creation Support Project. The purpose of the IoT Service Creation Support Project is to identify specific problems that should be overcome when creating and deploying IoT services through demonstration projects, build a reference model that will help solve the issues, and promote data utilization etc. In addition, it is to play a leading the role lead to the development and maintenance of the necessary rules for the IoT service. The group of Nonoichi City, NEC Solutions Innovator Co., Ltd., Yoshida Advertising Co., Ltd., Kanazawa Institute of Technology and Kanazawa Technical College was selected for this project.

This paper explains in detail the practical project that was carried out in Nonoichi-City. The city, located in Ishikawa Prefecture in Japan, requested the development of the ICT system for citizen support. We carried out an educational project in which the students themselves thought about a given problem and methods of problem-solving by collaborating with companies and the city. In an effort to solve the given problem, we developed an information terminal bus stop and submitted proposals to Nonoichi-City. The developed system comprised five sub-systems: Timetable and Transfer Guidance System, Children's and Elderly's Observation System, Disaster Countermeasure System, Advertisement System, and City Public Relations System. This system features image recognition software and provides service matching for each individual.

From active engagement with the project, students learned how to listen to individual requests, analyze the requests, and create the system. In addition, they also learned how to conduct the operational test, solve extraction problems, and improve the system. The project allowed students to receive hands-on education, and at the same time, also had favorable effects on the community. In fact, when using the prototype system for the citizens and conducting a questionnaire survey, we received numerous comments on its effectiveness in improving citizen life.

This paper is organized in the following manner. First, we explain the KIT Education system. Second, we present the intended characteristics of an ICT education in collaboration with Nonoichi City. The educational method of software development using PBL and the Spiral model is addressed in detail. Third, we explain their effects. Lastly, we offer a summary of the material presented.

1 SIGNIFICANCE OF PROJECT ACTIVITIES IN KIT

In KIT, students are educated in two wheels of curricular education and extracurricular education (Fig. 1). The Project Design Program (PD) is the backbone of the curricular education, it is carried out as a regular class for all students and has made great progress [2-3]. Project-Based Learning (PBL) is applied in PD courses.

Extracurricular activities also play an important role in KIT. They include YUMEKOBO Projects (YUMEKOBO is a Japanese term which refers to the Factory for Dreams and Ideas), Department/Lab-related Programs, Collaboration Programs with Industry and Community[4], and Internship Programs. In these activities, students can set up objectives by themselves and learn from the successes and failures. For example, YUMEKOBO Projects are self-directed projects to develop students' technical competence [5]. There were 16 YUMEKOBO Projects in 2016 [6]. The education project described in this paper worked as an extracurricular activity.

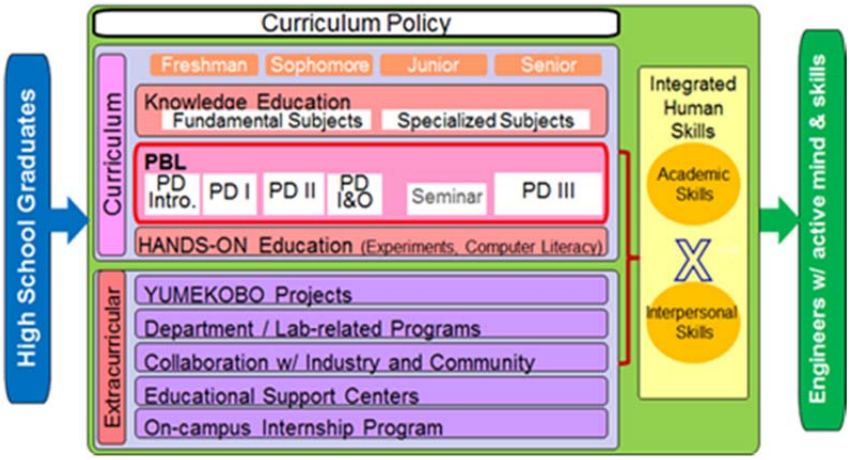

Fig. 1. KIT Pedagogical System

Fig. 2 shows the problem solving flow used in PD education at KIT. In PD education, students learn the flow of the discovery of the problem, clarification of the problems, creation of ideas, selection of ideas, and implementation of the idea. In addition, even in extracurricular activities students will use the same flow to solve problems. The difference between the regular curriculum classes and the extracurricular projects is that the flow is carried out repeatedly in the extracurricular projects.

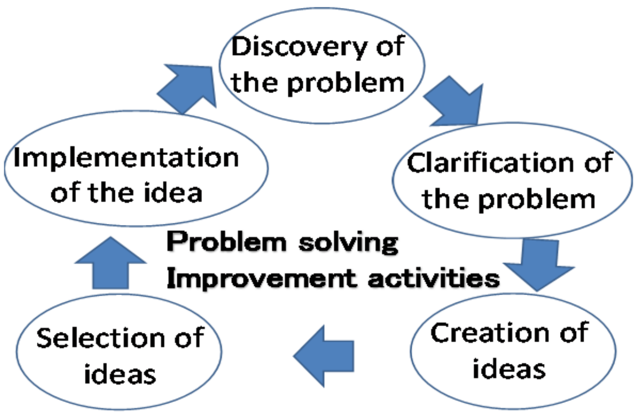

Fig. 2. Problem solving, improvement activities flow

In extracurricular activities, by repeating the improvement flow, students examine deep and complex matters. Students form a team with different grade levels unlike classes and execute the project. One benefit of working as a team consisting of different grade levels is that senior students are able to develop leadership skills. In addition, conducting the project allowed juniors to learn the importance of the regular curriculum classes.

2 DETAILS OF THE CITIZEN SUPPORT PROJECT ACTIVITIES

2.1 Project Objectives

Society is constantly changing. We believe that we need the ability to respond flexibly to this change. We also believe that the ability to create new value challenging and leading society in a better direction is important. We actively work on society's problems, improve society and think that the university's mission is to produce human resources that support the country. We are engaged in entrepreneurship education using the development of regional innovation system.

We believe that the three requirements for becoming a global leader are as follows, and we aim that students master these abilities. In the field of information processing, especially the change is intense, we felt that training of following skills is necessary, and decided to teach them through by the project activities.

A) Awareness / understanding of shifting trends and needs in society

B) Connect one’s interests an/or abilities

C) The mentality and action to make full use of one’s resources and solve social challenges

We decided to work on improvement of citizen's life, targeting a city with a university. We thought that it was meaningful for students who are citizens to solve the problems owned by them and to enrich the lives of citizens. We decided to develop a citizen support system to solve the city's problems and enrich the lives of citizens.

The other purpose of the citizen support project is to nurture software development abilities and to develop problem solving skills of students by developing an ICT system for citizen support. We aim to improve the student's skill as an information processing engineer by educating system design method while actually creating the system, which is difficult to teach in the outcome. In addition, the system we developed was designed based on the five-year plan issued by the Nonoichi-City so as to contribute to the revitalization of the city and the improvement of citizen's living. With the cooperation of Nonoichi-City, this project carried out many activities. In addition, we also received the cooperation with local companies in developing the system.

We aim to establish a system that transcends the mere extracurricular activities of students, and can actually be used in society, and that can operate in the long term and moisturize society. It aims not only to construct a system but also to manufacture a bus stop of an information terminal and to construct a mechanism which can actually be used as a citizen support system. This includes monetary aspects including maintenance. It is a great significance for students to consider and construct a system that can actually be commercialized. In addition, if the system has social significance, we think that its significance will be greater.

First of all, the project had done the discovery of the problem, clarification of the problem. In the discovery of the problem and clarification of the problem, we conducted based on Nonoichi City's five-year plan published by Nonoichi City. We addressed the following five problems to be resolved within a 5-year plan of Nonoichi-City. The correspondence division of Nonoichi-City is also shown below.

I. Timetable and Transfer Guidance ⇨ Area Promotion Section

II. Watch over of Children ⇨ Child-Rearing Support Section

III. Watch over of the Elderly ⇨ Regional Comprehensive Support Center

IV. Disaster Countermeasures ⇨ Environmental Safety Division

V. Advertisement and City Publicity ⇨ Secretary Public Relations Section

One of the more obvious characteristics of Nonoichi-City is that all of the 112 bus stops are consistently designed in the small city as 3 km in length and 3 km in width. The character named "Notty" is popular in Nonoichi-City, and this character is also used for the bus. Therefore, we tried to solve the problems that Nonoichi-City had, by making the information terminal bus stop which was shaped like a "Notty".

2.2 Flow of System Development

For the development of the system, students from the first year to the fourth grade of the university organized a team. It is a project of about twenty students. Within the project, system design and development were shared and carried out with a flexible group structure. In addition to the students, the project was conducted with four professors and two administrative staff members.

Fig. 3. Matching event of the Ministry of Internal Affairs and Communications Hokuriku

Since finding the problem and clarification of the problem was completed, students created the idea. As the ideas were completed, students submitted the ideas to the G space matching event hosted by Hokuriku of the Ministry of Internal Affairs and Communications, and we were awarded the Grand Prix. After that, Students developed a system specification from an idea, and led to their creation of a prototype system. The Ministry of Internal Affairs and Communications Hokuriku hosted a matching event with companies that supported the commercialization of the information terminal bus stop. We participated in a matching event and introduced the prototype system. Fig. 3 shows the situation of the matching event. Students were explaining about the system to companies. Thanks to this event, we found a company willing to cooperate in its commercialization. Subsequently, we developed prototype improvement activities in collaboration with companies as well as Nonoichi-City.

The system we created to solve the problem consists of the following five subsystems.

I. Timetable and Transfer Guidance System
II. Children's and Elderly‘s Observation System
III. Disaster Countermeasure System
IV. Advertisement System
V. City public relations System

The Information terminal bus stop has built-in Android terminal using the 3G network.

2.3 Interaction between Spiral Model and Problem Solving Procedure of KIT

The Waterfall model refers to a development model that gradually advances each development phase from system requirement definition to design, manufacturing and testing[7]. The Spiral Model is a technique to gradually expand the function by creating the main program and incorporating user's request[1]. Agile is one of the development methods to minimize risk by adopting a short development period unit called "iteration", meaning "quick", "agile"[8]. Each has its own strengths and weaknesses, and many Japanese companies are developing by Waterfalls model.

In the developing of the citizen support project, we selected the Spiral model. The merit of the Spiral model is that it is easy to reflect feedback and respond flexibly even when there is a problem regarding specification change from to feedback after trial use. As a result of repairing and repairing problems repeatedly, it is possible to finally create a quality system. We had to fix the system again and again, and it takes time to develop, but we thought that it would be good for students to wear skills slowly. Also, development could be done at the development pace that suit their abilities.

In utilizing the Spiral model, students were able to learn software development methods. In addition, the problem-solving flow adopted by KIT has much in common with the Spiral model, working together effectively and complementing each other. For example, if problems were found in the prototype, they were identified and solutions were devised. Based those discussions, solutions were developed and systemized. Since the Spiral Model is specifically designed to develop a system incrementally, it is easy to actualize the ideas through the programing.

3 RESULTS AND DISCUSSION

To better determine the impact and potential success of the system we created, we conducted a questionnaire survey among 50 citizens concerning the prototype of the information terminal bus stop within the bus-stop waiting area. Fig. 4 illustrates students conducting of the questionnaire survey.

One question concerned the “necessity of the information terminal bus stop.” As a result, thirty respondents answered that such an informational terminal was “necessary.” When asked why this was needed, 19 people answered that it was effective for improving the convenience of public transportation. In addition, 10 people responded that it would contribute to the safety of the local society. Another 9 individuals responded that they expected regional vitalization to occur as a result of providing information about the city to citizens. The responses to this survey are evidence that our system is expected to improve convenience of public transportation as well as provide effective regional vitalization and improve city safety.

Fig. 4 Demonstration of information terminal bus stop and questionnaire survey

Through the development of the information terminal bus stop, students conducted the request analysis, learned the techniques needed to build the system, and the request from the city and its citizens were satisfied. In addition, they learned the method of operation testing, extraction of the problem, and problem-solving skills.

Such hands-on, real-life interactions are important because students do not have the chance to experience in the regular curriculum classes. The knowledge that students gained as a result of this research has the potential to help society as a whole because of the skills they develop while participating in it. Students taught with respect to one another in the same school year and learned together. Throughout this educational project, students developed abilities required within society. For example, seniors gained leadership skills while they, and other project members, improved communication skills and acquired an understanding of cooperative learning as well as a sense of responsibility.

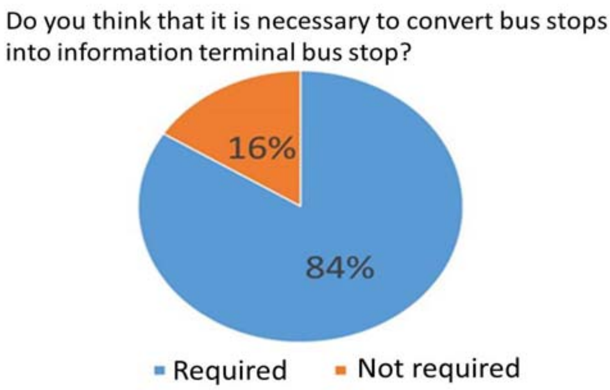

Fig. 5. Questionnaire Result 1

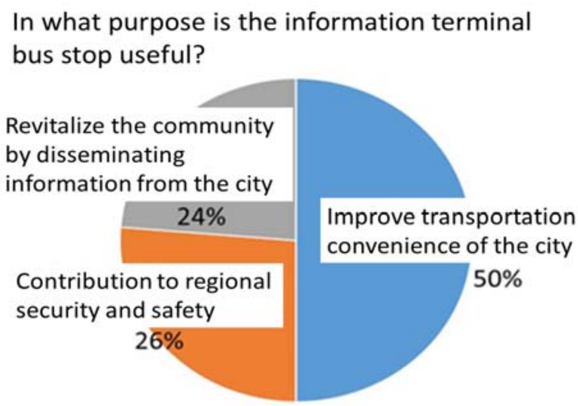

Fig. 6. Questionnaire Result 2

4 SUMMARY AND ACKNOWLEDGMENTS

This paper introduced the educational method of software development that encompasses the collaboration of industry and community. The method is based on Project-Based-Learning (PBL) and features learning software development technology by developing an authentic citizen support system using the Spiral model [1]. The project was supported as one of the Ministry of Internal Affairs and Communications IoT Service Creation Support Project. The purpose of the IoT Service Creation Support Project is to identify specific problems that should be overcome when creating and deploying IoT services through demonstration projects, build a reference model that will help solve the issues, and promote data utilization etc. In addition, it is to play a leading the role lead to the development and maintenance of the necessary rules for the IoT service. As a result of using the prototype system for the citizens and conducting a questionnaire survey, it is clear that our system can work to improve citizen life.

When implementing this bus stop project, we were supported by the industry-university cooperation office in KIT. We are very grateful to the member of the industry-university cooperation office. In addition, we are very grateful to those in Nonoichi-City that worked with us.

ACKNOWLEDGMENT

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A Preliminary Study of Integrating Creative Strategies in an "Industry 4.0" Project-based Course

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ABSTRACT

The present study aims to integrate creative strategies of "brainstorming" and the "six thinking hats" in an "industry 4.0" project-based course, in an attempt to cultivate creative climate and creativity for mechanical engineering and digital learning students. Participants were forty-three students enrolling in a project-based course. A post-survey of creative climate was conducted and students' final projects were evaluated for creativity. Results of regression indicate that, among the eight dimensions of creative climate, "sufficient resources" and "managerial encouragement" can significantly explain 19.4% of the variance in students' creativity ($F(8,32) = 2.200$, $p = .054$). The effects of "sufficient resources" on students' creativity was very likely resulted from the creative strategies employed in the course, while the effects of "managerial encouragement" may come from creative strategies as well as the teacher's supportive behaviors. Suggestions for future studies are provided.

Conference Key Areas: Curriculum Development, Engineering Education Research, Student Cooperation

Keywords: Creative-Thinking Strategy, Creative Climate, Creativity

INTRODUCTION

In the era of the "4th industrial revolution (industry 4.0)" where the combination of the Internet and future-oriented technologies results in innovation in industrial production [1], the development of creativity, whether in family, school, organization, etc. has gradually drawn attention worldwide. Creativity is indeed one of the key 21st century skills indicated in Trilling and Fadel's study [2]. Nevertheless, college students in the Taiwanese vocational education system have long been oriented towards pursuing higher education, and there is a lack of creativity competence; students generally do not know how to design and actualize creative products independently. Creative-thinking strategies are crucial for enhancing students' creativity. Studies have shown that teachers could utilize creative-thinking strategies for bringing out students' potential to create [3]. At the same time, the construct of a "creative climate" is a focal point among scholars when discussing factors for inducing creativity [4]. In view of this, the design of the present study is to integrate creative strategies into an "industry 4.0" project-based course, in an attempt to promote creative climate and to further spur students' creativity.

1 LITERATURE REVIEW

1.1 Creativity

Woodman et al. [5] suggest viewing creativity in social systems from the following components: (i) creative persons, (ii) creative processes, (iii) creative situations, (iv) creative products, and (v) the interactions of these components. Creativity can be viewed as a person's innate ability to create, a thinking process that generates novel solutions to problems and original, useful products. The environment one situates in can stimulate or suppress one's creativity, and vice versa. Creativity can also result from the complex interaction of personal traits, thinking process, and environment, and it manifests in various forms such as products or concepts. Mayer [6] found that most scholars have indicated that creativity relates to new and useful products, including concepts and concrete objects, and that "product" is the desirable target of assessment if one wishes to test the substantive ability to create. Consequently, the present study evaluates students' creativity based on the products created in a project-based course.

1.2 Creative climate

When it comes to cultivating students' creativity in classroom, the learning environment is one of the most essential factors [7]. The climate of an environment, such as an organization, is conceptualized as the shared beliefs or perceptions about the contingencies, requirements, and practices of the organization [8], such as employees' perceptions on the leaders' management styles, degree of workload, relationships among colleagues, and autonomy in conducting one's work. Environmental factors spurring creativity can be further characterized as creative climate [9].

Amabile, Conti, Coon, Lazenby, and Herron [10] developed "KEYS" to assess the climate for creativity. It is implied from "KEYS" that creativity could be enhanced through socialization of the work environment. "KEYS" comprises eight dimensions: (i) *organizational encouragement* refers to an organizational culture that judges employees' ideas fairly, constructively, and supportively. It rewards and recognizes creative work and utilizes mechanisms for generating new ideas. (ii) *supervisory encouragement* refers to supervisors who set clear goals, are able to establish good working environment, serve as a work model, and show confidence in employees. (iii) *work group supports* refer to being in a group where members communicate well, open to various ideas, trust, and feel committed to their work. (iv) *freedom* indicates the autonomy and control over what work to do and how to proceed. (v) *sufficient resources* are access to sufficient resources, such as funds, materials, facilities, and information. (vi) *challenging work* indicates that people realize they should endeavor to deal with challenging works and important projects. (vii) *realistic workload pressure* are lack of excessive time pressures, unrealistic expectations for employee's productivity, or distractions from work. (viii) *lack of organizational impediments* refer to an organizational culture that lacks internal political problems, conservatism, destructive internal competition, and harsh managerial structure.

1.3 Creative-thinking strategies

The purpose of creative-thinking strategies is to increase students' creativity via customized activities [11]. In the present study, the strategies are "brainstorming" and the "six thinking hats". "Brainstorming" [12] is a method for yielding a large number of ideas that are to be processed later. The guidelines of brainstorming are: (i) Negative judgment of ideas should be deferred until later. (ii) Truly wild ideas are desired. (iii) The more ideas produced, the greater chance of yielding useful ones. (iv) Elaborating on others' ideas to produce new ones [13]. Studies have found that brainstorming can help learners organize and arrange their thoughts [14]. The other strategy, the "six thinking hats", [15] allows one to pinpoint a certain type of thinking at a time, and competence in thinking can increase by adopting appropriate thinking styles. The six thinking modes are white (objective facts), red (emotion), black (critical), yellow (optimistic), green (creative), and blue (organization). It has been supported by studies that the six thinking hats can help one conceive more original and a larger number of ideas [16].

2 RESEARCH PURPOSE AND QUESTIONS

The purpose of the present study is to integrate creative strategies into an "industry 4.0" project-based course at a college to cultivate creative climate, and to examine if students' creativity could be promoted through such strategies. Especially, the main research question is how do creative-thinking strategies influence students' creativity?

3 METHOD

3.1 Instructional contexts: Creative-thinking strategies and project-based course

Authors of the present study and the instructors who teach project courses collaborated to develop a target course for the present study that is based on a pre-existent project-based course that teaches theories and practice of "industry 4.0". The main focus of the target course is to integrate creative-thinking strategies with industry 4.0 instructions. The course contains four topics: industry 4.0 and sensors, innovation and application in web of things, cyber physical system, and application of big data and cloud in industry 4.0. The course lasted one semester (eighteen weeks), with each session lasting four hours (one-hour practice class included), six of which comprising two hours of creative thinking instructions across the whole curriculum. Students were required to yield a plan for their projects related to "industry 4.0", such as creating a smart vending machine or an autonomous vehicle. Students then had to further bring their plans into practice. They were instructed to work in groups, utilizing creative-thinking strategies by discussing topics related to "industry 4.0" and cooperatively developing final projects. For instance, brainstorming was used to conceive how to apply web of things onto the final project. The "six thinking hats" was used to help students contemplate the contents and feasibility of the final project, as well as help them examine how big data can be applied into industry 4.0.

3.2 Participants

The participants were forty-three students who majored in mechanic engineering or digital learning at a college in Taipei city, Taiwan. They were students who took a project-based course called "Industry 4.0: Theory and Practice" in 2016.

3.3 Procedure

Assessment was conducted using James' revised version of "KEYS" [17] to measure creative climate, where students indicated their perceptions on each dimension of the course climate. The procedure included two stages: (i) *An "industry 4.0" project-based course* was carried out. (ii) *The creative climate questionnaire* was conducted at the end of the course with students' final products being evaluated by experts. Interviews were also carried out, where students were instructed to answer interview questions based on their experience in, perceptions on, and suggestions toward the course.

4 RESULTS

Excluding two invalid cases, there are in total forty-one effective cases for analysis. For the overall regression model, the eight dimensions of creative climate significantly explain 19.4% of the variance in creativity score ($F(8,32) = 2.200$, $p = .054$). We then aimed at finding which dimensions can significantly explain the creativity score, and results indicate that two dimensions have such effects. The one with a stronger effect is "sufficient resources" ($\beta = .469$, $p = .049$), and the other is "managerial encouragement" ($\beta = .396$, $p = .046$). The positive coefficients of both variables indicate that with an increase in "sufficient resources" or "managerial encouragement", students' creativity also increases.

Table 1. Multiple regression analysis for explaining creativity score on dimensions of creative climate

	Unstandardized Coefficient		Standardized Coefficient		
	B	*Se*	Beta	*t*	*p*
(constant)	55.318	10.665		5.187	.000
Freedom	1.686	3.528	.088	.478	.636
Challenging Work	-.282	2.665	-.022	-.106	.916
Managerial Encouragement	4.816	2.320	.396	2.075	.046
Work Group Supports	6.395	4.454	.512	1.436	.161
Organizational Encouragement	-5.637	4.341	-.443	-1.299	.203

Lack of Organizational Impediments	-4.291	3.848	-.278	-1.115	.273
Sufficient Resources	5.777	2.822	.469	2.047	.049
Realistic Workload Pressure	-2.199	1.842	-.230	-1.194	.241

5 DISCUSSION

The present study integrated creative-thinking strategies with a project-based course, finding that “sufficient resources” and “managerial encouragement” can predict students’ creativity performance. It is suggested that he application of creative strategies in the course may have successfully provided students with sufficient resources for tackling problems. For instance, in the interviews, many students gave credit to the “six thinking hats”; one student expressed that “the ‘six thinking hats’ allowed me to organize my ideas with structure” and that the method helped “create phrases in each category so there was something to discuss”. When students could not find essential resources at hand, they were nevertheless able to find creative ways to find replacement by using the “six thinking hats” method. Moreover, students were asked to make a list of the resources they needed for their projects during the “brainstorming” sessions, which very likely helped them know better about their resources. In addition, the requested resources, may it be tools, money, or other supplies, were provided immediately to students most of the times.

The increase of students’ creativity may also come from teacher’s encouragement. The design of the course may have encouraged the teacher to explain clearly the project goals to students, support students’ ideas, show confidence in them, and evaluate their works fairly and supportively. Furthermore, it is indicated that students did not show fear when proposing ideas, because the principles of “brainstorming” and “deferment of criticism” were emphasized by the teacher. All of the aforementioned elements of “managerial encouragement” resemble those of transformational leadership, which can increase employee creativity. This outcome is supported by the results of previous studies, such as that providing followers with confidence in them to excel at work [18], or that providing individualized consideration such as recognition and encouragement can both enhance creativity [19].

6 CONCLUSIONS

In the present study, “brainstorming” and the “six thinking hats” are applied in an “Industry 4.0” project-based course to enhance students’ creativity through creative climate. It is indicated that “sufficient resources” and “managerial encouragement” have positive effects on students’ performance on creativity. It is likely that creative strategies provided participants with thinking structures, when listing and organizing their resources, for example. Meanwhile, the teacher established a good learning environment by setting clear goals, recognizing students’ contributions, and encouraging ideas without harsh criticism. Thus, a conclusion can be drawn, that is, both mechanisms, “sufficient resources” and “managerial encouragement”, can help develop students’ creativity. Nevertheless, while the present study implies that creative strategies such as “brainstorming” and the “six thinking hats” do have positive effects, their effects manifested only in two creative climate dimensions. Thus, it is suggested that future studies employ other creative strategies to test whether they can trigger other aspects of the creative climate that can affect students’ creativity.

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Interdisciplinary collaborative learning of creativity and projects

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ABSTRACT

This study investigated the effect of interdisciplinary collaborative learning on creativity and communication. Students received lectures regarding Internet of things, big data, cloud computing, mechatronics, sensors, embedded systems, and cyber physical systems, as well as training in creative thinking strategies such as brainstorming and six thinking hats. Two classes of students participated in the study. In the experimental class (n=43), undergraduate engineering students (n=22) were partnered with graduate students from digital learning (n=21), whereas the comparison class (n=41) consisted of only undergraduate engineering students

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without interdisciplinary collaboration. In both classes, activities were conducted in groups. Each group created an interdisciplinary project. The data included their responses of using the creative thinking strategies and project proposal. The results found that the experimental class scored significantly higher in both the six thinking hats and brainstorming strategies than the comparison class. Moreover, the groups in the experimental class presented higher quality of proposal and provided considerably more descriptions of their projects. Through the interdisciplinary collaboration, engineering students were able to analyse a problem and examine a piece of work from multiple perspectives, create more ideas, and enhance written communication skills.

Conference Key Areas: engineering education research, curriculum development

Keywords: creativity, interdisciplinary collaboration, smart manufacturing

INTRODUCTION

This study investigated the effect of interdisciplinary collaborative learning on creativity and communication. Previous studies have revealed that engineering students are not comfortable thinking creatively, considering their designs for real-world contexts [1], and communicating effectively [2]. Council on Competitiveness (2005) has identified creativity or innovation as a major keystone of a knowledge economy [3]. We must equip engineering students not only with analytical and technical skills, but also with creative thinking [1]. The effort was mainly through art or design studio. Moreover, one of the factors that significantly affect engineering graduates' success in the workplace is oral and written communication [4]. Ford and Riley (2003) summarized four common approaches to enhance engineering students' communication skills: (1) integrating communication instruction within engineering curricula and including writing assignments within engineering courses, (2) collaborative instruction between engineering departments and communication departments, (3) promoting technical communication minor, and (4) establishing supporting systems such as communication and writing centers [2].

Previous effort on enhancing engineering students' creativity and communication was mainly through art or collaboration with the communication programs [1,2]. Inspired by McNair, Newswander, Boden and Borrego's (2011) interdisciplinary and multidisciplinary teaming approach [5], the current study created a course co-instructed by faculty from the education and engineering departments. The course focused on topics of Industry 4.0 and creative thinking. The graduate students from education and undergraduate students from engineering formed interdisciplinary teams that mimic the cross-functional and cross-disciplinary team structure of industry. They had to collaborate closely in all creativity activities and to write a proposal as they would work in the industry. Their performance in creativity and writing through this interdisciplinary collaboration was evaluated.

1 METHOD

1.1 Participants

Two classes of students participated in the study. In the experimental class (n=43), undergraduate engineering students (n=22) were partnered with graduate students from digital learning (n=21), whereas the comparison class (n=41) consisted of only undergraduate engineering students without interdisciplinary collaboration. The engineering students were junior or senior students, mostly from mechanical engineering and a few from electronical engineering. In both classes, activities were conducted in groups. The group sizes were controlled between 3 to 4 students. Each group created an interdisciplinary project, wrote up a proposal, and carried out the project.

1.2 Instruction

According to Borrego and Newswander (2008), for a cross-disciplinary engineering education collaboration to be successful, the participating parties should mutually understand and appreciate the nature of knowledge in each other's academic disciplines [6]. To build up this understanding, two faculty members from the education department and two from the engineering department as well as two students from each department have met every week since the semester before the course. All course content and activities were created, tested, and modified together.

The course met three hours a week for 10 weeks. Students received lectures regarding Internet of things, big data, cloud computing, mechatronics, sensors, embedded systems, and cyber physical systems, as well as training in creative thinking strategies such as brainstorming and six thinking hats. The discussing topics in the creativity activities were all based on the lecture topics and contributed to their team projects. At the end of a lecture, each group practiced the creative thinking strategies and attempted to integrate the lecture content into their project through brainstorming or six thinking hats. The group projects were chosen from the following topics: smart production in car industry (AGV, smart machine arm, and object identification system), intelligent vending machine, Gamebike (combining gaming and biking), and intelligent storage/ retrieval systems. The students had to turn in a proposal at the 10th week. They then spent another 8 weeks to carry out the proposal.

The education students played multiple roles as users, project managers and trainers for human resource. They were expected to learn engineers' perspectives from the engineering students and gain experience in leading a project and human resource training and development. The engineering students played a role as engineer. They learned to communicate with engineers from other fields such as electronic engineering, mechanical engineering and education. They would learn users' and managers' perspectives from the education students.

1.3 Data collection and analysis

The performance of the two classes in creativity and proposals was compared. Their responses of using brainstorming strategy were graded based on quantity/ the number of ideas (0-5), appropriateness to the topic (0, 1), practicality (0, 1), and uniqueness (0-3). The scores ranged between 0 and 10. For the six thinking hats strategy, the criteria were quantity/ the number of ideas (0-6), appropriateness to the perspectives of the hats (0-6), and uniqueness (0-3). The scores ranged between 0 and 15. Finally, the proposal was graded by two instructors with inter-rater reliability .83, and their length/word counts were calculated. The scores were compared using the t-tests.

2 RESULT

2.1 Creativity

The data of the experimental class showed that the digital learning students performed significantly better than the engineering students in the use of the six thinking hats strategy, but not in the use of brainstorming (Table 1). The education students were more able to evaluate a case or problem from different perspectives. However, they created about the same amount of ideas as the engineering students. Among the engineering students, the experimental class scored significantly higher in both the six thinking hats and brainstorming strategies than the comparison class (Table 2). In other words, even though both groups received the same creativity training, the experimental group, working with the digital learning students, were able to perform significantly better.

Table 1. Performance of creativity thinking between the engineering and digital learning students

	Engineering (n=21)	Education (n=20)	t(39)	p
Brainstorming	7.78(1.40)	8.24 (1.01)	1.21	.23
6 thinking hats	10.96 (1.27)	14.22 (7.28)	2.02	.05

Table 2. Performance of creativity thinking between the engineering students in two groups

	Experimental group (n=21)	Comparison group (n=48)	t(67)	p
Brainstorming	7.78 (1.40)	6.83(1.50)	2.45	.017
6 thinking hats	10.96 (1.26)	6.63(2.06)	10.09	<.001

2.2 Proposal writing

In comparing the proposal done by both groups, the teams in the experimental group presented higher quality of proposal and provided considerably more descriptions of their projects than those in the comparison group, $t(12.68)=4.13$, $p=.001$.

3 SUMMARY AND ACKNOWLEDGMENTS

Through the interdisciplinary collaboration, engineering students were able to analyze a problem and examine a piece of work from multiple perspectives, create more ideas, and enhance written communication skills. The results revealed that student interdisciplinary teaming is a successful approach to prepare engineers for the global and knowledge economy. The student collaboration creates invaluable learning experience. Future curricula may consider to offer such authentic learning experiences.

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Innovation in Continuing Engineering Education with focus on gender and non-traditional students' pathways

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ABSTRACT

The challenges of the 21st century call for supporting Continuing Engineering Education, a topic that is of increasing importance to universities worldwide. Furthermore, attracting new talents (women among others) into Engineering Education, is a key-element in contemporary higher education. Although the offer of studying programs alongside work has grown in recent years, there is still a need for research in context of accompanied studies and a lack of theory-based development in didactic concepts for learning professionals. This paper contributes to this research discourse and aims to generate new insights in a threefold way: (1) by specifying challenges and innovative approaches for accompanied studying programs in Business Engineering; (2) by explaining the theoretical framework for the methodical arrangement of exemplary engineering courses for non-traditional students; and (3) by describing first experiences with the concept during the development and implementation in selected engineering course. This paper also provides a new perspective on how to meet gender aspects. In this context, the influences of interdisciplinary orientation and student- centered course design were analyzed by using semi-structured interviews with female students.

Conference Key Areas: Continuing Engineering Education and Lifelong Learning, Engineering Education Research, Gender and Diversity

Keywords: Continuing Engineering Education and Lifelong Learning, University-Business cooperation, Curriculum Development, Attractiveness of Engineering Education, Gender and Diversity

INTRODUCTION

Recent socio- political and economic developments call for supporting Continuing Engineering Education, [1, 2]. Furthermore, attracting new talents into Engineering Education is a key-element in contemporary higher education. One approach to react to the strong demand is the broadening of the target group with an increased focus on non-traditional students, as in [3]. Although the offer of studying programs alongside work has grown in recent years, there is still a lack of theory-based development in targeted didactic concepts and associated empirical findings [4]. There is still a need for research in context of accompanied studies and student-centered contact with the specific target groups of learning professionals, e.g. [5, 6]. This paper contributes to this research discourse. In section 1, the term “non-traditional student” is specified and a professional master’s degree program for this specific target group is presented. Section 2 deals particularly with the theory-based course design for this specific type of students and illustrates the Model of Educational Reconstruction as an applicable framework for this methodical educational arrangement. Building on this, section 3 illustrates the implementation of the concept in selected engineering courses and describes first experiences with the concept. Section 4 covers gender aspects and debates, which framework conditions of the concept are beneficial to the motivation and participation of female students. Additionally, it addresses the opportunities that arise for occupational study programs. This approach generates empirically grounded knowledge on the theory-based course design for learning professionals and contributes to the translation of engineering education research to practice. Universities will have to face these challenges, in living up to the requirements of change processes in a sustainable manner.

1 CHALLENGES FOR CONTINUING ENGINEERING EDUCATION

1.1 Occupational study programs in Germany

Due to the demographic transformation into ageing societies and to the rapid pace of technological change, the European University Association recommended in their 2008 preamble [1] to open to continuous education. Since then, German universities have followed this central educational objective by opening universities to lifelong learning more intensively and by supporting flexible learning pathways, as in [2]. The group of lifelong learners is very heterogeneously, a differentiation is made in [7]. This paper focuses on the employed learners, those working full or part time during their studies. They show “…circumstantial diversity with age differences, disabilities, employment status, caring responsibilities or different financial backgrounds” [8]. Additionally, we find a diversity regarding their motivation, interest, and learning styles, e.g. in [7, 8]. In Germany, there are more than 130 engineering occupational master programs. Of these offered study programs, 13 are master programs in business engineering, which build the focus of this paper.

1.2 Professional master’s degree program in Business engineering: Research-to-practice contribution with focus on non-traditional students

To attract new target groups (women among others) as well as prospective students from working life, an innovative Professional Master´s degree in Business Engineering was conceived, that focuses on the intersection of management and technology. As a specific feature, the engineering master´s program is designed for *non-traditional students*, experienced professionals who do not originate from a technical field and who are repeatedly confronted with technical issues in the occupational context. The business engineering master’s degree is scheduled on the weekend. It is a four term (90 credit points) extra-occupational study program combining engineering content with business specialization[1]. This Master of Science program is now in its fourth iteration. The courses are designed with a focus on industrial production, combining the complex links between technology, business, and management. In the first semester scientific and engineering fundamentals are taught. The second and third semester include more detailed engineering courses as well as more complex topics

[1] To which extent these specific features of the study model are appealing especially to women, see within the scope of the qualitative study in Sec. 4.

that deal with the connection between technical and economic content. Throughout the entire study period, complementary courses offered that accompany the study (for example courses in leadership). The master course "Applied Engineering Sciences" presented exemplarily in this paper to explain the theory-based course design is from the field of scientific and engineering fundamentals.

2 THEORETICAL FRAMEWORK AND RESEARCH-BASED COURSE DESIGN OF THE EXEMPLARY ENGINEERING COURSE

2.1 The Framework of Educational Reconstruction with focus on continuing engineering education

The focus on non-traditional students´ pathways brings up the challenge of linking the course design and the individual learning process of the employed learners. This contribution dedicates to the research desiderates, e.g. [4-6], by presenting the Model of Educational Reconstruction. This theoretical framework was choosen because of its consistent student-centered conception. In general, the Model of Educational Reconstruction is a research framework widely used in scientific education, see [9, 10]. There are first results concerning the implementation of this adopted model in engineering, [11]. As a novelty, the model is implemented with a focus on employed learners, who do not originate from a technical field. Fig. 1 shows the generic model adapted for the field of engineering sciences and non-traditional employed learners.

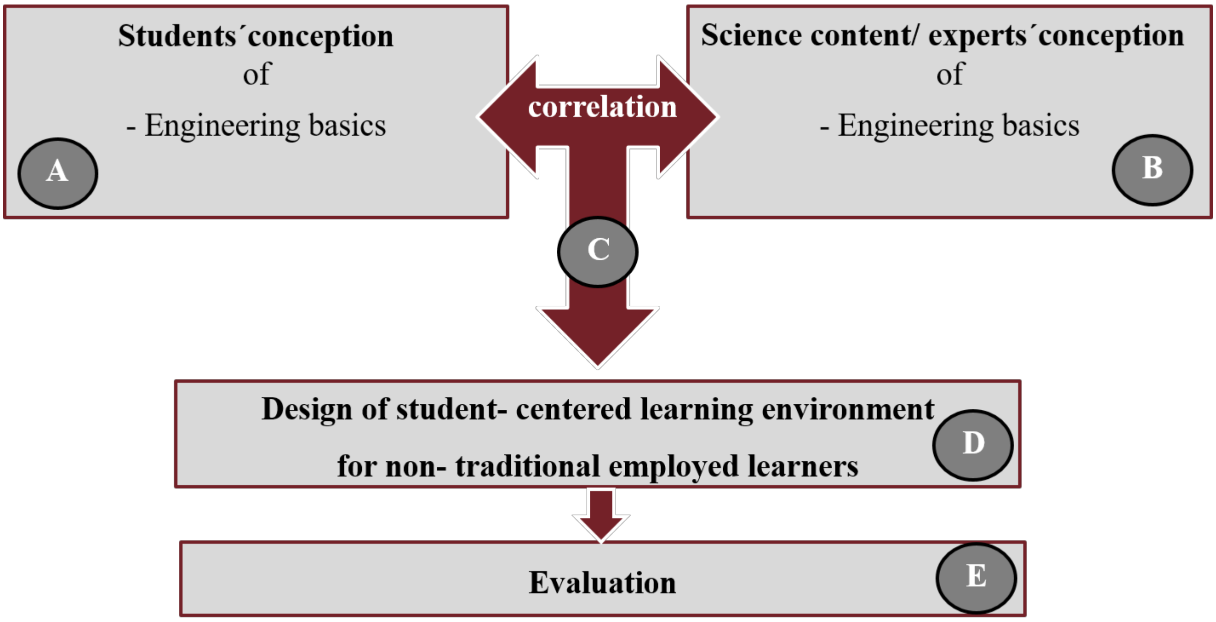

Fig. 1. The Model of Educational Reconstruction with focus on non-traditional employed learners: framework and methods used, based on [9, 11]

Constructivist learning theories, such as [12], build the theory framework, described by the teaching methodology triple [13]. There are three elements that interact- detecting of students' perspectives, the clarification of experts' conceptions, and the didactical structuring, [ibid]. The unique characteristic of this triplet is the equivalence of experts' conceptions and students' perspectives. To implement the model, all research steps A to E (see fig.1) had to be completed. In order to grasp the variety of aspects in a scientific manner, quantitative and qualitative research methods are used, according to the research steps A to E in fig. 1. Firstly, the students' conceptions about electro-technical concepts must be collected based on students' self-report (**step A**). Besides socio-demographic data, motivation to study, and background on technical subjects, the report contains questions for the employed learners about the current conception of engineering basics. At the same time, the scientific clarification as analysis from the literature is being prepared in **step B**. What do the concepts look like in science? What scientific models exist and where can coherences and limits of the imagination be found? In **step C**, the learners' understanding about the technical theory is reflected and differences between scientific perspectives and the perspectives of the learners are disclosed. Are there existing correspondences to the scientific model? At which point can you build on the learners' conceptions? As result of this correlation, research-based findings exist that prescribe what should to be regarded while introducing terms, concepts, and models to the students. Furthermore, with the goal of fostering the students' learning process, the result of the correlation proposes the appropriate interventions that are most likely to be successful. These interventions will be developed in correspondence to the framework of constructivist learning theories and implemented in an engineering teaching practice in **step D**, the result of this design phase is presented within the next section. A final evaluation by students' self-reports on knowledge base within the engineering topics (**step E**) delivers empirical evidence about the effectiveness of the courses. Further feedback from the students has been incorporated into the process of improvement of the course design.

2.2 Research-based Course design

The course design is based on the theoretical frameworks of constructivist learning theories, e.g. [12], and gender theories focusing on STEM education, e.g. [14,15]. Besides these theoretical frameworks, the analysis of the Educational Reconstruction has shown that the methodological-didactic construction of the courses needs to be understood consequentially from the learning process of the individual. The analysis of the students' conception revealed an extremely wide spread in every evaluated category (e.g. age, professional position, motivation). On the one hand, the self-rated technical backgrounds are similarly low. On the other hand, the non-traditional learners have expanded professional and everyday experience. This extended experience is not yet actively retrieved by the student as transfer knowledge, the link to the field of engineering cannot be made yet. Referring to the Model of Educational Reconstruction, these students' conceptions must be incorporated actively in the student-centered course design, to achieve an individual and optimal adoption for the best possible learning outcome and the development of the students' professional competence. The engineering fundamentals should be presented with a focus on taking up the professional context. The mentioned directives are anchored in the didactic concept, presented below:

- *Lectures* as on-site-events with practical examples selected from priority themes (presented by the teacher or the students),
- *Laboratory sequences* integrated into the lectures to anchor the link between theory and practice and to get hands-on experience, and
- *Guided self-study* with reflection and feedback phases (step-by-step conception of exercises fitted for the non-traditional target group, self-control must be possible permanently, online part with the teacher for feedback and reflection).

The theory-based course design guarantees appropriate learning activities for the non-traditional students and supports their learning process.

3 IMPLEMENTATION AND FIRST EXPERIENCES WITH THE CONCEPT

As an example, the implementation of the didactic design into the master course "Applied Engineering Sciences" is presented, currently running in its fourth iteration. The course provides the engineering basis for further specialist modules. Required outcomes are developing technical-methodological skills (e.g. basic techniques and engineering practices in the handling of simple electrical and mechanical problems) and developing practical knowledge (e.g. the analysis of equivalent circuits, the use of appropriate methods and instruments). The ***laboratory sequences,*** developed and adapted to the core statements of the course, are integrated to overcome the analysed specific deficits in practical preliminary knowledge. Driven by the theoretical framework, the laboratory session is often the starting point of the lessons. This procedure enables to address the unique deficiencies and baseline knowledge of the non-traditional students. Within laboratory group work, a continuous self-control of the students is applied and technical and methodical questions arise. Due to the small number of students, an individual support of the learning process during the experiments is possible, so the students can work out their necessary technical and methodical competencies. The ***guided self-study time*** was intended to adapt to the strong heterogeneity, to overcome deficits, and to strengthen the individual learning process of the employed students. Exercises concretely oriented toward the contents of the given lectures have been conceived that can be permanently worked on and that provide the opportunity for self-control. Detailed solutions are available for the student to validate their own considerations or to initialize the solving process. Content of the lectures is continually worked on, and a connection to the lectures is made by "do it yourself". In this way, the self-study time supports flexible learning styles and forms individual ways of learning.

First ***positive experiences*** with the concept are available. In the survey, every student self-reported a knowledge increase in electrical engineering. A further reference is the fact that every previous student completed the module and the exam successfully. In respect to the didactic course design, the employed students mentioned the practical laboratory part as very helpful. As additional effects, the integration of practical experiments shows an increase in interaction between teacher and students, a transfer of this culture of closer communication and direct feedback into the lectures became possible. Through the interweaving of economic problems and engineering education, a win-win situation for students and teachers is given. Not only is the transfer of new technologies into professional practice supported, but the students' input from their professional experience provides valuable feedback for the full-time courses.

4 QUALITATIVE STUDY TO EXPLORE GENDER ASPECTS

4.1 Targets and theoretical foundation of the study

Female employees are, as initially illustrated, clearly underrepresented in the STEM[2] sector and therefore are, alongside non-traditional students, a further and important target group. The aim of this qualitative study via guideline-based interviews is to analyze, if the professional master's degree program in Business Engineering can be a successful measure to acquire female potential for STEM-studies. Moreover, the framework conditions to successfully address women concerning a further education in engineering will be developed. An important role for the decision to study in the STEM sector play the self-efficacy beliefs, e.g. in [16]. The theoretical construct of self-efficacy was introduced by Bandura [17]. It describes a subjective confidence in one's own competencies to carry out actions successfully and to be able to meet

[2] STEM stands for science, technology, engineering and math.

expectations, e.g. in [18]. These statements are especially relevant in respect to the gender aspect, hence the construct of self-efficacy influenced the theoretical foundation of the guideline-based interviews and their evaluation. In addition, references to practical orientation and interdisciplinarity were examined in the interviews. Among others, Thaler and Hofstätter [19] highlight in this context a strong link concerning the decision for an engineering study.

4.2 Methodology and implementation of the analysis

Regarding the continuing engineering education, goals of the qualitative study were on the one hand to collect statements regarding the organization of the study model and to the learners' requirements. On the other hand, the interview study is used to identify the students' backgrounds, and the motivation for the field of engineering. For this purpose, the guideline covers the key issues mentioned above. Beside the socio-demographic data, educational background and the motivation to start studying were collected. The recorded interviews have been completely transcribed, while a memo was created for each interviewee. The assessment of the interviews in transcript was done in accordance with the procedure of qualitative content analysis [20] and under consideration of the in 4.1 explained theory. The interview survey includes seven interviews with first and second year female students of the master degree „Business Engineering". Hereafter, the female students will be denoted as interview person (IP 1-7). The women are between 22 and 30 years old, after a bachelor's degree in economics the female students have been working in the industrial sector.

4.3 Selected empirical findings and elaboration of the potentials for Continuing Engineering Education

The analysis of the interviews yielded results on several levels. In this paper, the focus lies on the aspects motivation to study, self-efficacy and student- centered course design. Almost all interviewees stated that the ***motivation to study a technological discipline*** is an insufficient technical know-how and a restricted judgement concerning technical issues and problems. Since they, as a consequence, felt constrained in their professional career an urge to study further in the technical area developed.

> *"And when discussions regarding specific topics arose, I reached my limit when I realized that my dialogue partner could tell me anything. I was not able to validate anything and only understood some problems after asking again or doing further research. That was when I realized that technology interests me and that I want to dive deeper into this topic."* (IP 4)

Concerning ***self-efficacy*** and confidence the analysis of the interviews distinctly indicates that a successful first degree and professional experience in the industrial context are to be interpreted as beneficial. IP 5 describes how she gained insight on the structures of an industrial concern through her occupation and detected that she possesses the skill to position herself technologically:

> *"(…) that is why I gathered all of my courage and said to myself: I have already achieved a lot and have proved myself in my first academic degree, which gave me strength once before. And now I will simply take my chances." (IP5)*

IP 2 shares this experience. She also gained access to technological coherences as well as dismantled barriers through her professional career:

> *"During my occupational experience, I realized that innovation is very fun-looking into the future and trying to see where the (technological) journey will go. But as innovation is always tangent to technology (…) I realized during my professional career that I am interested in these things as well." (IP 2)*

The selected statements confirm the results of the analysis, which prove an increased self-efficacy concerning the beginning of a technical study through previous occupational and academic achievements. Furthermore, the results show the particular importance of a ***strong connection between theory and practice within the master's degree program as well as the significance of interdisciplinary content and a close connection to the professional profile***. Most of the interviewees stated, that they only after the career entry got a clear understanding of professions and possibilities in the technological segment. As for example IP2, *"It was only during my professional career and with growing experience that I came to realize what engineers do".* It shows, that often a vague (or unattractive) occupational profile of the engineer exists, which discourages from a technical first degree. Within this context, Ihsen [21] constitutes that universities offer too few initiatives to renew outdated views on technical course of studies. Additional, the interviewees positively rated the interdisciplinary approach in conjunction with technical and economic study content. They especially underline the possibility to enhance an economic first degree with a follow-up degree in the technical area.

5 CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER WORK

Continuing Education and Lifelong Learning is an exciting and growing research area within higher engineering education. This paper presents a professional master program "Business Engineering", which innovatively targets students without a previous engineering degree. This specific non-traditional target group as well as female students were directly addressed while developing the program. The paper shows that the Model of Educational Reconstruction is well suited to execute a fitting course design for learning professionals in a theory-based manner. This student-centered framework is particularly valuable for the research discourse in this field. With the implementation of the theory-based course design a contribution to the translation of engineering education research into practice was made. The qualitative study with a focus on gender aspects underlines the positive impacts of a strong conjunction between theory and professional experience and of the interdisciplinary adaption of the master program. The next step is to expand the qualitative study on the full-time Master´s to deepen the gender-relevant insights and to explore potentials for the improvement of the master programs. Moreover, the results of the study provide valuable insights for specific student recruitment and counseling.

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Continuing Education for Technology Transfer:
Time matters.

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ABSTRACT

The aim of this article is to identify and analyse the potential influence of national cultures on the implementation of Continuing Engineering Education training courses, within the context of industrial technology transfer from the perspective of the transferors. Using the example of a Franco-Brazilian programme, which we were commissioned to analyse, our main focus will be to explore how the cultural dimension of time can have an impact on a training course with complex technological contents and high added value. Drawing on Trompenaars' notion of "cultural dilemmas" and that of Demorgon's "adaptive antagonisms", our methodology is based on the analysis of in-depth interviews with French experts

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training Brazilian engineers. The purpose of the present study is to identify the most pertinent profile for international trainers with intercultural competences which combine technological expertise, a broad vision of the industrial and cultural context and strategic planning and vision.

Key words: Engineering education, intercultural training, technology transfer, cultural dilemmas, Brazil, France

INTRODUCTION

Setting up high added value Continuing Engineering Education programmes to accompany technology transfer (TT) of systems, equipment and services, in an international, geostrategic and competitive context is both a sensitive and complex undertaking. In addition, cultural differences, such as variations in the relationship with time, space or people may present additional challenges. The in-house trainers in our study, which was commissioned by the technology provider, are confronted with the complexity inherent in this type of training programme. This can lead to strategic, commercial and technological contradictions. They are also exposed to often unknown cultural dimensions which can both represent additional problems and become indistinguishable from the technical difficulties of the programme. If we consider the anthropological dimension of culture as the "*solution to dilemmas"* [1], lack of knowledge of the clients' culture can create contexts which can potentially generate further dilemmas in addition to the original technical and human problems [2] [3].

1 TECHNOLOGY TRANSFER AND TRAINING

1.1 The impact of different concepts of time

The aim of this article is to identify and analyse the difficulties linked to differing concepts of time, one of the key elements which emerged during a study of a Franco-Brazilian TT training programme from the perspective of the transferors. These difficulties were often perceived by the engineer trainers with trainees from different cultures as paradoxical or as insoluble dilemmas. At the same time, we aim to distinguish between the different cultural and technical dimensions of the training programme, drawing on Trompenaars' notion of "*cultural dilemmas*" [1] and that of Demorgon's "*adaptive antagonisms*" [4] [5]. The use of these two notions can facilitate differentiation between the dilemmas inherent in TT and those linked with cultural differences, while also going beyond the descriptive elements of the "*cultural dimensions*" prominent in the Intercultural Management literature which can lead to overgeneralization.

1.2 The dilemmas of technology transfer training programmes

The objectives, contents and implementation of the TT training programme for Brazilian clients in this study, which is the first of its kind, require the engineer/trainer to adapt to three different elements: the requirements of the French company/employer, satisfaction from the Brazilian clients and the complexity and sensitivity of the technology involved in the transfer. Indeed, the trainer must sell his or her company's technology, train the clients and explain how the equipment and systems work but without giving away confidential information or intellectual property. Before embarking on any TT training programme, trainers need to reflect on three imperatives which we identified during the study as: the " *must, will, can dilemma*" [2]. They wonder how far they "*must*" go in transmitting their company's technological know-how without betraying their trust, how far they are "*willing*" to prepare their client to benefit from the technology autonomously and how far they "*can*" engage in their part time role as trainer, for their main remit remains technology design rather than transmission. Contradictions to do with their role and identities as engineering technologist, business engineer and trainer are thus added to imperatives at three levels (employer, client, technology). Finally, the international context requires systematic use of a foreign language, usually English and exposure to foreign cultures. This is the context, characterized by complexity and tensions, for the training programme for exporting industrial equipment to Brazil, which concerns hundreds of trainee-clients with diverse profiles, jobs, levels and backgrounds, to be trained over several years on sites in France and abroad. In France, the training sessions are in classrooms or directly on-site. The training budget, including logistics and other expenses represents hundreds of thousands of euros. The trainers selected by the company have only had a few months' preparation between the signature of the contract and the beginning of the training sessions, a time lapse which is considered too short, as we will see later. At the launch of the preparation for the training programme, the very first trainers displayed several different views concerning the duty, the willingness and the capacity of future potential trainers to design, organize and implement this training programme. This can be illustrated by two extreme reactions, firstly from an experienced trainer who had no doubts about the success of the whole of the programme: *"It's just common sense; each time there's a new trainee you always have to adapt your message to the population".* However, the trainer in the second example takes into account that, for many, the programme represents their first experience of a TT contract towards a foreign client, and seems to doubt the capacity of the company to run a training session: *This tightrope between what we can or cannot say."*

2 ANALYSIS OF A FRANCO-BRAZILIAN TT TRAINING PROGRAMME

2.1 Demorgon's six perspectives approach

In spite of all the contradictions and imperatives of the programme, the premise of this article is that they will not necessarily lead all the trainers to such insoluble dilemmas. In order to analyse the varying degrees of adaptation we draw on Demorgon's multisperspectivist approach where dilemmas are posited as "adaptive antagonisms" [4] [5]. Demorgon stresses the fact that situations can be presented as bipolar opposites but along a continuum, where we have to choose to decide and to act according to two or many demands [5]. This notion of adaptation which is culturally informed, chosen, deliberate and singular in each situation completes the notion of "*cultural dimensions"* in the Intercultural Management literature which is often applied as generalisations which can be measured and expressed as figures [6]. Demorgon considers that these cultural dimensions, such as monochrony/-polychrony, individualism/collectivism are pre-adaptive antagonisms to any decision or action, allowing, for example a trainer in a multi or monocultural context to act either by "*an immediate action*" or by a "*culturally informed action*" [5]. This "*culturally* *informed action*" in every singular situation through "*synchronic adaptation*" operates according to 6 perspectives [3]. These six perspectives include the *field* (religious, political, economic or technological) and the *levels* (individual, corporate and/or national) where cultural interactions take place. Demorgon makes a distinction between what is dependent on *self-organisation or disorganisation* (or dealing with uncertainty) and what is dependent on the *strategy* of the different actors. For example, a company needs a *strategy* which may or may not be culturally influenced, but its members must also be open and adaptable to unpredictable factors or changes which can, in this case, represent cultural or technological dilemmas. For Demorgon, culture is seen as an on-going process which can be changed over time, so s*ynchronic* intercultural situations should also be analysed from the *diachronic* or time perspective.

2.2 Description of a typical training sequence

The Intercultural Management literature identifies numerous cultural differences [7] which can be reduced to three major categories: relationships with people, space and time. For the purpose of this article we have chosen to focus on time, an aspect which was omnipresent in the interviews conducted with the trainers. Each training session is team-taught by two colleagues or by a hierarchical superior and subordinate. There are intergenerational, interdisciplinary and regional differences among the trainees, who are Brazilian engineers. The teaching team is made up of 26 men and 1 woman and represents three hierarchical levels. The classrooms are organized in rows, as in a formal lecture, and allow little contact with the trainees. Each training sequence, in lecture form, lasts 55 minutes, is pre-timed and limited to a maximum of 70 slides. It is prepared in a sequential and monochronic way with provision for a more polychronic phase of exchange and question and answers at the end. However, the trainees, who have received the slideshow one or two weeks before the training session, can look at the slides on their laptops in the chronological order chosen by the trainer or in any order of their choice, at their own pace. The models, tools etc. have been validated through a contractual process and cannot be modified in class. It is forbidden to use or create any other teaching aid. The presentation is filmed and can be interrupted or even cancelled at any time if the client's quality manager or a hierarchical superior from the supplying company deems it necessary. The contact specifies that English should be the working language which also has repercussions on the timing of the session, for, apart from some experienced experts, the trainers interviewed stressed the fact that the use of English added extra presentation time, ranging from 20 to 30%. In spite of this precaution and knowledge of the technical vocabulary made possible by a company lexicon with several thousand entries, they also considered there was a risk inherent in the use of the English language in this context.

3 THE INTERVIEWS CONDUCTED WITH TRAINERS

For the interviews with the trainers, given the complexity of technical training for TT, we looked for a training situation which was the most representative, standardised and recurrent as possible within the same training programme. We opted for training sequences implemented during a morning three- hour session with exclusively technological contents, using a lecture format according to the conditions negotiated and contracted between the supplier and the Brazilian client. By signing a confidentiality contract, we were allowed to observe several sequences of this programme, which allowed us to triangulate the contents of our interviews. These semi-directive interviews with trainers involved in training Brazilian engineers were conducted by three researchers. A total of 102 interviews and coaching sessions were carried out with trainers who were selected from a list of informal networks of both peers and hierarchical superiors. These lists were cross-referenced with the official lists provided by the company's Human Resource Department. The interviews were conducted between 2011 and 2012 on site, near to the informants' workplace. The informants were voluntary and provided with a guarantee of anonymity. Each interviewer followed a guide of seven questions per training sequence. The interviews lasted between 45 and 90 minutes and were recorded, transcribed and analysed.

4 DIFFERENT CONCEPTS OF TIME EXPERIENCED DURING THE TRAINING SESSIONS

In the following section we present three types of classes which reveal cultural dimensions connected with time. We differentiate, in order of complexity between introductory sessions, common core sessions and integrated systems sessions. The introductory sessions of the programme concern general principles and are taught by general engineers with contents which do not have high stakes and represent low industrial, technological or industrial risks. However, the informants were surprised by unexpected interruptions by the trainee/clients during the formal lectures, which is a good illustration of the cultural dimension of polychrony [8]. This situation becomes more complex when the training session deals with the technological problems specific to a common core session. Here it is no longer a question of transmitting more or less abstract knowledge but to transmit contents in the form of problem-solving activities which require a high level of participation from the trainees and reveals new relationships with time.

> *"For example, typically for the Brazilians you have to be careful (…) they don't use the past. The past for them is now. Everything which is going to happen afterwards is the future. You don't only provide results, you deal with work in progress. It's not because you've done something before. Everyone has their history, everyone has their experience but they are there from now and for tomorrow (…). When you presented your class it's good to say 'I've got 22 years' experience and 19, 000 hours of design'. But that, for them, was before. Now it's how is that going to benefit them. 'I'm going to be able to support you because your needs are to be able to create a system with automated elements which are a little more modern than what you have at the moment and in that phase I'm going to transmit my knowledge which you will be able to transmit to the next people etc. etc.' When the objective is presented like that (…) you can get the Brazilians on board."* (Part-time trainer and expert)

In designing the materials, the trainers take great care to involve the trainees by using a problem-solving approach, "*by dealing with demanding work in progress*". The ultimate aim is to achieve complete autonomy for the trainees so that they can train their future colleagues in their company in Brazil. This approach reveals cultural dimensions with different orientations to past, present and future [9] [1] which have a direct impact on the delivery of the training programme. In this example, the trainer tries to gain legitimacy through an experience which can only remain abstract and in which the trainee only sees an individual, professional status and, what is more, from the past. This only has a value if the trainees perceive that it can provide support for their future problem-solving in the immediate present of the sequence. The trainers as providers *must not, will not* and sometimes *cannot* (for strategic reasons or because they *cannot* have a complete overview of the industrial system as a whole) link together the past, present and future of the technological knowledge and know-how of their company without risking giving unauthorised information about experiences or innovations which must remain company property, regardless of the message transmitted to the trainees. Information about the future can only concern content specified in the client's contract and its sensitive character must sometimes remain vague for the trainers themselves, who do not have a global view of the whole system and equipment. On the other hand, the client-trainees try constantly to link past, present and future, in order to obtain information about recent concrete experiences, ongoing productions, or research and development projects so they can plan their own projects and future designs. This tendency for Brazilian culture to closely link past, present and future is confirmed in the literature [9]. This quote also reveals evidence of "*Long term orientation"*, or LTO, [6], another time orientation, closely associated with the previous one. This time orientation is not only also a characteristic of Brazilian culture, according to the literature, but reinforces the strategic element of the project which is planned to be implemented over several years. The link to the future, in an immediate present, forces the trainers to become very explicit and immediate concerning their objectives, contents and teaching design.

The second example is of an integrated systems session*,* which, although it was also designed as a lecture with a sequential and monochronic development, requires polychronic reactions from the trainer. The informants referred to the recurrent difficulty of the trainers who, in the here and now of the session have to have general knowledge of the global equipment system at the same time as highly specialised technological knowledge. In parallel, the trainers must also be extremely reactive to all the questions asked, although the profile of specialist giving priority to a monochronic development of the class in order to explain the technology in detail presents the risk of the expert transmitting too much information or confidential information and no longer being able to respect the timing of the training session.

> *"We have technological barriers which we have fixed ourselves which mean that we cannot reply to all of the questions. So, there, the trainer deliberately gives a vague answer. The question is asked again. And then finally the trainer is pushed to his limits. And the trainer, he falls down. He falls down literally on the spot, he collapses physically. We've already seen that. The trainer (….) bombarded with questions from the client, fell down. Because there's stress, the wish to do things right and eventually he is pushed to his limits and then he cracks up. So, that's why, during training sessions we systematically have the trainer and the Module coordinator. So that the Module coordinator can support the trainer and if it goes too far he can interrupt the class."* (Part-time trainer and expert)

The vast majority of the trainers interviewed highlighted the stress felt during the strictly timed training sessions when they found themselves with the "*must, can, will,* *dilemma*" [6] having to reply but not being able or willing to reply to a multitude of questions both general and specific, sensible or incomprehensible, without being able to distinguish between those that came from genuine learning needs or from manipulation.

5 SIX PERSPECTIVES TO ANALYSE THE TRAINERS' DILEMMAS

Demorgon's six perspectives theory, at the individual, *"synchronic level*" of the trainer, allows us to distinguish between antagonisms or dilemmas of cultural origin from other "antagonisms", while revealing the connections between them. For instance, with the cultural dimension of time, in a situation with a monochronic tendency, the trainer will adapt more easily to the "*must, can, will, dilemma*" [2], whereas polychrony, especially if it is experienced as pressure, loss of control and anxiety can transform it into an insoluble dilemma. Demorgon's theory highlights the fact that a synchronic cultural "*antagonism*" such as polychrony – monochrony can be reinforced by "*strategy*". In a power struggle between client and supplier the client is less inclined to adapt and can use, consciously or unconsciously, the cultural dimensions which suit him or her for strategic purposes. As we have seen, a group of Brazilian trainee-clients can strategically use polychrony which they culturally manage better than the French trainer, who is also almost isolated, to obtain more information, particularly if the trainer is already limited by contract to a monochronic, pre-arranged training sequence. The strategies used by the trainees are themselves generated and reinforced by the "*globalised, technological, competitive*" activity sector [5] of TT. It is therefore fundamental to know as much as possible about the history of the client's culture in its *"diachronic perspective"*. In this way, the French trainer can or cannot manage the complexity that Demorgon calls "*self(dis)organisation*" which characterises any international context at an "*individual, corporate and national level*". This is consistent with research by Lin & Berg [10], who concluded that, while prior international experience on the part of the transferor could enhance TT performance, it could also increase their bargaining power by limiting the flow of technical information.

CONCLUSION

In this article we have highlighted some of the influences of cultural dimensions on training Brazilian engineers by French trainers in the context of TT. We have explored and analysed how the national culture of the trainees can have an impact on the implementation of a training sequence with complex technological content and high added value. Demorgon's six perspectives theory, particularly the notion of "*adaptive antagonisms*" allows us to isolate, observe and analyse the cultural dimensions influencing the interaction. These "adaptive antagonisms" can be of different kinds and represent contradictions or mixed messages in a national, monocultural situation but additional cultural dimensions in an international context. We have concentrated more specifically on the "adaptive antagonisms" linked to time but as we have seen, synchronic adaptation also integrates interpersonal and spatial relationships. The interviews with trainers and our classroom observations revealed the emergence of two opposite and complementary trainer profiles, either implementing a training sequence through "*immediate action*" or "*culturally informed action*". The coexistence of these two "*antagonisms*" in the training team led the company to set up trainer partners in order to reduce the risk of failure for the client, the company and the trainers themselves. It appeared that the profile of senior expert with a global view and specialised knowledge was more able to deal with certain "*adaptive antagonisms*". At the company level, these senior expert trainers, demonstrating a capacity for long-term planning, also tried to participate in the company strategy from the outset of the negotiations for TT. In the contract, they tried to reduce in advance the influence of a training session organised in an exclusively monochronic manner, for they already realized during the negotiations that their Brazilian partners were extremely polychronic. The part-time expert trainers with a stabilised professional ethos seemed more confident in public and more easily able to appropriate the cultural ethos of different countries [3] in complex and difficult geostrategic situations. This led them, in the company under study, to set up very informal networks to exchange good practice. Based on this reflexive practice, it would seem pertinent for them to co-design training programmes for trainers in international contexts including intercultural pedagogy for industry.

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Collaborative PhD Tracks: Working Together for Sustainability

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ABSTRACT

This paper elaborates on a form of university–industry cooperation called 'collaborative PhDs'. Engineers working at companies or governmental organisations get the opportunity to do a PhD at the university. The aim of these science-based collaborations between academia and industry is to increase the impact of research on sustainable development. However, to fulfil this promise, how should doctoral engineering education for collaborative PhD tracks look like? A literature search, a benchmark on successful doctoral education programmes, in-depth interviews with 10 PhD candidates and their supervisors, as well as observations of meetings, revealed the requirements for a track that is consistent with the relationship and everyone's interest in it, as well as the needs and talents of the PhD candidate. The conclusion of the research is that collaborative PhD candidates come to the university to conduct research, but do not intuitively fit into the academic world. Some feel squeezed between their jobs as, for instance, project managers on the one hand and doctoral candidates at the university on the other hand. This research led to 10 recommendations for setting up a track within the graduate school.

Conference Key Areas: Continuing Engineering Education and Lifelong Learning / University-Business cooperation

Keywords: Contract PhD students, doctoral education

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INTRODUCTION

Many institutes for higher education maintain good contacts with business and governmental organisations. It is from these contacts that professors regularly recruit talented candidates for PhD projects. These PhD candidates remain stationed elsewhere and their companies granted them part-time leave to follow a PhD programme. The added value of this PhD research can be significant. Knowledge and insights developed by PhD candidates can be applied in practice immediately – which is in line with the 'Europe 2020' goals and the need to speed up the process of sustainable development.

The Deltas Infrastructures & Mobility Initiative (DIMI) and Delft Energy Initiative (DEI) at Delft University of Technology (TU Delft) have launched a pilot for this group of PhD candidates who are employed not by the university, but by companies or governmental organisations interested in the same research themes. They are called ‘contract PhDs’ and their trajectories ‘collaborative PhD tracks’. These PhD candidates defend their dissertations at TU Delft. Their theses must meet the same requirements as the fulltime employed PhD candidates at TU Delft.

The goal of these collaborative PhD tracks is to jointly develop knowledge that is useful for transforming practice and at a sufficient level for a PhD defence. These PhD tracks strengthen the cooperation between the university and industry and this interaction increases the potential for innovation. Especially for research with a link with practice, these PhDs have an advantage over regular PhDs in understanding the context and having access to practical data. However, what sounds appealing in theory is not so easy in practice. Not only is the time available for research a problem for externally based candidates, but they spend a relatively large amount of time learning to do research (searching for literature, formulating research questions, selecting research methods, etc.). It is sometimes years since they last attended university, which means that they possess a great deal of practical experience but need to be trained as scientific researchers. Furthermore, former research shows that implementing innovations generated by PhD projects is not a matter of course. Moreover, the competences needed for a future career in industry and the competences needed in a PhD project do not always correspond [1]. An important condition to fulfil the promise of sustainable development is that these collaborative PhD trajectories run smoothly. The research question therefore is: *What does doctoral engineering education for collaborative PhDs look like?*

We will discuss doctoral education from the broader perspective of the knowledge triangle, the interplay between research, education and innovation (chapter 1). In chapter 2, the interests of all parties involved will be discussed. In the third chapter a need analysis will be described. A series of interviews were held with supervisors, PhD candidates and companies in order to identify the specific needs of each party and be able to co-design a tailor-made track within the graduate school. In chapter 4, the outline of the track will be revealed. Finally, the conclusion describes in 10 recommendations how these pathways can be made more efficient and more effective.

1 COLLABORATIVE PHD TRACKS IN THE PERSPECTIVE OF THE KNOWLEDGE TRIANGLE

Joint PhD projects are a promising form of research collaboration, connecting universities to firms or governmental organisations. One organisation alone cannot achieve the goal of developing critical knowledge for sustainability challenges. For example, to accomplish integrated design and management for resilient, durable infrastructures or system integration in the energy sector, universities, companies and other institutions need to collaborate for a longer period of time. Technological change and economic success no longer depend solely on capital and labour; they require knowledge and other intangible entities like the interaction between public and private organisations and their ability to refresh: 'renewal capital' is an equally important driver of national growth [2]. A PhD project in this context therefore entails not only the training of an individual to become a scientific researcher, but also a collaborative project in which new knowledge is developed that should lead to innovation. These collaborative PhD projects are a way to implement the knowledge triangle.

The Lisbon Agenda introduced the knowledge triangle at the dawn of this century in order to enhance Europe's competitiveness. As shown in figure 1, the knowledge triangle links together research, education and innovation, with special platforms and processes on its three sides. It replaces the traditional one-way flow of information, from research to education and from educators to students, with a circular flow between the three corners of the triangle.

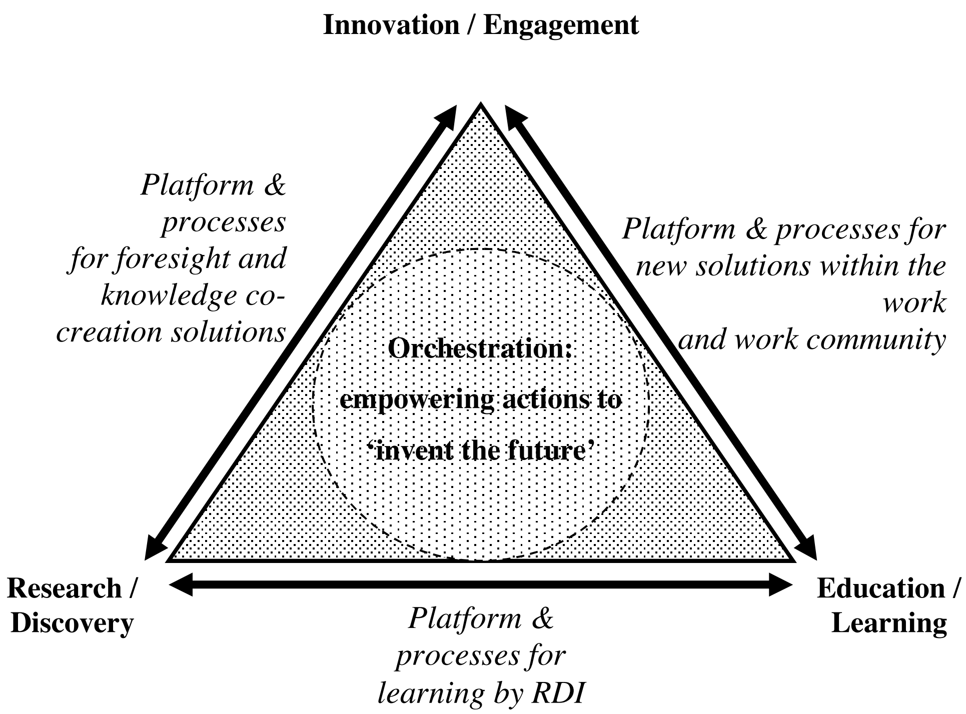

Fig. 1. The Knowledge Triangle [3]

The concept of collaborative PhDs covers all corners of the knowledge triangle. First of all, these PhD candidates are lifelong learners, educated to be scientific researchers. Doctoral education is therefore a form of continuing engineering education. Moreover, these PhD candidates can be involved in ordinary education. Second, the learning process of PhD candidates is strongly linked to research. The aim of the PhD study is to contribute to science, therefore delivering new knowledge. At the same time, these PhD candidates are incorporating the third corner of the triangle in ensuring sustainable economic or societal innovation. So this PhD concept offers tremendous opportunities for education, research and innovation, provided that these processes are well designed.

2 NEED ANALYSIS: THE INTERESTS OF ALL PARTIES INVOLVED

2.1 Introduction

As Pronk et al. [4] showed, one of the success factors of a collaborative research project is clarity regarding everyone's objectives, benefits and risks. This paper briefly discusses the interests of the parties as described in the introduction.

2.2 University

The benefits for the university can be found in various policy documents. Contract PhD candidates and their employers address research themes that are relevant to business and society. By initiating these joint projects the university satisfies both their research and knowledge valorisation efforts in developing, implementing and commercialising their knowledge [5]. The Dutch government also encourages cooperation between universities and industry. The government wants to increase the number of PhDs in business since they contribute to increasing the competitiveness of the country [6].

The interests of academic staff regarding contract PhDs differ. We interviewed four TU Delft professors who are supervising several contract PhDs for approximately one hour each. The semi-structured interviews were conducted using an interview template, and were recorded and transcribed. All transcripts were then analysed. Furthermore, in the past two years, we spoke with many researchers and professors about their experiences during and after various meetings: from informal one-to-one meetings with PhD candidates to official go/no-go meetings. In this paper, we focus on why the professors are interested in starting with a contract PhD and the problems they encounter during the various phases of the PhD project. We leave out of consideration the various ways they supervise these PhDs.

The manner in which university supervisors get involved in these collaborative PhD projects differs. A professor and PhD candidate may know each other for a longer time: 'It's someone from my network' or ‘It’s a former student’. It also happens that an organisation, for example the tax authorities, asks a university professor to conduct joint research on innovative ICT applications. The university professor may then select one or more PhD candidates from this organisation.

Although there are several reasons to collaborate, university professors tend to be mainly interested in PhD candidates who will contribute to their own research. The goal is to publish jointly in the scientific journals in which they themselves publish. The greatest advantage of contract PhD candidates is that they have direct access to cases and data. For more context-related research, the experience of the PhD candidates has been viewed as very important: 'The contract PhD candidate understands much better what is going on at major complex infrastructure projects than a recently graduated PhD candidate who has been at the university only.' The other side of the coin according to some scientists is that contract PhD candidates, due to their experience, do not always want to contribute to the core of their research. Furthermore, the supervision of a contract PhD can take a great deal of time. That also has to do with the fact that the quality of the PhD candidates – and thus the quality of the dissertations – varies significantly.

Contract PhD candidates may also contribute to education. They can give guest lectures in order to link theory and practice or supervise graduate students. In addition to these well-known forms of education, contract PhD candidates can be enablers of innovative teaching methods, for example through participation in living labs, MOOCs, sustainable business idea competitions and so on. This collaboration increases awareness of sustainable development among the next generation of students.

2.3 Private and public organisations

The best chance for success is when the parties already collaborate [7]. Pilots with collaborative PhD tracks could therefore be set up with companies and organisations already involved with the university. Public and private organisations participate in collaborative PhD projects for different reasons, since they have different goals and responsibilities. In this section, we concentrate on companies. It was possible to provide an overview of the benefits for some companies by consulting several representatives (mostly managers) from companies in various consortia.

Companies are currently experimenting with how they can shape and maintain their intellectual capital. It is important for companies to offer individual employees interesting opportunities in their career development. The company gets more motivated and better trained employees in return. A partnership with a university also means access to the academic world. The development of cutting-edge technology and the foresight knowledge of universities will make these companies able to strategically respond to future developments or, in other words, ‘co-create the future’. They can take advantage of the good name and reputation of the university, thus increasing the market value of the company. Furthermore, by participating in a PhD project, several regular students can also become involved (e.g. for their Master’s thesis), which can help to attract young talent. Managers, however, differ in expectations of the applicability of the results. They mainly appreciate three or four related studies with intermediate results instead of one large-scale study.

2.4 PhD candidates

We also studied the needs of PhD candidates employed elsewhere. Because their talents and expectations are at stake the most, we decided to elaborate in more detail on the needs of the PhD candidates.

Ten PhD candidates were interviewed for approximately 90 minutes each (see table 1). The semi-structured interviews were conducted using an interview template with seven blocks of questions. Each interview started with general questions about the motivation for, background to and subject of the PhD study. The second block contained questions concerning the educational programme. This was followed by blocks of questions about the problems they encountered during the first year, during the next phase and during the final phase of the PhD project. Finally, there were questions relating to external partners: what kind of support do you receive from your company? There were also questions about the future: what do you want to do with the end result, both in terms of career development and implementation of the results? The interviews were recorded and transcribed. All transcripts were then analysed using the seven blocks of questions. Respondents 7 to 10 were followed and interviewed several times during their first year. In this paper, we focus on the motivation to start a PhD project and the problems encountered during the various phases of the PhD project.

Table 1. Background of the respondents and their motivation to start a PhD

	Background (study)	**Background (work)**	**Motivation**
1	Information science, MBA	Employed at energy company	- Value for the enterprise - Personal development
2	Mechanical engineering, process technology in chemical engineering, executive MBA	Self-employed (formerly employed at [different] energy company)	- Academic career
3	MTS, HTS	Teacher at university of applied sciences	- Achievement of highest level on this topic
4	Electrical engineering	Teacher at university of applied sciences	- Interest in the topic
5	School for business administration and economics (in Dutch: HEAO), Master's in Information management, register accountant	Registered accountant at Dutch tax and customs administration, and trainer at a university	- Tax administration has opted for ICT research - Own motivation: more freedom and appreciation, higher level of teaching
6	Civil engineering	Staff/policy-making position at a water supply company	- Expert training, possibly to find a new job
7	Civil engineering	Project manager	- Achievement of highest level on this topic
8	Civil engineering and MBA	Self-employed (senior consultant)	- Intellectual challenge - Develop own ideas - Useful for company
9	Bachelor's in mechanical engineering, Master's in business administration	Project manager at design and engineering firm	- Validate scientifically what works of current activities
10	Internal relations (political science)	Innovation manager (energy company)	- Real contribution to discussion in society - Personal driver/ intellectual challenge

The motivation to do a PhD varies significantly, as table 1 depicts. All PhD candidates showed an interest in the topic and made an effort to change something essential in the current situation through their research. However, their ultimate goals vary, from a future academic career to innovation in their company or public organisation. In the case of two teachers at two different universities of applied sciences, it was less clear what they want to do with their PhDs; it might be self-evident that they use them in their teaching, but it could also be that too little attention is paid to the career prospects of teachers at universities of applied sciences with PhDs.

Success factors identified by the five first-year PhD candidates were: 1. quality of the supervisor; 2. flexibility to organise work; 3. substantive linkage PhD topic with work. What they described as difficult in their first year was: 1. finding the right scientific frameworks and getting it on paper; 2. continuous balance: work and PhD, practice and science; 3. administration around it.

A large part of the interviews was designed to create an overview of the problems encountered by PhDs or what they feel is lacking in the process. Some of these problems can be easily solved. Administrative problems and IT-related problems, for instance, can be solved through a proper intake process and by appointing someone who is responsible for organising an effective infrastructure.

This study, however, revealed other problems that are less easy to solve since they arise from differences between the domain of practice and that of scientific research. These PhD candidates work in a company (domain of practice), often for many years, and are motivated to solve a practical problem. They want to make a difference in practice through their research, which is another starting point that differs from an internal PhD candidate carrying out a subsidised project with a proposal written by a scientist. The translation of a practical problem into a scientifically interesting research question is a difficult issue for most contract PhD candidates. They use their own reference scheme to solve this issue, but that approach falls short. Some supervisors also speak a language different from what the PhD candidates are used to. In terms of the Model–Activity–Utility (MAU) framework, developed by Sjoer, Nørgaard and Goossens, universities and companies operate on the basis of different models, carrying out different activities. What is more, the incongruity regarding the production of satisfactory results poses problems for contract PhD candidates and universities [8].

3 OUTLINE FOR A COLLABORATIVE PHD TRACK

Collaborative PhD tracks that overcome these problems should be designed in such a way that they are consistent with the relationship and everyone's interest in it, as well as the needs and talents of the PhD candidate. This approach should lead to more successful doctoral education programmes. Based on the results of this study and the existing literature, a tailor-made track within the graduate school of the university was defined. We consider the first year of the PhD study in this paper.

There are several ways to get in touch with the university to arrange a PhD trajectory, and there are different paths to success. Candidates differ in backgrounds, motivation and skills. The route outlined below is therefore not a fixed but a flexible way to better support contract PhD candidates.

Preparatory phase
Every PhD candidate starts with an on-boarding module: ‘From Practice to Science’. The goal is for the candidate to discover what a PhD trajectory requires, what the differences are between the world of practice and that of science, and the language that goes with it, and to combine practical and scientific relevance towards an initial research proposition. Meeting other contract PhDs and exchanging experiences are

also part of this module. This module can be done online or blended, and results in a F2F presentation of a (written) research proposition. At this meeting, there are important points on which agreement should be sought:

a. Are all parties sufficiently interested and is the theme of sufficient strategic and scientific interest? The subject of the research should be interesting for all parties involved. This sounds obvious, but all parties (PhD candidate, organisation and university) should be committed to a topic for a longer period of time. So the topic should be the core business, or sufficiently related to the future core business, of the organisations involved.
b. Are all those concerned committed to carrying out or supervising this PhD research for a longer period, namely towards the go/no-go decision (after approximately 1–1.5 years and then after approximately a further 3–4 years)? All parties should be able to work together for a longer period of time. Continuity in the guidance team is a well-known success factor. A recommendation for all parties involved is to invest in the relationship and to pay attention to the selection criteria for all supervisors. For instance, selection criteria for the company supervisor might be the ability to contribute to the implementation of the results and a knowledge level on the specific topic that is roughly in the same range as that of the allocated university supervisor (cognitive proximity) [9]. On the side of the university, we observed that many PhD candidates prefer to be supervised by professors they already know; however, other professors might be more appropriate.
c. Are the expectations, wishes and conditions of the company supervisor, the university supervisors and the candidate discussed satisfactorily? Topics such as time allocation, funding, guidance, intellectual property rights, and publications need to be agreed upon. As stated by Salimi [10], the success of a collaborative PhD project is more likely if there is joint decision-making, which is more often the case when there are mutual dependencies. That means that no one party controls all critical resources.

As a result of this meeting an agreement should be signed and the candidate should be registered at the graduate school as a PhD candidate.

First year

At the start of a doctoral education programme, a short introduction module will be assembled in consultation with the PhD candidate. Many compulsory start-up modules at graduate schools are designed for a different target group and are done at times that are not suitable for part-time PhDs. Further, a workplace with ICT facilities, a library card, etc. is provided by the faculty of the PhD candidate. Moreover, the candidate will be invited to join the scientific community related to his/her topic. It is recommended to see whether several collaborative PhD projects can reinforce each other. The projects contribute to the same body of knowledge and, although PhD candidates run their own projects, they could meet, share insights and stimulate each other.

The graduate school of TU Delft has an extended doctoral education (DE) programme. The DE skills training programme offers a range of courses and activities that help candidates to acquire transferable skills, increase their disciplinary competences and obtain research skills. In the guidance team of the contract PhD candidate, training needs should be discussed. Nearly all PhDs examined are especially in need of research-related skills. They follow courses such as The informed researcher (at the library), Research design and, if relevant ‘How to make a questionnaire and conduct an interview' and 'Discovering statistics using SPSS'. Additionally, 'Scientific writing in English' courses are popular. The knowledge acquired in the courses should be applied immediately in their own research, which is often part of the course design; however, it also requires on-the-job coaching afterwards. For the courses to teach discipline-related skills or transferable skills, customisation is needed since the offerings are not tailored to this target group. Therefore, the process of getting a PhD and the needs and talents of the candidate should be discussed regularly. HRM plays a role in this.

Many graduate schools and doctoral education programmes have a form of performance assessment in place. At TU Delft, the products for the go/no-go decision point after 12–15 months usually consist of a research proposal and/or a first article. It seems best to structure a collaborative PhD track according to a set number of scientific articles. In this way, progress is made visible and there is always something to celebrate. In addition, it fits the rhythm of engineers, who often work in successive projects. Further, the extent to which the cooperation runs smoothly can be assessed. Most contract PhDs are goal oriented. They want to know the precise requirements for the deliverables for the go/no-go meeting and they make a detailed plan of how to get there.

Not all PhD candidates, however, survive their first year. As literature shows, there are several reasons why doctoral candidates drop out: they either do not come up with a concrete research question or they receive inadequate guidance [11]. Yet, for contract PhDs there are some other pitfalls such as their unrealistic expectations (over- or underestimation), not being taken seriously as PhD candidates, little physical presence so that they become 'invisible' and socially isolated. In all cases, guiding a contract PhD is guiding a 'transition' in identity development [12]. We believe that the aforementioned ingredients of a collaborative PhD track strongly support contract PhDs and their companies in overcoming these problems.

4 CONCLUSION AND RECOMMENDATIONS

This paper answers the question what does doctoral engineering education for contract PhDs look like in order to run smoothly and fulfil the promise of sustainable development. By interviewing stakeholders (PhD candidates, university supervisors and company supervisors), observing several collaborations, consulting literature and performing a benchmark with other university programmes, we identified requirements for a collaborative PhD track within a graduate school. We identified 10 recommendations to better train an experienced engineer in becoming a scientific researcher while at the same time facilitating a collaborative project in which new knowledge is developed that should lead to innovation.

1. Set up the collaborative PhD track as a multi-year collaboration between the PhD candidate, the employer of the PhD candidate and the university.
2. Introduce a preparatory phase. One of the most difficult issues for contract PhDs is the transformation of the world of practice into the world of science. Important questions for an engineer who has been away from university for quite some time are: what are the scientific frameworks, which language fits with it and what makes a topic scientifically interesting? This phase ends with the presentation of a written research proposition that is interesting for all parties involved.
3. Discuss expectations and formalise commitment with the employer of the PhD candidate before starting a PhD trajectory.

4. Offer an introductory programme in consultation with the candidate instead of a compulsory programme at inconvenient times. This approach is critical to setting a tone of flexibility and enabling rather than standardisation and bureaucratising.
5. Create a tailor-made educational programme. The actual educational needs should be defined. The focus should be on what is really necessary for this PhD candidate to become a good scientist, not on obtaining all kinds of exemptions. It appears that mainly research-related skills are important. Time, attention and credits should be based on what is needed.
6. Ensure that administrative and ICT-related issues are well organised and not time consuming. Many candidates from industry are used to a well-organised infrastructure in which they receive good support.
7. Facilitate relationships between contract PhDs themselves and between contract PhDs and their scientific peers. It is important to ensure that this PhD trajectory is not a lonely journey, but a joint effort in a learning community that pays off for all parties.
8. Better prepare academic staff, since adult learners' needs differ from those of regular students. Furthermore, collaborating in a multidisciplinary PhD track is not always easy. It requires specific training expertise and 21st-century skills that cannot be transferred through an information meeting, but requires forms of coaching and peer review, or more unusual arrangements such as job rotation. For example, a daily supervisor can work for a certain period of time in a company, and the PhD candidate can provide regular education.
9. Assign a dedicated person for collaborative PhD candidates within the graduate school.
10. Ensure a link between the subject of the PhD candidate and the strategic needs of the company of the PhD candidate; It increases the chance of success substantially.

A collaborative PhD track can be valued as a multi-year collaboration between PhD candidate, employer and university, with an explicit commitment for a longer period of time. In these tracks, the flow of academic expertise into practical application is accelerated and the promise of sustainable development can be realised. The focus is not only on the best practice, but also on 'the next practice'. And above all, collaborative PhD tracks ensure an interesting learning process for all parties involved.

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Co-designing a new engineering curriculum with industry

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ABSTRACT

Global changes in technology and culture have drastically altered the needs of industry and society and thus the graduate engineering workforce required to fulfil those needs. With access to the whole body of human knowledge at the touch of a fingertip, learning is moving away from merely accumulating a body of facts. Instead, future engineering graduates need skills in assimilating and applying knowledge, thinking creatively, working collaboratively and in being agile and embracing change. As the mind-sets, skill-sets and knowledge-sets needed by engineering graduates shift, so too must higher education curricula, shifting to an experience-based curriculum that stimulates students to develop personal qualities and professional skills alongside the specialist knowledge of their field. Authentic, relevant student experiences that give engineering students employable skills cannot be created in isolation in universities thus a new curriculum is needed, to be co-designed with employers, industry experts, professional bodies and education specialists. This paper describes efforts underway to develop a new engineering curriculum with industry-led and project-based learning experiences running throughout the course and will propose a model for the co-design of this curriculum with industry and other key stakeholders.

Conference Key Areas: Curriculum Development, University-Business cooperation, Skills and Engineering Education

Keywords: Curriculum, Work-integrated learning, Industry, Project-based learning

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INTRODUCTION

Global changes in technology and culture have drastically altered the requirements of industry and society and thus the graduate engineering workforce required to fulfil those needs. With access to the whole body of human knowledge at the touch of a fingertip, learning is moving away from merely accumulating a body of facts. Instead, future engineering graduates need skills in assimilating and applying knowledge, in thinking creatively and collaboratively, in being agile and embracing change in a rapidly transforming world. Many studies and reports have called for a new approach to engineering education (e.g. Beanland and Hadgraft [1] and King [2]), indicating that different types of engineers are needed in 21st century engineering practice. Being able to synthesise information to solve problems and create solutions has become far more important than the ability to remember facts. The ability to understand diverse consumer needs and communicate in many ways with diverse stakeholders is key to working in a global market.

Research in engineering education has seen some changing trends with the increased application of project-based learning, team work, flipped classrooms, use of open online resources, and more authentic assessment practices. Work-integrated learning opportunities, along with study tours and service learning projects, are also becoming more widely valued. However, many changes are incremental and often project and team work, study tours or placements are either optional extras or bolt-ons that are experienced once by the student but not integrated into the curriculum of the wider degree program.

Though most, if not all, accreditation bodies include professional skills as a crucial part of their accreditation processes [3-5], there has been a conflict between the growing awareness that engineers need to possess a wide array of personal and professional skills and the perceived need to cover in depth all of the increasing technical content [6]. Professional skills such as communication, teamwork and ethics are also often perceived as difficult to teach and assess, though there are many examples of how these skills can be taught if explicitly targeted (see Shuman, Besterfield-Sacre [7] for a comprehensive overview).

A recent report by the Australian Council of Engineering Deans made a series of six recommendations to ensure engineering schools can meet the country's future need for engineers, one of which was for "educators and industry practitioners to engage more intensively to strengthen the authenticity of engineering students' education" with "more effective and increasing input from industry practitioners to engineering schools in the processes of setting, reviewing and tracking attainment of graduate outcomes" [2]. Authentic and relevant student experiences that develop professional skills in engineering students cannot be created in isolation in universities. For true work-integrated learning a new curriculum is needed, including experiences that must be co-designed with employers, industry experts, professional bodies and education specialists. Engineering practitioners and employers are best placed to identify the tasks that engineering graduates will be faced with and the knowledge-sets, skill-sets and mind-sets they need to accomplish those tasks.

This paper outlines a framework for co-designing a new engineering curriculum with industry, moving away from a content-driven curriculum and towards an approach aimed at developing professional skill-sets and mind-sets. Though this work is undertaken in an engineering context within Swinburne University's Engineering Practice Academy, it is with the aim that the consultative curriculum co-design process will be applicable to other discipline areas in higher education.

THE CONSULTATIVE CURRICULUM DESIGN PROCESS

1.1 Overview

An overview of the curriculum design process is presented in Figure 1. The curriculum co-design requires input from a range of stakeholders which is fed into an iterative development process under the overarching goal of developing graduates with skills allowing them to work as the engineers of the future. The proposed course requires an experience-based rather than a content-focused curriculum with the objective that the engineers graduating from the course must be employable. Employability is defined by Yorke [8] as having “skills, understandings and personal attributes – that makes graduates more likely to gain employment and be successful in their chosen occupations, which benefits themselves, the workforce, the community and the economy.”

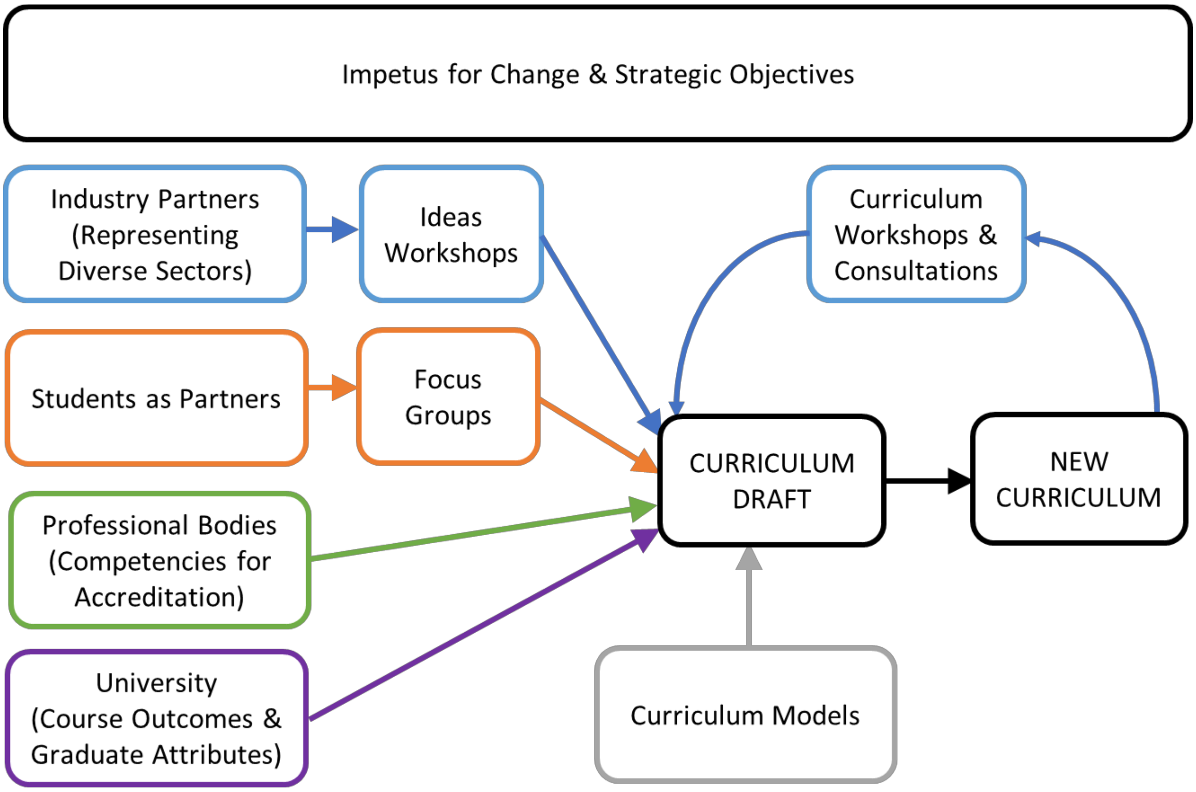

Fig. 1. Framework for consultative curriculum co-design

The structure was adapted from the “Design your Discipline (DYD)” stakeholder consultation process [9] which was created to facilitate curriculum renewal in undergraduate programs. In the DYD process consultation takes three forms: “stakeholder consultation” to gather a full range of views from diverse stakeholders, “consensus building” to come to an agreed position and “engagement for change” to engage stakeholders in future change processes. Engagement for change is particularly important in this case as the industry partners being consulted are also being sought as partners in the delivery and assessment of the future course and their input will ideally be ongoing. The aim of engaging industry partners in the creation of the curriculum at all stages is both to benefit from their expertise and give them a sense of ownership of the program being developed.

Current engineering students have also been consulted as part of the process and it is the intention to involve future cohorts of students in the shaping of the curriculum and other aspects of the course. ‘Students as partners’ is a growing field of study in the education community and has emerged from international acknowledgement that new approaches are needed to engage students in their learning [10]. The UK Higher Education Academy (HEA) has published a framework for engaging students as partners based on dozens of documented case studies, one outcome of which is the advocacy of student partnership in curriculum design and pedagogic consultancy [11]. This paper however focuses on consultation with industry; forthcoming papers will describe the consultation process with students.

Close consultation with relevant professional bodies is also necessary. Engineering Australia (EA), as the professional body responsible for accrediting engineering programs, was consulted. The EA Stage 1 competency standards for Professional Engineers (the competencies deemed necessary for entry to practice corresponding to an accredited 4-year Bachelor or 5-year Masters degree) were used as a guiding input to the curriculum design. The specific university course objectives and graduate attributes for current engineering courses, which were developed from and closely linked to the EA competencies, were also used alongside broader university-wide values and goals.

1.2 Ideas Workshops

Potential partners were identified by the University collaborations and partnerships team, leveraging existing research connections and seeking new partnerships. The aim was to connect with a range of partners spanning as broad a range of organisations as possible spanning, for example defence, mining, not-for-profits, spanning small local businesses to large multinational corporations. Sixty-six individuals from fifty organisations participated in three workshops, split between on-campus and external venues, and morning and afternoon time slots, so participation was not limited by geography or scheduling.

The workshops included a presentation about the vision of the project but the main focus was not on telling the participants what was being planned, but asking them for their input. The key messages were that anything was possible and that genuine collaboration was integral to the whole enterprise.

The bulk of the workshop consisted of three micro-sessions where questions were posed and discussed by the industry participants in mixed groupings, consisting of participants representing diverse industries to encourage varied viewpoints. Notes were taken by project members and groups fed back to the wider workshop, with common themes emerging, but some groups providing unique insights.

The themes of the micro-sessions were:

- Emerging industries and industry trends
- Skill-sets and mind-sets required of graduates
- Tasks performed by graduates

The notes were then transcribed and coded to identify key themes and the frequency with which they were mentioned. Many of the themes occurred across all the micro-session discussions, for example “interdisciplinarity” and “working globally”. The data on emerging industries and trends was used to inform the creation of new specialisms and aspects of the discipline-specific curriculum and are not discussed further in this paper. The data on the professional skills and personal traits required by engineers were used to inform the next stage of the curriculum design process. A summary of the outcomes of the workshops was also circulated to all industry participants.

1.3 Analysis and framing

Information about the skills required of the engineering graduates of the future gathered from the ideas workshops was combined and compared with Engineers Australia's Stage 1 Competencies and the university's own stated Engineering Competencies as well as considering more general competencies such as Lominger's 67 competencies to measure a person's effectiveness in business [12].

These were grouped by the authors who debated the structure and links between the skills and organised them into common themes. Innovative curriculum and learning models (e.g. Thinking Like and Engineer [13] and Vitae [14]) and other conceptual frameworks for categorising competencies such as constellations and multidimensional representations [15] were used as examples of how to organise and structure skills into a curriculum framework. Once a curriculum framework was agreed on, the skills and competencies identified from the ideas workshops and other sources were mapped to the framework to form a draft curriculum.

1.4 Curriculum development workshops

A total of 21 participants from 18 organisations took part in the second set of workshops. Most participants had been involved in the ideas workshops but 6 were new participants. The format was similar to the previous workshops, with the initial presentation explaining the current curriculum draft and the facilitated group work involving discussion around the draft with feedback presented by group members. The questions industry participants were asked to focus on were:

- Sense check/ communicative validity – the new skills curriculum is very different from traditional content focused curriculum. Does it make sense?
- Are there any skills missing or requiring more emphasis?
- How could this framework be used to describe graduates given it is very different from a transcript listing grades and subject areas?

The draft curriculum was updated after the first workshop and the second draft dissected by participants during the second workshop. The process of co-designing a curriculum with industry partners is necessarily iterative and can be repeated as many times as needed until the additions to the curriculum are negligible. Individual consultations with industry partners on specific aspects are also useful at this stage, to further break down particular curriculum points.

1.5 Draft curriculum

The draft curriculum is presented in figure 2. It consists of four domains, each of which is divided into three sub-domains.

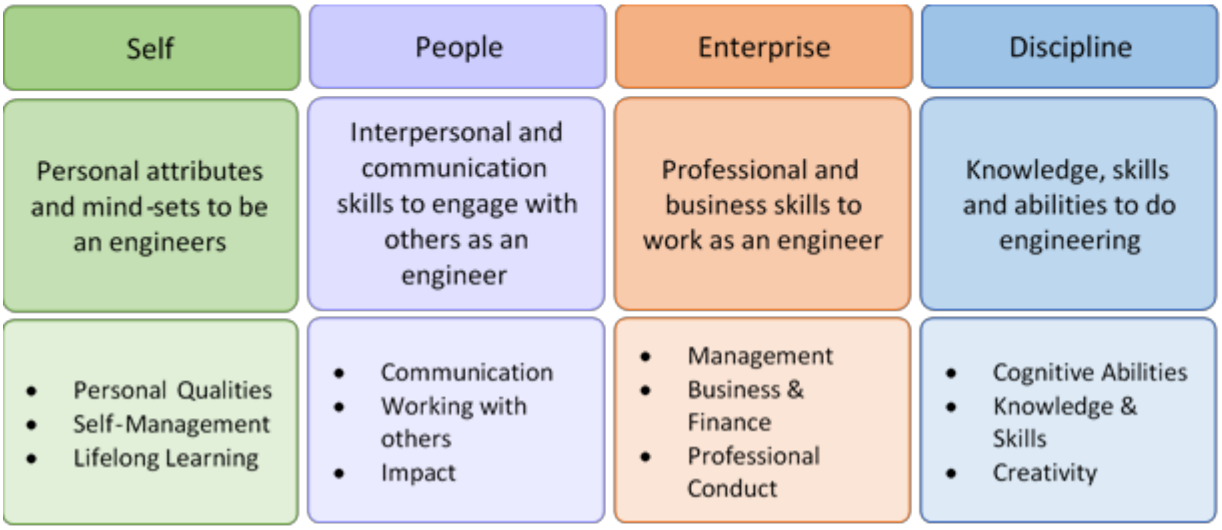

Fig. 2. The domains and sub-domains if the draft curriculum.

2 REFLECTION

Industrial partner buy-in and enthusiasm are key, and so far have been extremely high. From the very first ideas workshops, industry participants were using language such as “we” when discussing the creation of the new course and in later workshops participants discussed having actively promoted the new curriculum ideas in their organisations and with external clients.

The draft curriculum, with a much greater focus on professional skills and personal attributes than in traditional programs, seems to have resonated with workshop participants, with for example one industry partner summarising this as “I hire a person, not a position”. This is consistent with results from the literature where attitudinal and non-technical competencies have been rated as just as if not more important than technical knowledge [16].

The areas of the curriculum that industry partners particularly contributed to in the curriculum development stage were around business and enterprise and the knowledge and skills graduates would need in this area. They also contributed to expanding on the self-management, career literacy and creativity skills that graduates would require. In areas such as communication and disciplinary knowledge the model was validated but not much expanded upon after the initial ideas workshop.

There are several areas for further study that have emerged from the curriculum design workshops. One repeated theme in the early ideas workshops was that of “the fundamentals”, with industry participants adamant that these still be taught without a clear explanation of what this meant, and without clarity as to whether participants from different industry sectors all considered the fundamentals to be the same knowledge set. This requires further investigation as to what fundamental maths, science, or other engineering knowledge is required by modern engineers, as opposed to what is expected to be taught based on an adherence to what has been taught in the past.

Another area of investigation is how to present the outcomes of this curriculum model in a form that can be understood by employers in the manner of a transcript. This is an important concern as a key goal of this new degree is to increase employability, and any improvements in graduate skills are moot if these skills cannot be communicated clearly to potential employers. More than just listing the competencies graduates will have demonstrated, there will also need to be a way to differentiate between students and elucidate in which curriculum areas they have developed specific depth.

An interesting aspect of this process of co-designing a curriculum with industry participation is how quickly ideas and language develop. Initial curriculum discussions among the academics were based around a skills triad of knowledge sets, skill-sets and mind-sets. After the ideas workshops it rapidly became apparent that four categories were required, with skill sets subdividing into business & enterprise skills and communication & interpersonal skills, each of which were deemed sufficiently crucial and broad in terms of sub-themes to warrant separate consideration. The language also evolved, for example from initially talking about 'mind-sets' during the consultation process to subsequently using terminology such as 'self' and 'personal attributes'. This continual development of language and ways of thinking is a sign that the co-design is more than a token consultation, but is a true co-construction of ideas.

Another interesting aspect of the process is how it can be applied in many areas beyond engineering. This is both in terms of the transferability of this framework to other disciplines, indeed it is designed to become part of a wider university strategy, but also in terms of the curriculum developed. The curriculum, while containing some aspects unique to engineering practice, is primarily comprised of competencies that apply to many if not all fields of study in higher education.

3 CONCLUSION

A rapidly changing world requires engineers with different skills sets and thus radically different engineering degrees to prepare them for the workplace. This paper has proposed a framework for co-designing the curriculum for such a degree with industry partners, ensuring its relevance in the workplace and the employability of graduates from such a program. The process has been embraced by industry partners who have contributed enthusiastically to the initial ideas workshops and by providing insights into subsequent draft versions of the curriculum. The process is ongoing, both in terms of the academic-industry collaboration in developing the curriculum but also beyond into industry partners being involved in the setting, delivery and assessment of student projects. Future work will involve establishing frameworks for this continued collaboration as well as expanding on aspects of the curriculum such as "fundamental knowledge" and investigating how such a revolutionary curriculum can be presented to potential employers in terms of explaining graduate capabilities. Overall, the process of co-designing the curriculum has been one of true collaboration that has been positively received by industry partners and is the first step in creating an engineering degree with high levels of industry engagement leading to highly employable graduates.

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The Influence of Government Supported CPD of Engineers on the Development of Engineering Education: TPU case

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ABSTRACT

The article is focused on continuing professional development (CPD) of engineers and technical professionals in Russia supported by the Government and its influence on the development of engineering education. Specifically, it explores a case of Tomsk Polytechnic University (TPU) that took part in the Presidential programme for advanced training of engineering personnel (2012–2014) and in the Departmental special-purpose programme aimed at professional development of engineers and technicians (2015–2016). The study incorporates a mix of quantitative and qualitative methods that helped define the common features of engineering CPD programmes and provided insights into the contribution of such programmes to the development of engineering education and university-industry collaboration. In particular, according to the study results the delivery of government supported CPD programmes for engineers encouraged the engagement of industrial companies in development and delivery of bachelor's and master's degree engineering educational programmes. The TPU experience is a good example for development of university-industry strategic partnership that might result in a higher quality of engineering education.

Conference Key Areas: Continuing Engineering Education and Lifelong Learning, Engineering Skills, Sustainability and Engineering Education

Keywords: engineering education, continuing professional development, university-industry collaboration, engineering personnel

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INTRODUCTION

Continuing professional development (CPD) of engineers and technical professionals is an essential factor for the development of human capital which tends to have a great impact on industry evolution and economic growth. The ability to be engaged in independent lifelong learning and to undertake CPD activities sufficient to maintain and extend his or her competence is considered to be one of the key professional engineer's competences [1–5]. Traditionally, continuing engineering courses include in-house training and courses offered by educational institutions, private organizations or professional communities and associations (see e.g. Engineers Ireland, Engineers Australia). In Japan, continuing engineering education in enterprises and research organizations is widespread [6], whereas in other countries the universities continue to be the preferred CPD provider while they combine research, innovation and education [7, 8]. The involvement in engineering CPD is a challenging task for the universities and it requires an active interaction between the university and the company during development, delivery and evaluation of CPD courses [9].The European bodies such as the European Society for Engineering Education (SEFI) and the European Federation of National Engineering Associations (FEANI) are working in the field of engineering CPD, they set CPD policy and guidelines as well as provide methodological support and launch some relevant projects and studies in the field.

The formation of highly qualified engineering personnel belongs to the strategic objectives of the Russian Government. In 2012, the Executive Order On the 2012–2014 Presidential programme for advanced training of engineering personnel was signed. The programme aimed at professional development of engineering personnel working in the strategic industries as well as at modernization of engineering education in the context of strategic partnership of Russian educational institutions and industrial companies. In 2015, it was decided to launch the similar Departmental special-purpose programme aimed at support and promotion of the best practices in engineering CPD.

1 DEPARTMENTAL SPECIAL-PURPOSE PROGRAMME "ADVANCED TRAINING OF ENGINEERING PERSONNEL IN THE YEARS 2015–2016"

1.1 Programme description

The Departmental special-purpose programme "Advanced training of engineering personnel in the years 2015-2016" was launched by the Order of the Ministry of Education and Science of the Russian Federation in May 2015 [10]. The programme is aimed at support and promotion of the best CPD courses for engineers and technicians in the priority areas of science and technology in the Russian Federation including nanosystem industry, information and telecommunication systems, life sciences, sustainable use of natural resources, transport and space systems, energy efficiency, power saving, nuclear power engineering, etc. The programme goal is to increase the contribution of educational institutions to the development of human resources in strategic industry fields that might stipulate technological modernization of economy, increase in labour productivity, and creation of highly productive jobs.

The objectives of the programme include the development of public-private partnership by professional development of engineering personnel and modernization of content and educational technologies of engineering CPD courses. The training courses that take part in the programme must be developed by Russian educational institutions in collaboration with targeted enterprises and industrial companies, which have to provide no less than 50% co-funding. Besides engineers, there are master's degree and post-graduate students, as well as engineering educators among the trainees.

The programme incorporates the concept of the Triple Helix of university-industry-government relationships proposed by Etzkowitz [11]. The universities develop and deliver engineering CPD courses in strong collaboration with industry companies to develop human resources of engineering enterprises and this process is supported by the government and industrial companies. All the participants of this process have got their benefits: the government gets highly qualified engineering personnel and economic growth as a consequence; the universities develop the relationships with industry followed by an active engagement of employers in their activities; the industry companies can reduce expenses on staff professional development by sending the employees to the government supported CPD courses chosen in competitive selection process.

1.2 Programme results

The competitive selection of CPD courses for engineering personnel organised by the Ministry of Education and Science of the Russian Federation allowed choosing 385 professional training courses for engineers and technicians offered by 82 educational institutions. Over 8000 engineers and technicians employed by 751 industrial companies took part in these courses. Under the terms of the programme no less than 20% of trainees (1804 persons) went on on-the-job training on the premises of Russian industrial companies and engineering centers, no less than 10% (979 persons) went on practical training on the premises of industrial companies and engineering centers abroad in 38 countries [10].

The feedback results gathered from CPD courses' graduates show that 96% of respondents point out, that the competencies developed during the training courses are highly relevant for their professional activity. About 90% of industrial companies recognize that this government supported programme has contributed a lot to improvement of the company effectiveness [12].

One of the important results of the Departmental special-purpose programme "Advanced training of engineering personnel in the years 2015-2016" is the creation of the engineering CPD courses' pool incorporating the best practices of vocational education and training courses (see http://engineer-cadry.ru/).

2 GOVERNMENT SUPPORTED CPD COURSES FOR ENGINEERS: TPU CASE

2.1 Course development and delivery

Tomsk Polytechnic University (TPU), one of the leading engineering universities in Russia took part in the Departmental special-purpose programme "Advanced training of engineering personnel in the years 2015-2016" as well as in the 2012–2014 Presidential programme for advanced training of engineering personnel. As a result of the competitive selection in the frameworks of these programmes TPU gained the right to deliver about 40 CPD courses. More than 700 engineers and technicians from 125 Russian industrial companies were trained (see *Table 1*).

Table 1. Results of the government supported programmes aimed at the advanced training of engineering personnel: TPU experience

Year	Number of programmes	Number of trainees	Number of companies
2012	4	117	23
2013	10	187	27
2014	9	135	25
2015	6	90	12
2016	12	197	38
Total	**41**	**726**	**125**

In 2016 TPU gained the right to deliver 12 CPD training courses for engineering personnel, it was the best result among the Russian universities that took part in the competitive selection. The high quality of TPU courses was recognized, their common features are described below.

1) ***Targeted course design.*** The collaboration between a university and a company is critical in the establishment of an effective framework for professional development [9]. The intended learning outcomes of each CPD course offered by TPU were developed based on stakeholder needs and requirements of correspondent professional standards. The outcome-based approach helped develop in-demand training courses, which graduates demonstrate professional and general (non-technical) competencies relevant for a particular industry field.

2) ***Adoption of the best practices in engineering education.*** Being the member of leading international organizations and initiatives dealing with engineering education including SEFI, IGIP, CDIO Initiative, etc., TPU adopts and implements modern teaching and learning approaches. The university has developed a coherent CPD system aimed at the development of faculty competencies [13]. The system combines over 40 training programmes that contribute to the development of key faculty competencies such as ability to design, deliver and evaluate educational programmes in compliance with national and international standards, ability to use various educational technologies and active learning methods, ability to conduct students' project and research work, etc. Besides, there is a list of programmes aimed at the development of specialized faculty competencies connected with design, implementation and operation of engineering products, systems and technologies.

   The CPD courses for engineering personnel offered by TPU are delivered using collaborative learning, problem-based learning, project work, integrated learning experience, e-learning technologies (some courses are supported by e-courses in LMS Moodle). Each course consists of lectures and practical studies in university premises (more than 72 h), internship in Russian leading industry companies and engineering centers (to 50% of trainees), and internship abroad (to 30% of trainees). The trainees develop professional theoretical skills in addition to the practical work skills; they also gain the experience of working abroad in an international team which is very important in the process of internationalization of engineering profession.

3) ***Facilities and equipment.*** The CPD courses are provided with engineering workspaces, laboratories and modern equipment to emphasize hands-on

learning. TPU has a few authorised centers (Hughes-TPU Center, SolidWorks Authorised Training Center, Accreditation, Monitoring and Diagnostics Regional Center, etc.). The created learning environments allow developing practical engineering skills (see CDIO engineering workspaces [14]).

4) ***Strategic partnership.*** TPU has a well-developed network of contacts with Russian and foreign industrial companies, research and engineering centers. It helped find partner for development and delivery of CPD courses for engineering personnel to provide on-the-job training and internships in Russia and abroad.

2.2 Findings and interpretation

The results of a questionnaire delivered to the industrial companies which employees took part in the TPU professional training courses show their positive attitude towards these government supported CPD programmes. The main results are the following:

- 70% recognize the need for lifelong learning.
- 67% are ready to take part in TPU career events for students and graduates.
- 67% have a wish to be involved in students' job-placement.
- 56% want to make some research projects in cooperation with TPU.

All the respondents expressed a wish to be engaged in development, delivery of engineering educational programmes and assessment of learning outcomes. It is a crucial result in the context of quality assurance of engineering educational programmes, as according to the accreditation criteria of the Association for Engineering Education of Russia (AEER) used for educational programmes in engineering and technology, the employers as the main stakeholders have to take part in the definition of learning goals and intended learning outcomes, as well as in the evaluation of programme graduates [15].

The companies' representatives highlighted in their interviews that the government supported CPD courses helped save financial expenses for the professional development of their staff. They also pointed out a high quality of methodological support and qualification of faculty members engaged in training courses. They confirmed that the engineering CPD courses offered by TPU are in full correspondence with current industry needs.

These results demonstrate that delivery of government supported CDP courses for engineers and technicians has a positive impact on both industry companies and educational institutions as well as on the development of industry-university collaboration.

3 SUMMARY

The development of human capital is a crucial aspect for economic growth of any country. The government supported programmes for advanced training of engineers and technical professionals realized in Russia in 2012-2016 could be a good example of public-private partnership by professional development of engineering personnel. The case of Tomsk polytechnic university shows that these programmes have a positive influence on the development of engineering education. In particular, they contribute to the engagement of industry representatives in design and delivery of engineering educational programmes. The companies which employees took part in CPD courses offered by TPU expressed a strong wish to develop partnership with the university.

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Fueling Industry 4.0: A professional doctorate in technology

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ABSTRACT

Competitiveness, quality and sustainability critically determine the viability of enterprises on both sides of the Atlantic and around the world. Today's technologically advanced age requires systematic research and development – not the abstract theory-focused research so typical of university, basic and PhD research – but rather the use-inspired, agile and practically-focused research called for in *Pasteur's Quadrant* [1] and more recently the Swiss National Science Foundation [2]. The paper presents a model for a *professional doctorate* program that develops leaders with such skills at the very highest end of this capability spectrum. Such individuals are in demand, particularly by high-tech industries operating at new intersections of technologies. The program is delivered by a hybrid fusion of distance- and campus-based learning technologies and it is focused on enhancing the effectiveness of industry and other enterprises by providing high-performance leaders possessing a significant technological R&D skill set and inclination. The authors see the professional doctorate as essential to any nation seeking to evolve Industry 4.0 [4]. Our concept draws upon the experiences of colleagues in Europe, Australia and in North America and is enhanced by lessons from American entrepreneurship, innovation and distance learning.

Conference Key Areas: 2 • University-Business cooperation
6 • Open and Online Engineering Education
8 • Curriculum Development

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Keywords: Doctoral Programs
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INTRODUCTION

This paper presents a work in progress, namely a model for a professional doctoral program designed to meet the current and future needs of contemporary European, North American and Asian business and industry for people with a high level of technology research and development skills and leadership strengths. In particular, the R&D personnel needed to fuel Industry 4.0 are addressed by this program. The paper is organized in three major sections beginning with an Introduction that highlights the core of the need and rationale for the program. Subsequently in section 1 the model for the program is described and in section 2 an implementation plan is presented. The paper's third section shares the authors' conclusions and envisioned next steps.

Clearly competitiveness, efficiency, quality and sustainability are critically important and increasingly interrelated characteristics that determine the future viability of enterprise on both sides of the Atlantic and in fact around the world. These characteristics require systematic research and development – but not the abstract theory-focused research that is so typical of university, basic, and PhD research – but rather the use-inspired, agile and practically-focused research called for in *Pasteur's Quadrant* [1] and more recently the Swiss National Science Foundation [2]. Fraunhofer IAO's Gelec & Wagner [3] noted in particular the increasing need for, and importance of, highly skilled R&D personnel as a major conclusion of their 162 advanced industry study. Clearly these such people will be instrumental in achieving the aspirations associated with Industry 4.0 and, because of their need to understand and have systems level competencies with technology, it is exactly the engineering and technology programs that SEFI encompasses that will have major responsibility in supplying such personnel.

But, where do the people come from who have such skills and inclinations? Particularly those at the very highest end of this capability spectrum? These are the individuals who are most in demand--particularly by high-tech industries -- many of which operate at new intersections of technologies, and/or disciplines, previously thought unrelated.

This paper presents a design for a professional doctorate in technology that will be delivered via a hybrid fusion of distance- and campus- based learning technologies. The program is focused on enhancing the effectiveness of industry, business and other enterprises by providing high-performance leaders armed with a significant technological R&D skill set and motivation to innovate. Importantly, an implementation plan that offers applicability to other institutions around the world is also presented in the paper.

The authors see the professional doctorate as essential to nations seeking to evolve Industry 4.0 [4] because such a doctorate is a flagship strategy for developing the critically needed cohort of technologically capable leaders. Our concept draws upon the experiences of colleagues in Europe, Australia and in North America, enhanced by lessons drawn from American entrepreneurship, innovation and distance learning. For example, Maxwell [5] reported on the rise of this kind of doctoral degree in Australia, New Zealand, England, the Netherlands, and Canada. They encompass disciplines in Business, Design, Technology, Engineering, Industrial Technology, and Engineering Science. In addition, Doctorates of Professional Studies exist in a further variety of fields ranging from Bioethics to Nursing. According to Zusman [6] by 2013 there were professional practice doctorates in at least a dozen fields in the U.S. with “more than 10,000 degrees awarded just in 2011-12 and roughly 35,000-40,000 students enrolled. (p.1)”

1 WHAT IS A PROFESSIONAL DOCTORATE?

The authors concur with Kot & Hendel [7] that currently, there exists no singular, widely accepted, and formally approved, definition of the professional doctorate. We have, however, noted, based on a synthesis of what European, Australian, and North American thought leaders and early deployers of such programs consider as the core tenets and essential characteristics of professional doctoral programs, that such degrees share enough commonalities to enable formulation of a way forward. In an initial exploration of the concept the authors [8] found that:

> Simply put, professional doctorates focus on in-depth, cutting-edge technologies, innovation skills and the leadership and effective organization of teams and corporate units. Such programs seek to prepare advanced level practitioners for business and industry rather than basic researchers for the academy. The goal is enabling increased competitiveness, sustainability and socially responsible endeavor. (p.27).

Insight as to the nature of a professional doctorate can be derived by comparing it to the characteristics of the traditional research-based Ph.D. Table 1 (on the following page) presents a detailed analysis of similarities and differences with respect to 19 key attributes as adapted from Bourner et al. [9]

In addition to the design characteristics highlighted by Bourner, in the American context, it is of critical importance that the Purdue University Polytechnic Institute’s program meets the US Government’s requirement to be recognized as a doctoral level degree. The US Department of Education’s Integrated Postsecondary Education Data System (NCES, n.d.) (IPEDS) classifies “Doctor's degree-professional practice” as follows [10]:

> A doctor's degree that is conferred upon completion of a program providing the knowledge and skills for the recognition, credential, or license required for professional practice. The degree is awarded after a period of study such that the total time to the degree, including both pre-professional and professional preparation, equals at least six full-time equivalent academic years.

Because of this requirement, and as depicted in Figure 1, the Polytechnic Institute’s professional doctorate program was designed to build upon a master’s degree and consequently the doctorate is structured to enable completion in 2-3 years or as determined by the student’s intensity of pursuit.

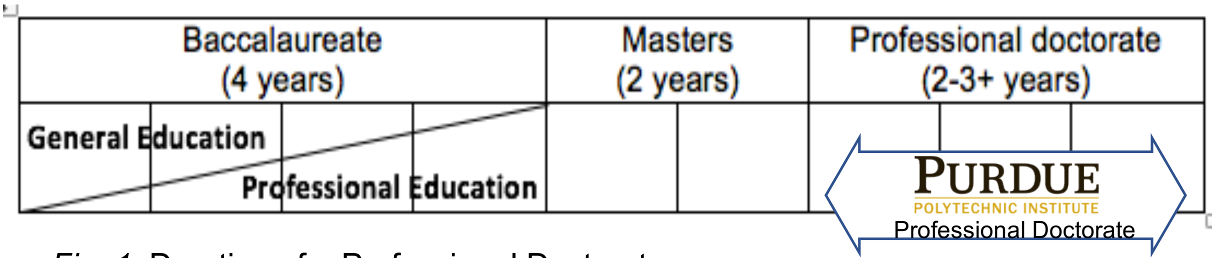

Fig. 1. Duration of a Professional Doctorate

Table 1. Professional vs. Research Doctorates [9] (p.30)

Attribute	Academic Ph.D.	Professional Doctorate
1. **Career focus**	Entry into academia	Professional doctorates nearly always claim to address the career needs of aspiring professionals
2. **Domain of research topic**	Disciplinary theory	Professional practice
3. **Research type**	'original investigation undertaken to gain new knowledge and understanding but not necessarily directed towards any practical aim or application' (p. 71)	Issues of real interest to the profession
4. **Research focus**	A perceived gap in the literature	A problem encountered in practice
5. **Starting point**	Finding what is known in the literature	A problem for which the solution is unknown
6. **Intended learning outcomes**	Contribution to the literature	'A significant original contribution to knowledge of • professional practice through research, plus one or more of the following: • personal development (often specifying reflective practice); • professional level knowledge of the broad field of study; • understanding of professionalism in the field; • appreciation of the contribution of research to the work of senior professional practitioners.' (p. 72)
7. **Entry qualification & degree**	Undergraduate degree with high marks	A Master's degree is often required
8. **Experience as admissions requirement**	None	1-5 years usually expected, with a median of 3
9. **Taught component**	Minimal, under the "traditional Ph.D. model"	Ranges from 15 to 50% of degree requirement
10. **Modularity**	Relatively unstructured according to the "traditional Ph.D." model	Modular course and credit structure
11. **In-service vs. Pre-service**	Pre-service for research career	In-service for professional career, often taken while working
12. **Mode of study**	Full-time	Part-time
13. **Integration of work/study**	N/A	High
14. **Integration of practice/theory**	Low	High
15. **Cohorts**	No	Yes
16. **Variability of duration**	Very high	Low
17. **Research outcomes**	Long dissertation	Shorter dissertation, often more than one; project reports
18. **Assessment**	Dissertation driven	Separately assessed components
19. **Breadth**	Narrowly focused	More broadly focused, problem-driven

Given the findings of the graduate faculty's review of the literature, survey feedback from professional master's degree alumni, and needs assessments, the team worked to create an applied research – use-inspired, technology-focused, professional doctorate. The program is designed to serve an experienced and mature clientele who will demonstrate their proficiency in use-inspired research with an applied dissertation.

1.1 Professional Doctorate Program Design.

The Polytechnic Institute graduate faculty team has formally proposed the creation of a Doctor of Technology graduate degree program to be delivered as a hybrid model from the Purdue University-West Lafayette campus to active/employed technology professionals. In this proposal, they [11] stated:

> This degree program will be distinctly different than the existing Ph.D. in the Polytechnic in multiple ways including the delivery mode, the target clientele, the focus of learning activities, and the research aims of the program. In addition to purposing the degree towards the development of technology and R&D competence needed by business, industry and government, our vision is to employ a hybrid delivery system involving predominantly distance learning education plus some campus-based experiences that make the achievement of a doctoral degree far more accessible to practicing professionals who would not pursue a doctorate or Ph.D. in a traditional campus setting due to their work and home responsibilities.
>
> …
>
> The proposed Doctor of Technology degree is a professional doctorate [12], i.e., a terminal degree, focusing on in-depth understanding of and capability with technology and the concomitantly necessary, innovation and leadership skills of middle and senior leaders in industry, business, and government as well as NGOs. As contrasted to the 'traditional' Doctor of Philosophy's intent to develop *professional researchers*, the professional doctorate is designed to develop *researching professionals in technology* primarily for environments other than the academy. (p.3)

In accordance with the aforementioned design considerations, students in the professional doctorate program will be required to demonstrate the following competencies to graduate:

- Envision, plan and conduct applied research and development activities;
- Identify, comprehend, analyze, evaluate and synthesize research and professional practice;
- Evaluate technologies and technology-related programs and leadership activities;
- Assess individual performance with, and understanding of, technology;
- Communicate effectively and employ constructive professional and interpersonal skills; and
- Function at a high level in one or more of the technology disciplines.

1.2 Target professionals

The Polytechnic envisions that the bulk of the students who will be choosing to pursue the proposed Doctor of Technology will be practitioners from the middle and upper ranks of business and industry, i.e., persons with a documented record of performance and considerable relevant experience. Typically, this is observable by an upwardly directed career trajectory of increasing responsibility. Because the Doctor of Technology focuses on advanced practice, such indicators have more utility for predicting success potential than do standardized examinations.

1.3 Learning experiences & knowledge base

The Doctor in Technology design incorporates best practice instructional and learning technologies to deepen and accelerate learning by employing andragogic approaches and tailoring of the learning experiences to aid aspirants in furthering their education. The outcome will be competencies that can be readily applied in business, industry, government and NGOs, as well as by entrepreneurs, to solve complex technology-related problems. The proposed curriculum systematically develops enhanced skills and understandings that enable professionals, already holding a Master's degree or equivalent, to apply their heightened technical and conceptual understandings of technology, research and development as they work to develop strategies to advance/enhance their enterprise. Consequently, the Doctor in Technology will accelerate and further the career of such individuals as they contribute to enterprise performance, efficiencies and sustainability through contemporary applied research-based techniques. All students will be required to complete a dissertation focusing on applied/use-inspired research of direct relevance to professional practice.

The program builds upon the particular strengths of Purdue University, and its Polytechnic Institute (the largest technology unit at a Research 1 institution in the nation), by leveraging the national recognition and well established capabilities from existing units including Aviation and Transportation Technology, Computer and Information Technology, Computer Graphics Technology, Construction Management Technology, Engineering Technology and Technology Leadership and Innovation. Given the importance of information to advances in technology, engineering and science the noted strength of Purdue's Potter Library is germane to this point also. Furthermore, other units across the Purdue University Campus also provide a rich environment for the proposed professional doctoral program by enabling supporting/cognate areas of study. These units include, but are not limited to, the Krannert School of Management, and the Colleges of Education, Engineering and Science. [11]

Pursuant to the plan of study, students are required to take:

- 21 credit hours[2] of core curriculum consisting of:
    - Technology and Society (3 credit hours)
    - History of Science and Technology (3 credit hours)
    - Philosophy of Technology (3 credit hours)
    - Technology Policy and Economics (3 credit hours)
    - The Design Process (3 credit hours)
    - Technology from a Global Perspective (3 credit hours)
    - Technology Clusters and Domains (3 credit hours)
- 15 credit hours for a dissertation is required for the Professional Doctor Technology degree. This will be an applied R&D project focused on a current problem of a company or industry and the results must be defended to the graduate committee.
- 24 credit hours of specialization in any of the technological fields offered by the Polytechnic Institute and by Purdue University. These specializations range from aviation technology, various computer technologies, electrical, mechanical and industrial technologies, as well as technological innovation and leadership.

1.4 Innovative learning and instructional methodologies

The Doctorate of Technology degree program is a predominately distance program with an on-campus weekend face-to-face element; in this sense, it is a distance-hybrid program. Over 50% of the program will be administered through distance modalities. In a typical weekend format, each three-credit hour course will meet for approximately 5-7 face-to-face class hours; three times per semester, for a total of 15-21 seat hours

[2] A credit hour is the equivalent of 15 person hours of class time plus the attendant amount of homework and independent study

in each semester. Given 15 seat hours per credit hour in a given semester (45 seat hours per 3-credit hour course), that directly implies a distance percentage of 53% to 66% of each course will be provided via distance delivery. This mode of delivery will enable the practitioners to continue to work at their current jobs while taking courses to expand their breadth and depth of knowledge for their specialty.

1.5 Culminating/Capstone research and development experience

All students will be required to complete a dissertation focusing on applied/use-inspired research of direct relevance to professional practice in any of the arenas of today's complex technology-based enterprises. Typically, such dissertations will advance a state of a technology or practice from one Technology Readiness Level to the next higher level. This dissertation must necessarily be defended before the candidate's graduate committee. Note that it is recommended that the graduate committee contain one member from industry with specific expertise relevant to the dissertation topic and not a direct superior in the candidate's employing organization.

2 IMPLEMENTATION PLAN

The team's implementation plan for the proposed doctorate is detailed in the following bulleted steps. The initial steps involve securing the necessary approvals to offer such a degree and then the subsequent ones involve a sequenced process of piloting, revision and enhancement pursuant to continuous improvement and quality control principles.

1. Secure Institutional approval
2. Secure state government approval
3. Announce availability to potential ProSTAR[3] clients & recruit first cohort
4. Conduct doctoral faculty and major professor focus sessions
5. Deploy degree planning materials to enrolled cohort
6. Conduct induction training of first cohort students
7. Deliver semester one courses
8. Debrief cohort and faculty members
9. Revise and/or update semester 2 experiences
10. Schedule value-adding experiences
11. Conduct semesters three and four

3 CONCLUSIONS AND NEXT STEPS

Based on the reviewed literature as presented in this paper's Introduction, the authors concluded, as did the cited colleagues around the world, that a need for a professional doctorate did exist. Furthermore, it was also concluded, based on alumni and potential student surveys, that sufficient interest was manifested to make such a program viable. Pursuant to these two conclusions the author team evolved the program design presented in section 1 and then outlined the implementation steps in section 2. These steps are now underway and approval is being secured as per the outlined sequence.

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CURRICULUM DEVELOPMENT FOR DUAL EDUCATION

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ABSTRACT

The paper presents the main objectives and intended outcomes of a Erasmus + Project *Towards Excellence in Engineering Curricula for Dual Education* (TEEDE) coordinated by the University Rovira i Virgili (URV, Spain). The project has received funding under the Key Action 2: Capacity building in the field of higher education. This joint multi-country project including partners from Europe, Russia, China, India and Cambodia aims to promote the modernization, to expand the availability and to develop the internationalization of higher education in the partner countries: to promote intercultural and interpersonal exchange, and to promote the voluntary convergence with the tendencies of the development of higher education in the EU.

The main output of the project will be upgraded/developed curricula in engineering trades. It will be possible through development of methodological guidelines on professions and qualifications based on the analysis of the economic needs of the different regions involved.

Conference Key Areas: University-Business cooperation, Curriculum Development

Keywords: dual education, engineering education, curriculum development, university - industry cooperation

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INTRODUCTION

Today many countries all over the world are seeking ways to strengthen the linkages among employers, workers, higher education institutions, and governments. One of the possible ways to meet this challenge is dual education. In this system, training for industrial trades is a shared responsibility of firms and schools. Trainees divide their time roughly equally between classroom and on-the-job training, with both pathways developed in paralel. As trainees, they (might) receive a lower wage than regular workers, but are guaranteed secure, well-paid jobs at the firm upon successful completion of the program and receiving of a certificate [1].

1 WHAT IS DUAL EDUCATION

Even a preliminary literature review [2,3,4] reveals a lot of distinctive features how dual education is understood and implemented in different countries. The variation in the details is not relevant for the purpose of this paper, as we will refer to the context of the TEEDE project [5], which determines the most important characteristics of the dual system as the following:

- Combines apprenticeships in a company and formal education in the same course.
- Students are workers of the company.
- Students have some sort of labor contract.

This means that perform an internship or develop the final year project in a company is not considered as a dual education, as the involvement of the companies are more superficial

Crucial to the system's effectiveness is the close collaboration of industry and higher education institutions. If we manage to establish/reinforce this kind of cooperation, then it will provide important advantages for all stakeholders:

- Labor contract.
- Development of apprentices under real conditions.
- Apprentices benefits also from coworkers knowledge.
- Hard and soft skills are simultaneously developed in the company environment.
- Facilitates school-to-work transition.
- Improved retention for employer.

The limitations for succesful implemetation of such a system could be:

- Training is more expensive than the school-based approach.
- Companies have to follow many regulations
- Companies are often specialized and unable to train apprentices in all areas and with the broad view of a master (*e.g.*, small and medium enterprises).
- More student effort required, as they have to combine both tasks.
- Organizational changes are required also for Universities, which are not characterized by fast response times and actions.

In order to share best European practices and to make dual system more widespread in engineering education in such regions as Asia and Russia the Erasmus + project *Towards Excellence in Engineering Curricula for Dual Education (TEEDE)* has started in October 2016 [5]. The project has received funding under the Key Action 2: Capacity building in the field of higher education. This joint multi-country project including partners from Europe, Russia, China, India and Cambodia aims to:

- Promote the modernization
- Expand the availability and to develop the internationalization of higher education in the partner countries
- Promote intercultural and interpersonal exchange
- Foster the voluntary convergence with the tendencies of the development of higher education in the EU.

2 TEEDE PROJECT

2.1 Consortium

The TEEDE project consortium consists of:

- University Rovira i Virgili (Universitat Rovira i Virgili): URV, Spain. Project Coordinator.
- University of Tampere (Tampereen Yliopisto): UTA, Finland.
- Institute Technology and Education (Universitaet Bremen): ITB, Germany.
- University of Pavia (Universita Degli Studi di Pavia): UNIPV, Italy.
- Tomsk Polytechnic University: TPU, Russia.
- Far Eastern Federal University: FEFU, Russia.
- Katanov Khakass State University: KHSU, Russia.
- Omsk State University: OSIS, Russia.
- Jilin University: JLU, China.
- Shenyang Ligong University: SYLU, China.
- Institute de Technologie du Cambodge: ITC, Cambodia.
- Royal University of Agriculture: RUA, Cambodia.
- Indian Institute of Technology Madras: IITM, India.
- The Indian Institute of Technology Kanpur: IITK, India
- European Association for Quality Assurance in Higher Education: ENQA, Belgium.
- Association for Engineering Education of Russia: AEER, Russia.

All partners of the consortium have a strong focus on technology and engineering and serve as regional centres for implementation of national strategies for training professionals. The problem of training professionals for the real sector of economy has emerged due to immense development of high technologies, shortening the period from development to implementation, growing technological needs of the society. As a result there exist a need for new approaches to the development of curricula sensitive and flexible to demands of companies based on innovations. This challenge is common for all regions involved in implementation of the project: EU, Russia and Asia.

2.2 Objectives

To meet this challenge in the course of the project partners will:

1. Identify needs, select key professions and areas of training.
2. Develop and modernize curricula implementing the principles of the dual education under the guidance of European experts.
3. Launch new or upgraded curricula, combining periods of study with periods of

training at leading enterprises.
4. Create a system of continuous professional development.
5. Create communication and recourse centres at partner universities.

The specific objectives of the TEEDE project are the:

- Modernization and creation of the bachelor and master's degree programs in engineering based on the European principles of dual education;
- Development and implementation of the methodology of management of educational processes in universities following the dual education approach;
- Strengthening relations of universities with exterior economic and social environment, creation and development of variants of the cooperation of universities and enterprises, promotion of employment of graduates;
- Creation of communication and recourse centers for promotion of the projects results and further implementation of the project's outputs beyond the project cycle period;
- Establishment of the unified procedure of evaluation of qualification level achieved by the persons who are studying in engineering and the recognition of learning;
- Construction of the trajectory of lifelong learning for the engineers.

2.3 Outputs

The main output of the TEEDE project will be upgraded/developed curricula in engineering trades. It will be possible through development of methodological guidelines on professions and qualifications based on the analysis of the economic needs of three regions.

These outputs will be available to all stakeholders through the created communication and resource centres as well as the project website and through open communication of the partners that secures the reliability and high quality of the project outcomes.

3 ACKNOWLEDGMENTS

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Smart HEI-Business Collaboration for Skills and Competitiveness

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ABSTRACT

Smart HEI-Business Collaboration for Skills and Competitiveness (HEIBus, www.heibus.eu) is an Erasmus + Knowledge Alliances 2 (KA2) project. Its duration is 36 months (1 January 2017 – 31 December 2019) and it aims to develop smart and innovative new methods for Higher Education Institution (HEI) - company cooperation. With a budget of about one million euros, the project brings together five universities and seven companies from five European countries with strong expertise and experience in different fields. JAMK University of Applied Sciences is the main partner of the project. Seventeen associated partners from six European countries follow the progress of the project, utilise the results and take part in some project activities.

In the HEIBus project, there are eight work packages, which are 1) Management, 2) Best practices of HEI-company cooperation, 3) Multidisciplinary student-level real-life problem solving, 4) Expert-level real-life problem solving, 5) Flexible student mentoring by companies, 6) Quality assurance, 7) Evaluation and 8) Dissemination & exploitation.

The HEIBus project focuses on strengthening the collaboration between HEIs and companies by creating new innovative cooperation models. These models facilitate the involvement of students and staff from HEIs in international Research & Development & Innovation (R&D&I) projects proposed by companies.

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Conference Key Areas: University-Business cooperation, Attractiveness of Engineering Education, Engineering Education Research

Keywords: Collaboration, innovation, multidisciplinary, flexible mentoring

INTRODUCTION

Europe is trailing behind the USA, Japan and Canada with regard to building a smarter economy. Competitiveness and rising levels of productivity are a crucial force behind sustained levels of economic progress and the wellbeing of citizens. In short, Europe needs improvements. To tackle the problems Europe has launched the Europe 2020 strategy, with objectives on employment, innovation, education, social inclusion and climate/energy. The Europe 2020 strategy identifies actions to boost growth and jobs.

The schooling systems in Europe are on a very good level, but we still need to improve the velocity of innovation, productisation and commercialisation. At HEIs, both the students and university personnel are frequently handling innovations that could be the basis of improved business in small- and medium-sized companies (SMEs) or create new business possibilities for larger enterprises.

Economic success demands that the company is innovative, which in turn requires different kinds of multidisciplinary know-how. The purpose of the HEIBus project is to increase, improve, widen and deepen HEI-company cooperation at the student and expert levels, promoting entrepreneurial thinking and innovations. The earlier RePCI project (www.repci.eu, funded by the EU Lifelong Learning Programme and carried out in 2013-2015) led to a fruitful cooperation between HEIs and companies. The feedback of HEIs and companies showed a clear need for even deeper and wider cooperation, however, such as multidisciplinary study area cooperation and HEI-company expert-level cooperation.

HEIs have many challenges, such as meeting future needs and challenges set by working life and developing teaching methods which motivate students to learn and carry out their studies in time. The labour market is constantly evolving, with the necessary skills, competences and qualifications changing over time. Traditional education does not always answer the needs of the field, and new teaching and learning methods for new skills are needed. It is important that the needs of working life (companies) be matched with the education provided. This is an ongoing process and can only be reached with HEI-company cooperation.

One key factor for the success of the companies is competent and motivated personnel. One way to achieve this is through deeper integration of the company with the student groups throughout the studies, which provides the company with a good recruiting tool.

1 BACKGROUND AND BASIC INFORMATION OF THE HEIBUS PROJECT

1.1 Partners

The HEIBus project consists of five university and seven company partners from five different European countries (Finland, Germany, Hungary, Romania and Spain) taking part in the project as full partners:

- JAMK University of Applied Sciences (main partner, www.jamk.fi/en/) and ITAB Pikval Oy (www.pikval.fi/en/) from Finland

- Technical University of Cluj-Napoca (www.utcluj.ro/en/), SC PRO Tehnic (www.pro-tehnic.ro) and Automates ACM SRL (www.automatesacm.ro) from Romania
- University of Miskolc (www.uni-miskolc.hu/en/), Electrolux (www.electrolux.com) and Robert Bosch Power Tool (www.bosch-garden.com/gb/en) from Hungary
- University of Applied Sciences Esslingen (www.hs-esslingen.de/en/) and Stoebich (www.stoebich.com) from Germany
- University of Jaen (www.ujaen.es/serv/vicint/home/index) and Valeo Lighting Systems (www.valeo.com/en) from Spain.

The group of company partners consists of SMEs as well as some large companies. Three HEI partners are academic universities while two are universities of applied sciences. The partnership comprises a perfect variety of different types of organisations and professionals. This provides very interesting and fruitful cooperation with different perspectives on each aspect of the project. There are also 17 associated partners (companies and organisations) from six European countries who follow the progress, utilise the results and take part in at least some of the project activities.

The project focuses on strengthening the collaboration between HEIs and companies by creating new innovative cooperation models. These models facilitate the involvement of students and staff from HEIs in international Research & Development & Innovation (R&D&I) projects proposed by companies.

1.2 HEI-company cooperation

Currently, HEIs and companies around the world are experiencing a renewed interest in strengthening their forms of cooperation. It has been proved that bridging the gap between HEIs and companies benefits both parties. Cooperation between HEIs and companies is not a new concept. There are cooperation programmes, which date back to the first decade of the 20th century [1] or are well-known internationally that have served as a reference model [2]. However, the idea of integrating working life with the learning process has its detractors. They place strong emphasis on exploitative internships and non-enriching jobs in which students are just observing instead of being engaged in productive work. To tackle this problem, there are associations such as the Canadian Association for Co-operative Education (CAFCE) [3], the Cooperative Education & Internship Association (CEIA) [4] and the German Central Evaluation and Accreditation Agency (ZEvA) [5] that guarantee the quality of cooperation agreements.

The mechanisms offered by HEIs to provide students with the opportunity to gain work experience, in their career fields, are included in the generic concept of Work Integrated Learning (WIL) [6]. According to the definition adopted by the Higher Education Quality Council of Ontario [7], work-integrated learning is the process through which students come to learn from experiences in educational and practice settings. It includes the kinds of curriculum and pedagogic practices that can assist, provide, and effectively integrate learning experiences in both settings. Depending on the context, the term WIL is often used interchangeably with other, similar terms such as “work-based learning,” “practice-based learning,” “work-related learning,” “vocational learning,” “experiential learning,” “co-operative education,” “clinical education,” “internship,” “practicum,” and “field education” [8]. However, many of these terms are also used to describe specific types of work-integrated learning. The most widespread types of WIL are:

- Cooperative education
- Internship

- Apprenticeship
- Field experience
- Mandatory professional practice
- Applied research learning
- Service learning

1.3 Work packages

The HEIBus project consists of eight work packages which are Management (WP1), Best practices of HEI-company cooperation (WP2), Multidisciplinary student level real life problem solving (WP3), Expert level real life problem solving (WP4), Flexible student mentoring by companies (WP5), Quality assurance (WP6), Evaluation (WP7) and Dissemination & exploitation (WP8). Four of them (WP2, WP3, WP4 and WP5) are implementation work packages which will be explained deeper in the following chapters.

The project addresses the flagship initiatives of innovation union, youth on the move and an agenda for new skills and jobs. The HEIBus project carries out several tasks where students, HEI experts and company experts are involved in solving real-life problems of companies. This boosts the new innovative ideas that can be quickly taken into use in companies.

2 BEST PRACTICES OF HEI-COMPANY COOPERATION

The aim of the Best practices of HEI-company cooperation work package (WP2) is to analyse the existing cooperation models providing real-life experiences between HEIs and companies in the following way:

- to analyse the state-of-the-art HEI student-company cooperation models
- to analyse the state-of-the-art HEI expert-company cooperation models
- to analyse different platforms and forums used in HEI-company communication
- to analyse the best practices on company involvement in HEI education

Descriptions of existing cooperation models and the main tasks are in *Table 1*.

Table 1. Existing cooperation models and the main tasks of work package 2

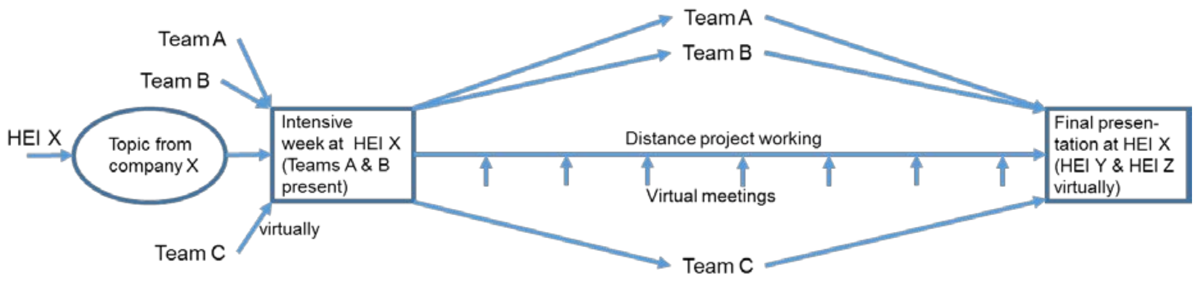
Student-company cooperation models	**HEI expert-company cooperation models**	**Internet based platforms for HEI-company communication**	**Company involvement in HEI education models**	**Coaching for virtual activities**
To search different existing methods or models	To search existing models	To find and analyse 15 internet based platforms	To search different existing methods or models	To ensure effective participation of all partners in virtual activities
To find at least 10 good and beneficial models	To find at least 10 good and beneficial models	To search best practices for communication	To search different levels of involvement	To organizes coaching of virtual methods
To select 5 models for deeper analysis	To select 5 models for deeper analysis	To build a new platform or to join in best available platform	To analyse different levels of involvement	To use social media for different project activities
To form background for the Multidisciplinary student level real life problem solving (WP3)	To form background for the Expert level real life problem solving (WP4)	To help continuation of the HEIBus activities after the project	To form background for the Flexible student mentoring by companies (WP5)	To invite associated partners to take part in virtual coaching

So far, all work package leaders have searched existing methods and models for HEI-company cooperation, which the leader of WP2 has collected. During April - May 2017 the best models for deeper analysis were selected. Regarding the outcomes of this work package, the best and most comprehensive ideas and models for HEI-company cooperation are expected to be found. These models will form a good background for the other implementation work packages, WP3-WP5.

3 MULTIDISCIPLINARY STUDENT LEVEL REAL LIFE PROBLEM SOLVING

The aim of the Multidisciplinary student-level real-life problem solving (RLPS, WP3) work package is to create a new model on how to spread the real-life problem solving method to a new multidisciplinary cooperation level. The aim of the work package is also to build a virtual implementation of the RLPS method. This frees the RLPS method from the confines of space and make it more accessible to students unable to travel, among others. It also makes the method easy to use anywhere in the Europe. RLPS focuses on bringing students, HEI staff and companies together. The idea is that students from different study programs and nationalities form mixed groups in order to solve a real-life problem that has been given to them by a company, as shown in *Fig. 1.*

In every pilot projects, three multidisciplinary and international student groups work upon and solve the proposed topic during one academic semester and compete with each other.



Team A: 2 students from HEI X + 2 from HEI Y and 2 from HEI Z
Team B: 2 students from HEI X + 2 from HEI Y and 2 from HEI Z
Team C: 2 students from HEI X + 2 from HEI Y and 2 from HEI Z

Fig. 1. Pilot Projects of WP3

At the end of the semester, the company tutors select a winning solution and HEI supervisors give grades.

Three first-round projects will be carried out in autumn 2017. In spring 2017 partner HEIs have had meetings with partner companies, discovered applicable and good topics and required tailored lectures for these implementations, created their own information material and have possibly held information sessions for suitable student groups, as well as announced an application period for students. The companies who will offer the topics for the first-round projects are ITAB Pikval Oy from Finland, Andaltec (www.andaltec.org/en/) from Spain and Automates ACM SRL from Romania. In May 2017, supervisors of HEIs chose the students for these three pilot projects. Finnish, German and Spanish students and supervisors will take part in ITAB Pikval project, Finnish, Hungarian and Spanish in Andaltec project and German, Hungarian and Romanian in Automates project. In the beginning of the implementations, two student groups will have one intensive week in the home country of the company giving the topic and the third student group will take part virtually in this intensive week. After the intensive week, all students will work at their own HEIs and members of a certain student group will cooperate virtually until the end of the implementation. After the first-round pilot projects, feedback from students, HEI supervisor and company tutors will be collected and possible improvement will be conducted before the second-round pilot projects. Three second-round pilot projects will be carried out in autumn 2018. This work package is expected to produce motivated students with good teamwork, project management, cultural and language skills.

4 EXPERT LEVEL REAL LIFE PROBLEM SOLVING

The Expert-level real-life problem solving (EXPERT, WP4) work package aims to develop and pilot a new cooperation model between HEIs and companies. This enables companies to bring more complex problems to be solved by international and multidisciplinary experts. This promotes innovation and knowledge transfer between HEIs and companies as well as increases the skills of HEI experts and the working life relevance of education.

In the beginning, a step-by-step process model is built and pilot projects for testing the model are planned, as shown in *Fig. 2.* In order to search for companies and their topics for pilot projects, an information sheet about expert-level real-life problem solving is created. Each HEI involved in WP4 makes a list of companies in their own country to be contacted (including partner companies and possibly other companies), sends them the information sheet and asks potential project topics. The topics are listed and each involved HEI selects two topics for the pilot projects from a list of the topics. The selection criteria are practical: when does the project need to have results, are suitable experts available for the project, etc.

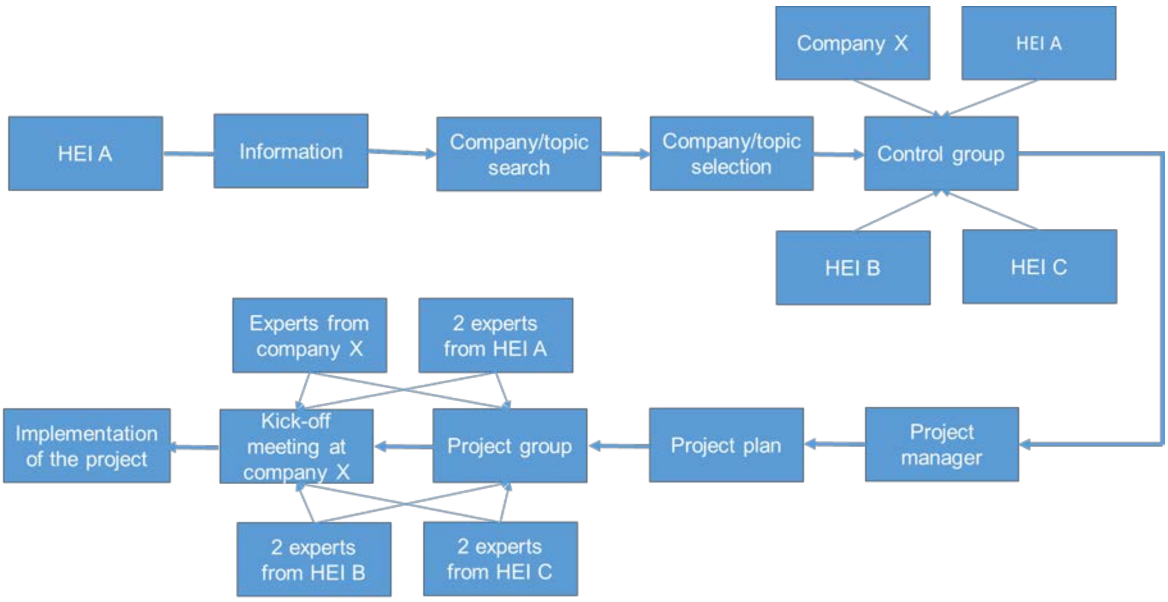


Fig. 2. Pilot Projects of WP4

There will be a total of six pilot projects where companies introduce a real-life problem to be solved by a team of experts from HEIs and companies. In order to make improvements and test the method, the six pilot projects will run in two phases. A control group consisting of representatives from each involved HEI and the company of the topic will be formed for each pilot project. The control group selects a project manager who is responsible for following the implementation, reporting the progress to the control group and running the practical issues of the implementation.

The project manager also makes the project plan, which is then accepted by the control group. The schedule of each pilot project depends on the needs of the company and the problem to be solved. The project manager supported by the control group finds and selects best experts for the problem to be solved and these experts form the project team. One team includes a total of six experts from three different HEIs (three different countries) and two experts from the company whose problem the team is solving.

The project is led by the project manager and implemented by the project team according to the project plan. In the beginning of each project, a kick-off meeting in the company is arranged where the whole project team is present. Other project meetings and the final meeting at the end of the project are arranged by video conferences (virtually). The project team agrees on the best ways of working together including virtual meetings, individual work, forming smaller teams inside the project team etc. The project team works on solving the real-life problem of the company and proposes a solution. With the help of the project team, the project manager reports the results of the project to the company.

After the pilot projects are implemented, feedback is gathered and analysed. In addition, an action plan for widening the international expert cooperation model outside the partner group is made.

The Expert-level real-life problem solving work package includes also building a virtual Expert Support Service with easy and quick access for all companies looking for expert services by HEIs. The Expert Support Service offers direct expert contacts for starting an expert-level RLPS, and a possibility to ask quick support for smaller problems.

5 FLEXIBLE STUDENT MENTORING BY COMPANIES

The Flexible student mentoring by companies (Flex Mentoring, WP5) cooperation model aims to find and test flexible ways to involve companies in the education process of students. Flexibility comes from different levels of involvement. Virtual reality, which is not dependent on time or place, is present in many activities, such as expert lectures and info sessions for a wider audience that makes it possible for students from international HEI partners, among others, to join by video conference, etc. The cooperation model also seeks to find out if Flex Mentoring could be a feasible solution for improving students' employment rate after graduation and helping students lacking behind in their studies or at risk of dropping out completely.

During implementation, one or more companies walk hand-in-hand with one study group from the beginning until the end of the studies. Each HEI partner selects two suitable student groups: one group consisting of students at the beginning of their studies and another group in which the students are at a more advanced level. Each HEI and company chooses the involvement level and methods best suited to them, in a flexible way. HEI teachers inform the student groups about the Flex Mentoring programme.

This work package contains the following tasks:

- to make plans on how the Flex Mentoring programme is implemented

- to select the most suitable involvement methods and to make detailed plans for the execution for each study year
- to review the plans after every study year and to modify if needed
- to create info materials of Flex Mentoring
- to introduce the materials to selected companies and student groups in every partner country

The main outcomes of this work package will be:
- increase motivation and study success for students
- easy recruitment way and a good labour force for companies
- good knowledge transfer between HEIs and companies

6 SUMMARY

The HEIBus project started in the beginning of 2017. So far, the biggest challenge has been getting all the needed documents from some company partners in time. Most of the activities have focused on WP2 because it forms the basis for other implementation work packages. Also in WP3 the planning of the first-round pilot projects is progressing well. In WP4 the process model has been created, and planning for the first-round pilot projects has started. In WP5 the plans on how the Flex Mentoring programme is implemented have done, the most suitable involvement methods have selected and the detailed plans for the execution for each study year have made.

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Development of a series of design build projects
- Preparing students for industrial placement

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ABSTRACT

Many modern engineering degree programmes make use of active learning often built around a variety of problem and project based learning activities. Structuring these to ensure a progression of both technical and professional competencies is key, with the emphasis often being focussed around the scientific and technical competencies to the detriment of the generic skills needed in industry.

This paper describes the creation and evolution of a series of major group projects over the first two years of Bachelors level degrees in Mechanical Engineering & Product Design aimed at developing students to a point where they are both confident enough and competent enough to undertake a year in industry at the end of their second year.

Mapping both the technical and personal qualities of a successful placement student and the typical entry competencies of our students, a series of requirements were developed and these structured into a coherent programme of project modules spanning two years.

Conference Key Areas: Curriculum Development, University-Business cooperation

Engineering Skills

Keywords: Industrial Placement, Skills, Employability, Project Based Learning

INTRODUCTION

To provide the best for engineering students, educators work hard to provide engaging and relevant programmes which are valued by both the students and the industries into which they will be recruited.

An increasingly common focus is the need for "employability" to try to ensure graduates emerge into the workplace with a holistic set of both technical and non-technical skills necessary to succeed and be readily useful to their employer. The use of industrial placements with students working in industry for a period of typically up to a year at some point during their degree is seen as a key part of this employability strategy for many but it itself requires students to be adequately equipped to successfully take on these positions in industry.

1 CONTEXT

1.1 Engineering Curriculum Design

In spite of Universities often emphasising research to inform staff recruitment and other strategic decisions, increased competition for students, availability of programme quality information to potential students and governmental pressures have seen much more emphasis placed on the quality of teaching provision.

This has seen Universities rethink their curriculums to best achieve the desired outcomes. [1]

In particular while discrete under-pinning scientific knowledge remains core, a greater emphasis has often been placed on holistic curriculums which integrate technical knowledge with broader personal, organisational, problem solving, commercial and team skills. This is exemplified by initiatives such as “CDIO” which aim to provide broad based programmes delivering high levels of employability. [2]

1.2 Employability

Employability is a key driver in the provision of the majority of engineering degree programmes. This is not unsurprising in a vocational subject with graduates enrolling in degrees to allow them to be equipped with the necessary skills, knowledge and personal qualities required for a career within the discipline. In addition, employability metrics – eg. proportion of graduates in graduate level posts – are commonly used in programme and institution league tables and rankings.[3]

Achieving employability within engineering programmes involves creating a curriculum which covers not only the technical skills required of engineers but also builds the students’ confidence, people, team, commercial and other skills with these non-technical skills often to be found lacking particularly among engineering students. [4-9]

For engineering students, learning is typically developed through a blend of conventional lectures, tutorials, formal laboratory exercises and projects. While lectures may be seen as a resource effective way of transferring underpinning engineering knowledge, they often lack context and this can be particularly the case for the personal, social and professional skills needed of the employable graduate and as a result a more experiential project based learning approach can be seen as more desirable.

1.3 Industrial Placement

For students at many Universities in the UK and elsewhere there is an opportunity to take part in a short or long term industrial placement as part of their degree. This is designed to allow students to not only contextualise the knowledge and skills being developed at University but also to expose them to the workplace, its approaches, conditions and cultures and in so doing develop their employability ahead of returning to their studies and graduation. Placements are typically taken after two years of study. For satisfactory placement experiences for both the student and the employer it is therefore important that adequate skills, both technical and non-technical are built up ahead of the student undertaking the placement.

2 PROJECT BASED LEARNING

2.1 Focus

To try to develop a broad based engineering education, significant emphasis has been placed on project and problem based learning. See eg. [10-12]

Aston University in Birmingham, UK runs mechanical engineering and product design degrees following a CDIO approach. As with all degrees at Aston, they offer students the opportunity to undertake year long industrial placements between years 2 and 3.

Prior to adopting the CDIO approach the degrees at Aston were very traditional, with large numbers of discrete modules, generally focussed around core engineering science disciplines with little integration between modules or attention given to non-technical skills. Under the adoption of the CDIO principles a project based focus was evolved and a plan was developed to determine the contents of these to ensure students would grow as individuals, while also developing the necessary technical and non-technical skills and knowledge to enable them to undertake a successful placement.

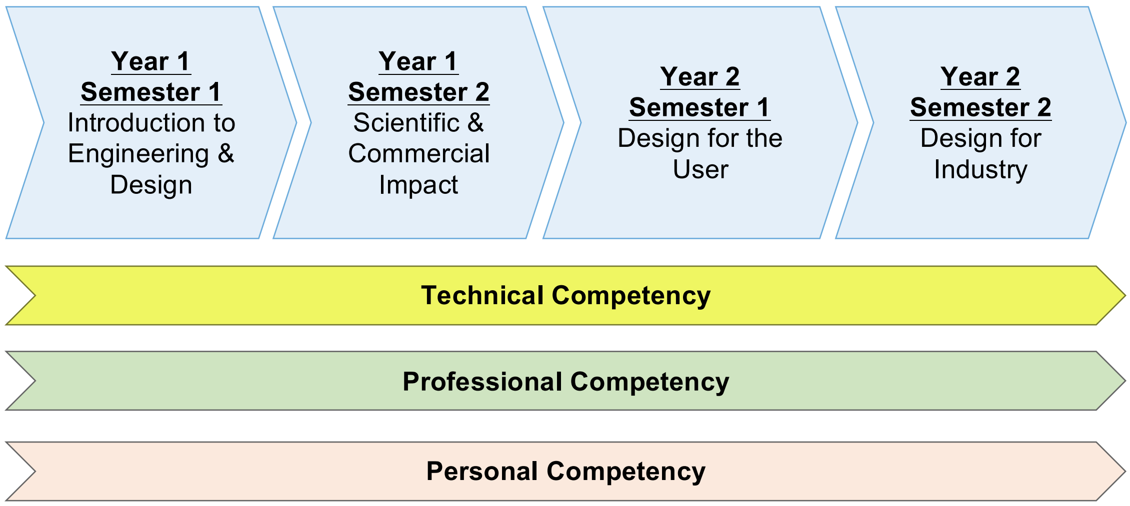


Fig 1. Student journey through year and two projects

It was decided that the first two years of the programme would therefore feature four major project elements accounting for half the students' time and credits, the balance being more traditionally taught engineering science and mathematics classes. These projects would then hopefully impart many of the employability skills necessary for successful placement. *Fig. 1* shows a top level approach to the resulting project curriculum with a theme identified for each project.

3 PROGRAMME DEVELOPMENT

3.1 Curriculum requirements

From reviewing research in the area and working with our own industrial board it became apparent that our previous programmes offered little opportunity for students to develop or practice their non-technical skills. These were entirely absent from the curriculum or existed in a theoretical and non-contextualised approach eg. a module in project management, taught purely by lecture and assessed by exam.

A range of technical and non-technical skills which might be required of a student entering an engineering placement were drawn up based on the literature, dialogue with industrialists, our own experiences and also the requirements of the relevant accrediting body. A list of some of these skills can be seen in table 1 with the intention that these could be developed through the project modules.

Table 1. List of Technical, Professional and Personal Competencies to be covered by project modules.

Technical Competency	Professional Competency	Personal Competency
Technical drawing	Commercial awareness	Self-reflection
Design methods	Engineering ethics	Self learning
Design for manufacture	Presentation skills	Time management
Analysis to support design	Project management	Leadership
Experimentation in design	Communication	Team membership
Critical review	Team working	Organisation
Component selection	Costing	Time keeping
Engineering standards	Meeting management	Accountability
Tolerancing	Documentation	Responsibility
Product specification	Legal responsibility	Confidence
Product requirements	Intellectual property	Empathy
Problem solving	Etc…	Etc…
Systems design	….	….
Etc…		
…		

3.2 Phasing

As with any educational approach it is important to introduce material to students at an appropriate phase in their development and also allow opportunities to reinforce, deepen and broaden the particularly key topics and where possible these link into non project areas of the curriculum.

In year 1 it was felt key that students focus on their technical and personal competency. Students were typically entering University directly from school and had come from a very heavily coached environment with often little consideration for the uncertainty and variability of real problems. They were also unfamiliar with group projects and working with others in a meaningful way. Professional competency was phased in more heavily at a later stage as students developed through year 2 and approached their placement at the end of the year.

3.3 Mapping

Table 2 shows the mapping of some of the key competencies with the student journey toward placement.

Table 2 : Mapping of core technical, professional and commercial competencies against the project modules.

○ Topic Introduced

◆ Topic Reinforced

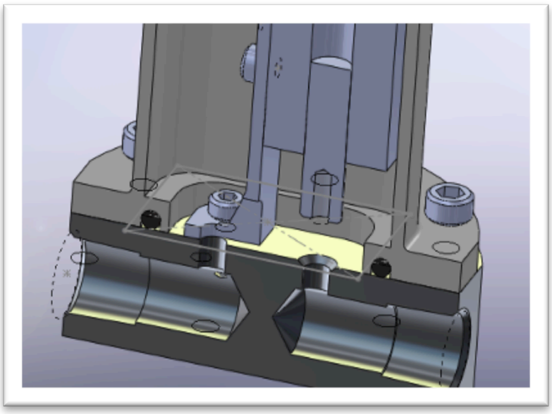
	Year 1 Semester 1 Introduction to Engineering & Design **Electric Car**	**Year 1 Semester 2** Scientific & Commercial Factors **Wind Turbine**	**Year 2 Semester 1** Design for the User **Medical Product**	**Year 2 Semester 2** Design for Industry **Pneumatic Product**
Technical Competency				
Technical drawing	○	◆		◆
Design methods	○	◆	◆	◆
Design for manufacture		○		◆
Analysis to support design	○	◆	◆	◆
Experimentation in design		○	◆	
Critical review			○	◆
Component selection			○	◆
Engineering standards		○		◆
Tolerancing	○	◆	◆	◆
Product specification	○	◆	◆	
Product requirements	○	◆	◆	
Problem solving	○	◆		
Systems design		○	◆	◆
CAD		○	◆	◆
Professional Competency				
Commercial awareness		○	◆	◆
Engineering ethics			○	◆
Presentation skills		○	◆	
Project management	○	◆	◆	
Communication	○	◆	◆	
Team working	○	◆	◆	
Costing		○	◆	◆
Meeting management	○	◆		
Documentation		○	◆	◆
Legal responsibility			○	◆
Intellectual property			○	◆
Personal Competency				
Self-reflection	○	◆		
Self learning	○	◆		
Time management	○	◆		
Leadership		○	◆	◆
Team membership	○	◆		
Organisation	○	◆	◆	
Time keeping	○	◆		
Accountability	○	◆		
Responsibility		○	◆	
Confidence	○	◆	◆	◆
Empathy			○	

Fig. 2 shows the core design artefacts associated with the project modules.

Year 1 Semester 1
Introduction to Engineering & Design
Electric Car

Year 1 Semester 2
Scientific & Commercial Factors
Wind Turbine

Year 2 Semester 1
Design for the User
Medical Product



Year 2 Semester 2
Design for Industry
Pneumatic Product

Fig. 2. Artefacts produced by each of the projects in years 1 and 2.

4 REVIEW AND CONCLUSIONS

The programme is now at a stage of maturity with a number of cohorts having emerged from these projects and progressed into industrial placements and beyond into the workplace. Feedback from students emerging from placements is that these modules are key in helping them once in placements and while they can only partly provide some of the culture and learning they will experience once in work, certainly smooth the pathway.

Moreover the modules are seen as important in helping secure the placement posts which are typically competitively recruited among under-graduates from a range of programmes and Universities. Students are encouraged to take along project log books or other materials from their projects to evidence their development to the potential employers and this has proved a key factor at converting interviews to offers.

A recent quote from a student is typical – "*at my interview I presented my log books which details all the projects I have taken part in from the CDIO modules at Aston. The company representative at the interview was very impressed with how the course focuses on projects and specifically mentioned that the skills I had gained as a result were well suited to the industry."*

The approach is not without issues. The mapping aligns the technical, professional and personal topics to modules based on a theoretical ideal but this may then conflict with the theme of the module not always being a perfect fit for all the outcomes. Alternatively there may be resource issues with staff or workshop availability needing to be synchronised carefully.

The operation of the modules and the preparation of students for industrial placement is however one of continuous improvement and the approach and detail within the projects is continually evolving.

Nonetheless our experience has shown that, well-structured holistic modules are a key asset in help students obtain and succeed within industrial placements.

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Realization of Industry 4.0 in Objective Identification and Smart Sensing with OpenCV and NI Vision

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ABSTRACT

We developed a project to achieve the realization of Industry 4.0 in objective identification and smart sense through network communication in an echo system of production lines. The machine vision was carried out with OpenCV and NI Vision. With robotic-assisted Uarm Metal, measurements of the specific physical properties for the identified objects were implemented with embedded microcontroller utilities. Finally, the test results were uploaded to the public cloud server, ThingSpeak. The connection on the practical mechanical system and the platform of information interaction demonstrated the paradigm of the cyber-physical system.

Conference Key Areas: Engineering Skills, Physics and Engineering Education

Keywords: objective identification, smart sense, internet of things, industry 4.0

INTRODUCTION

The fast development in network communication and cloud computing in the past decade has boosted the evolution of computer technology, programming design, and information management to a whole new stage of application and service, and has stimulated the dream of the realization of the Internet of things (IoT) [1]. Benefiting from the worldwide population of wireless remote control, sensing devices, and advanced measurement and display instruments, innovations in the IoT related technologies and market demand continue to expand and are setting the standards of future technology. Meanwhile, the integration of embedded systems and computer languages has turned the production and manufacture into new types with better efficiencies—smart sensing, together with custom manufacturing, have established the key feature of Industry 4.0 (I4) [2]. Furthermore, with the development of the cyber-physical system [3], the connection between virtual and real worlds has been established, bringing with it IoT environments with vivid objective communications, artificial intelligence, and human-computer interactions.

As the current industrial production still faces many critical challenges in smart automation because of the increasing complexity and the need for flexibility [4], the requirements that include portability, interoperability, and reliability have been identified as prerequisite for future industry. Among various strategies, machine vision provides innovative solutions to reduce difficulties in the direction of industrial automation [5]. A variety of applications of vision systems provide evidence of the practices and effects of optical inspection. In general, the processes of machine vision include image acquisition, image processing, feature extraction, and identification judgment. To achieve precise identification in complex or highly-sensitive environments, such as face recognition, a feature-based or figure-based algorithm would be considered. As a result, reliable identification depends not only on high-resolution image acquisition; the efficiency of the recognition software matters as well.

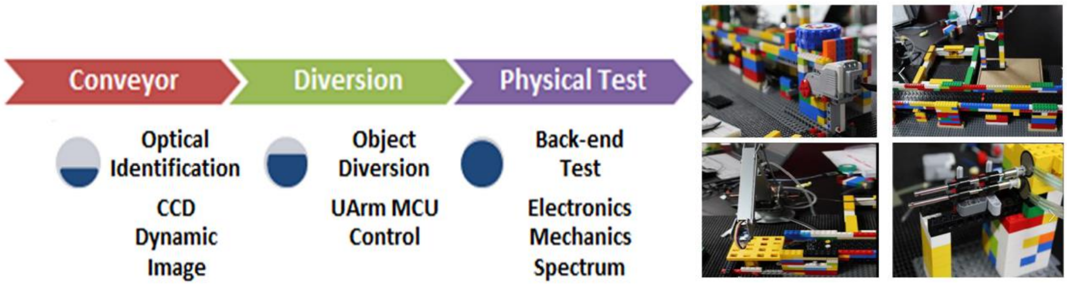

Figure 1. The flow of optical identification, object diversion, and back-end test. The production line and measurement platform are constructed from LEGO modules.

In this work, we report the development of a project in cooperation with Yulon Motor Group to achieve the realization of I4 in objective identification and smart sensing through network communication on an echo system of production lines. The project was implemented in the two-month summer vacation after a four-month lecture course that introduced the kernel, the aim, and the practice of I4. Before proceeding, students have to submit the proposal and the budget to demonstrate their idea, schedule and processes to design the project with the classroom equipment by applying the previously learned domain knowledge. In doing the project, students were guided to construct, review, and revise their blue chart. This greatly helped build a clear picture for what to do, how to do, and flow debug, and then greatly increase the probability for students without engineering background to complete the project of image identification in time.

In terms of the software structures, the image identification was implemented parallel with two schemes, OpenCV (Open Source Computer Vision) and NI Vision (National Instrument Vision). OpenCV is open source software with powerful libraries for image processing, and supports C, C++, Python, and JAVA. In contrast, based on the graphic-based interface, LabVIEW, NI Vision was designed as commericial software. In this work, we designed programs for dynamic image acquisition, identification and analysis with Python and LabVIEW, and compared the identification results and specific advantages of the two algorithms.

In terms of the hardware structures, we constructed and controlled the conveyor and mechanical system with LEGO EV3 and servo motors. After image identification, the object diversion to the back-end physical-test platform was performed with robotic-assisted Uarm Metal. The utilization of the ATmega168 chip and Arduino IDE (Integrated Development Environment) helped easily realize the simultaneous control of three-axial motors and Bluetooth sensors, and completed the diversion. In this project, we further designed a measurement platform for three physical properties including notch depth, battery capacity, and strain. The control of the mechanical system of the platform was achieved with Arduino Uno combining pressure and voltage sensors. The measurement of the strain in terms of optical pulse deviation from fiber gratings provides an alternative for fragmental detection. Finally, the test results were uploaded to the public cloud server, ThingSpeak, via the ESP-8266 Wi-Fi module to supply the service for information interaction and feedback.

EXPERIMENTAL SETUP

Based on the LEGO EV3 dynamic modules, we developed a project of objective identification and established a physical-test platform on an industrial production line to simulate the object diversion and quality management in the smart manufacturing. The experimental setup is demonstrated in Fig.1.

EXPERIMENTAL METHOD

With a CCD/webcam to capture the image of objects (tires, batteries, and engine gaskets) that are carried randomly on the conveyor belt dynamically controlled by servo motors (Fig.1 right & Fig. 2a), we use two computer vision software packages (OpenCV and NI Vision) for the recognition of object characteristics. The item information of passed objects is transmitted to the robotic arm, Uarm Metal, by the bluetooth module, while the defective objects are disposed of in the recycling area. The three-axis motor and electromagnet are controlled via the ATmega chipset in the Uarm, by which the objects will be suspended and carried to the correct backend platform for property characterization, including tread depth, battery power, temperature, and pressure. We use Arduino and different sensors for measurement, and the test results are uploaded to the cloud server, ThingSpeak (Fig. 2b) by Wi-Fi. This web page is a public platform, where both the engineers and customers can freely check the dynamic production line process, and send their opinions back via the embedded Google form. The complete experimental procedure is depicted in the flow chart below (Fig. 3).

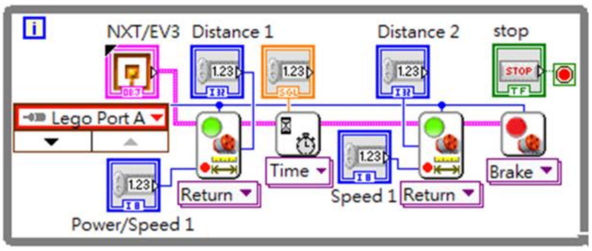

Figure 2a. Driving and speed control of servo motors for the conveyor.

Figure 3b. The current theme of ThingSpeak.

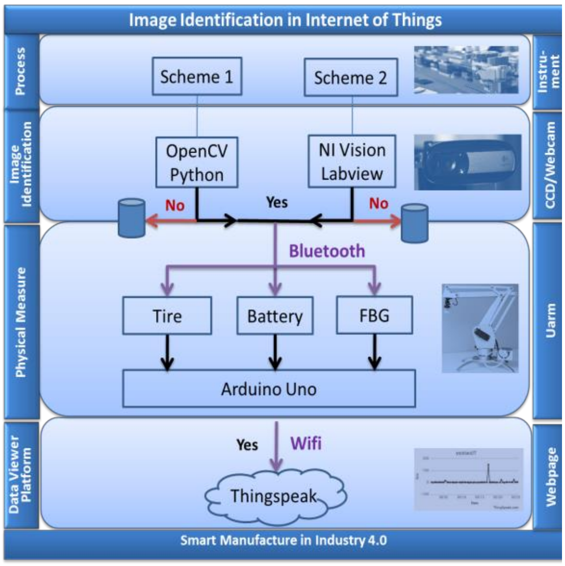

Figure 3. The flow chart of smart manufacture, from identification to quality testing and to the public cloud.

RECOGNITION THEORY

[1] OpenCV—Python

The OpenCV supplied machine vision is completed via (i) background photo shooting with the webcam or CCD, (ii) grey-scale transformation, (iii) dynamic image acquisition and background extraction, (iv) threshold setting and noise filtering, (v) configuration positioning, and (vi) Matchtemplate supplied database comparison.

In the edge control and threshold setting, the Canny Edge Method [6] also known as the optimal detector, is adopted. With the Canny algorithm, the image recognition through Gaussian filtering, Sobel test, non-maximum suppression, and two-threshold hysteresis would be expected to satisfy a low error rate, good localization, and minimal response.

Template Matching is a method for searching and positioning of a template image in a larger image. In the convolution process, the template image slides over the input image and compares the template and patch of input image under the template image. By using TM_CCOEFF, it returns a greyscale image of global maximum (R) according to

$$R(x,y) = \sum_{x',y'} (T'(x',y') \cdot I'(x+x',y+y')), \tag{1}$$

where

$$T'(x',y') = T(x',y') - 1/(w \cdot h) \cdot \sum_{x'',y''} T(x'',y''), \tag{2}$$

$$I'(x+x',y+y') = I(x+x',y+y') - 1/\,(w \cdot h) \cdot \sum_{x'',y''} I(x+x'',y+y''), \tag{3}$$

record the correlation of the neighbourhood of the pixel between the template T in the size of $w \cdot h$ and the object image I.

[2] NI Vision—LabVIEW

The NI Vision supplied machine vision is completed via (i) localhost setting and dynamic vision acquisition, (ii) threshold setting, (iii) look-up table generating, (iv) grey morphology, and (v) OCR/OVR conversion.

After image acquisition, we set the threshold for color-grey conversion and set the pixel number in the grey scales by means of bilevel thresholding. To enhance the contrast and the lightness of the image, we then generate a look-up table to renew the grey scales. Further, we apply Greyscale Morphology to trim the configuration of the object in terms of masks of erosion, dilation, opening, and closing [7]. Finally, we apply OCR (Optical Character Recognition) and OCV (Optical Character Verification) to work out analog-digital conversion for computer recognition. The identification program in the LabVIEW structure is shown in Fig. 4.

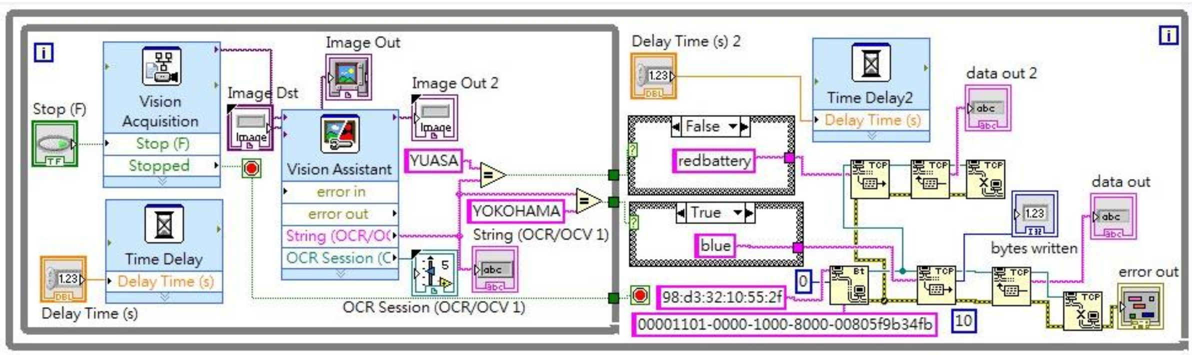

Figure 4. Implementation of objective identification by graphic-based interface of LabVIEW.

RESULTS

Fig. 5 and 6 display the flow charts of objective identification with text-based OpenCV and graphic-based NI Vision, respectively. In both schemes, the recognition proceeds following the rule: image acquisition, image processing for background extraction, grey-scale modulation for noise elimination and contrast enhancement, and finally database comparison. Essentially, the threshold setting is critical in the determination of the limitation and efficacy of grey-scale modulation to shape and configure the image. For database comparison, we adopt surface inspection to implement the characteristic identification. To avoid reflection smear, a strong color contrast is suggested to clearly distinguish between the characteristic symbol and the image body.

In this project, the recognition is precisely achieved in both schemes. However, compared with the commercial suite, it is truly a challenge for the beginners to understand the recognition theory and build the programs with the open source. But on the other hand, the use of OpenCV takes the advantages to easily connect with the embedded system while the realization of remote control via LabVIEW-for-Arduino becomes a new task, too.

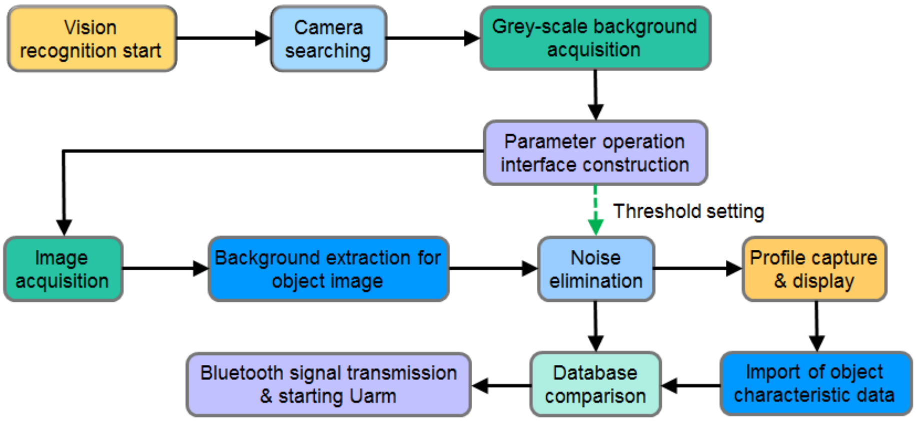

Figure 5. The flow chart of objective identification with OpenCV.

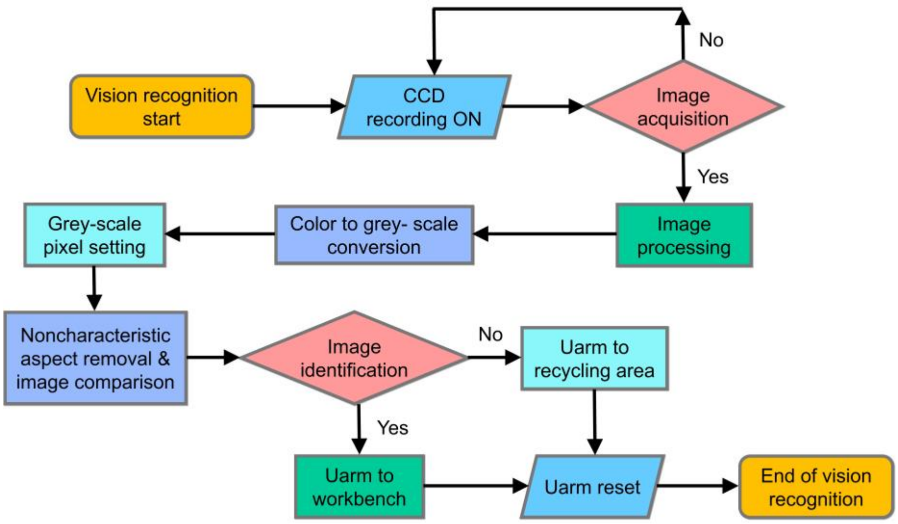

Figure 6. The flow chart of objective identification with NI Vision.

Fig. 7 left demonstrates the grey-scale images of the objects and characteristic surfaces that serve as templates of the database. The image identification is to calculate the correlation between adjacent pixels of the template and the object via the convolution process. As blue lines depict uncorrelated patterns, the red lines denote well-matched patterns that are delivered to physical tests (solid) or to recycling area as defects. The graphic interpretation of the digital image convolution is shown at the right-hand side of the figure.

After image identification, the object diversion to the back-end physical-test platform for notch depth, battery capacity, and strain measurements is carried out with robotic-assisted Uarm Metal. The utilization of the ATmega168 chip and Arduino

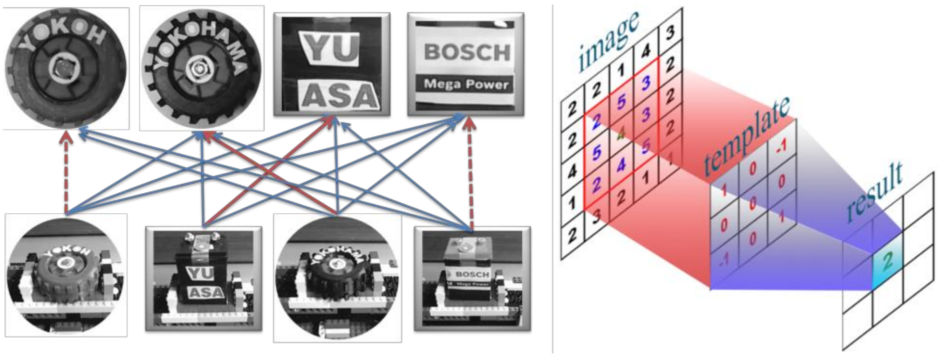

Figure 7. Grey-scale images and graphic interpretations of image convolution of characteristic templates and objects.

IDE help realize the simultaneous control of three-axial motors in the Uarm and Bluetooth receiver and transmitter, and complete the diversion.

The control of the mechanical system of the platform was achieved with Arduino Uno combining pressure and voltage sensors. The measurement of the temperature- and tension-induced strains in terms of optical pulse deviation from fiber Bragg gratings provide an alternative for fragmental detection. In Fig.8 we show the variation of strain intensity with wavelength measured by the high performance optical spectrum analyzer, Agilent 86146B.

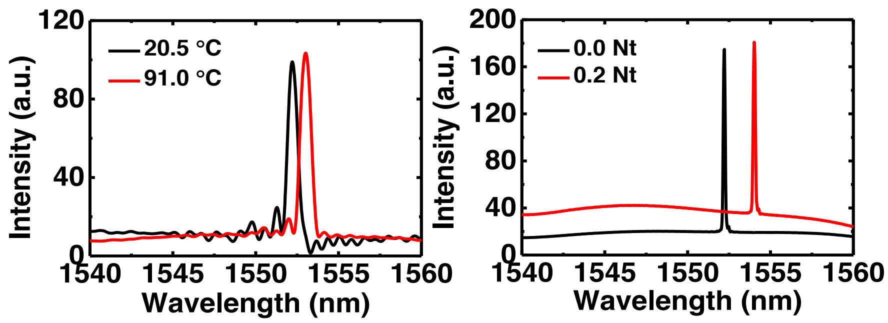

Figure 8. Temperature- and tension-induced strains on fiber gratings.

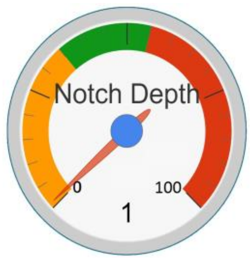

Figure 9. The notch depth meter on ThingSpeak.

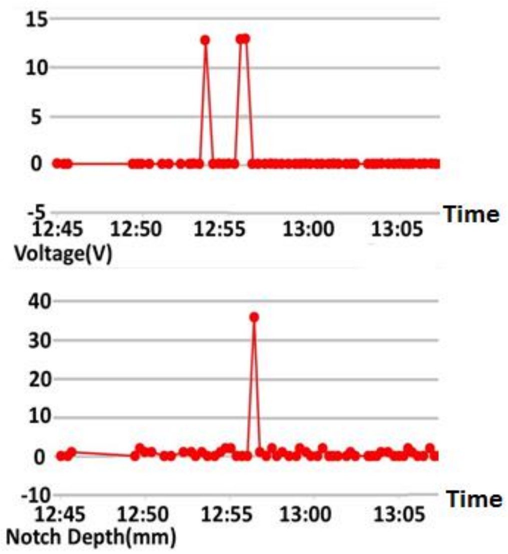

Figure 10. The dynamic records of voltage and notch depth on ThingSpeak.

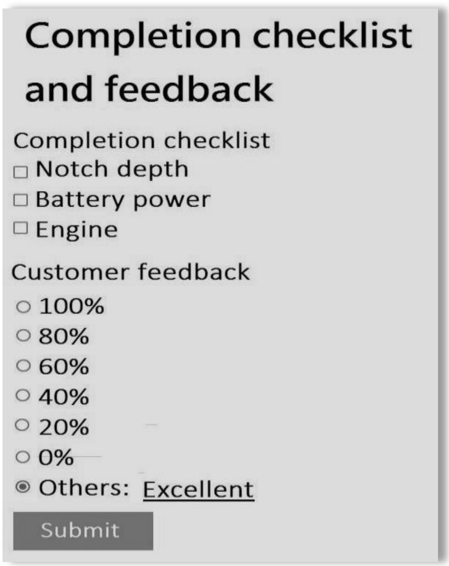

Figure 11. The completion checklist and real-time customer feedback.

Finally, the test results in terms of notch depth meter (Fig. 9) and dynamic records (Fig. 10) were uploaded to the public cloud server, ThingSpeak, via the ESP-8266 Wi-Fi module to supply the service for information interaction and real-time customer feedback within the Google form (Fig. 11).

SUMMARY

Via the integration of embedded microcontroller utilities and physical sensing environments, this project successfully demonstrates in the laboratory the kernel of Industry 4.0 in customized smart detection and the Internet of things through front-end objective identification, back-end physical properties measurement, and a cloud-supplied information platform and stimulate interdisciplinary collaboration between science and engineering for physics undergraduates.

From the perspective of engineering technique, the connection of the practical mechanical system and the platform of information interaction demonstrate the paradigm of a cyber-physical system. From the perspective of engineering education, the project-oriented training provides the opportunity for students to experience the practical operation, difficulties, and the need in maintaining a factory. Therefore, this provides the opportunity for students of science and engineering to work together and to stimulate new ideas and imagination to propose feasible solutions and suggestions to help improve the reliability and efficiency of the production and the manufacture. By means of the image identification, physical tests, and cloud interactions, our project has successfully demonstrated the idea and operating processes to approach the dream of smart factory.

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3.

Engineering Skills

Enhancing Employability through Leadership Training

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ABSTRACT

Most university engineering degrees include elements of teamwork experience to a greater or lesser extent and students are frequently placed in positions of leadership. Few universities, however, actively develop leadership skills or provide targeted training as a primary objective within course modules. Leadership coaching is a competence that is outside the experience of most engineering academics and providing it offers a new challenge for them. This paper compares two models for teaching 'leadership', offered as options in the final-year of an undergraduate engineering programme. Both use methods far removed from the usual diet of lectures and examinations. One is focused around a semester-long activity where senior students take responsibility for a team of younger students undertaking an industrially-based project. It is supported by a series of activity-based workshops. The second has similar objectives but is very different in style; it encapsulates a three-day intensive outdoor management course that exemplifies team-work and leadership theory through hands-on activities and provides the main focus for pre-course learning and post-course assignments. This paper describes the two variants and the philosophy that inspired them. A short survey reveals how a year-group of students responded to the different training methods and provides a comparison of the two educational models.

Conference Key Areas: Curriculum Development; Engineering Skills; Continuing Education and Lifelong learning.

Keywords: employability; skills; teamwork.

1 INTRODUCTION

When asked to describe what professional engineers do, most think strictly in terms of science and technology. They point to examples of familiar products and constructions such as cars, aeroplanes, computers, or bridges to describe outputs of the various engineering disciplines. Not surprising then, that if asked what students of engineering should be taught, we would naturally fall on the fundamental science that lies behind the understanding of these complex products together with the principles of design that brought them into being.

The most valuable asset of an engineering business however, is neither its steel stock nor its production machinery but the people it employs. Engineering is a team activity; possibly more of a team activity than any other business. Modern manufacturing depends on people with a diverse range of knowledge and skills who must work together to a common end. We, in the universities, are training tomorrow's employees of engineering business, so we should devote at least some of our available time on people skills if our graduates are to become effective members of the team right away.

Whilst 'hard' intellectual skills still dominate in academia, there appears to have been a transition in the workplace where skills which develop Emotional Intelligence (EI) are, apparently, just as important. It was recognised thirty years ago, that intrapersonal and interpersonal intelligences are just as important as the type of intelligence typically measured by IQ[1], and later studies declared them to be even more so. For example, Feist & Barron [2] wrote that social and emotional abilities were four times more important than IQ in determining professional success and prestige, while a recent UK survey further emphasised the importance of soft skills in respect of employability, personal development and career progression. It declared that hard skills help engineers qualify for a job or role, but soft skills dictate career growth and progression. [3] Highly developed EI is particularly important for tomorrow's leaders. The UK Institute of Leadership and Management quotes Daniel Goleman's work [4] in which he suggests that these skills contribute more than 85% of what enables star performers to become great leaders.

Goldberg [5] suggested that students currently spend 80% of their time studying technical subjects but these technical skills developed only constitute 20% of an individual's working day. So, not surprising that the recruitment of graduate engineers seems to focus more than ever on soft skill competencies.

In response, the ASEE [6] proclaimed that "engineering education programs must, not only teach the fundamentals of engineering theory, experimentation, and practice, but be relevant, attractive, and connected," preparing students for a broad range of careers and lifelong learning. And both ABET and the Engineering Council (EC), the bodies in the USA and UK respectively that define engineering accreditation routes list the required 'professional competences' including both 'hard' and 'soft' skills. Specifically, the EC now specifies generic competences for Chartered Engineers that include the ability to "Lead teams and develop staff" and to "Organise and lead work-teams" [7]. While most university degrees include elements of teamwork experience, few specifically address these leadership requirements or provide targeted training. Leadership training tends to be the preserve of professional development specialists and is outside the experience of most academics in engineering.

Despite this, and similar proclamations in other parts of the world, later studies highlight the perception from industry professionals of a soft skills gap within graduates and hold higher education institutions responsible. Meanwhile, employers are becoming more reluctant to invest in graduate training and development[8] due to the perception that this generation that are more likely than ever to leave the company after a short period. Kumar and Hsiao [9] summarised that *"Engineers learn soft skills the hard way"* supporting the theory that engineers enter the market place technically qualified but not sufficiently competent in soft skills.

A small number of curriculum designers in the UK have been inspired to respond, taking advantage of the additional teaching time available in our extended undergraduate Master of Engineering (M.Eng.) Degree. The integrated M.Eng degree was promoted and controlled by the Engineering Council in the late 1990s to be the premier fast-track route to senior professional registration for high achievers. These degrees were to have enhanced learning outcomes beyond those of the Bachelor degree in respect of both technical and transferable skills. With regard to leadership and teamwork skills, the question is; how should they be taught? If we are to prepare our most able students in the image proposed by our professional body, it is apparent that we will need to learn and adopt some pretty innovative methods.

2 UNDERGRADUATE LEADERSHIP MODULES

Two innovative 'leadership' modules have been introduced to the final year of a mechanical engineering M.Eng programme. The students choose which route they prefer. Both modules use methods of teaching and learning, far removed from the usual diet of lectures, tutorials and unseen examinations. The first is built around a semester-long 'mentoring' activity where senior students are given responsibility for a small team of year-2 students engaged in an industrially based project. The central activity is supported by a series of activity based training workshops that focus each week on a different 'people management' skill. The second module encompasses a 3-day intensive residential teambuilding and management development course that exemplifies a short preparatory course of management and leadership theory through hands-on exercises and challenging outdoor activities.

2.1 Module D500 'Project Leadership'.

All second-year students complete a mandatory team project which runs from October to February taking up one afternoon per week. Each team of four students is assigned to an industry-inspired project generated and supported by a group of companies known as the 'Loughborough Teaching Contract'. A final-year student studying project leadership is then attached to each project team, as mentor and this experience forms the central activity of the 'Project Leadership' module. Mentors are expected to chair weekly team meetings that last about 45 minutes and become involved in all aspects of the project at a supervisory level.

The mentor's primary role is that of project manager, who deals with project planning, gives advice and guidance, allocates duties to team members and encourages effective progress. Mentors assist with the promotion and development of ideas, and offer sound one-on-one advice on methodology, analysis and evaluation. They are, however, told to refrain from directly generating solutions or actually performing the technical tasks. Mentors quickly learn the effects of different leadership styles and the need to pay attention to human factors as well as to the technical tasks.

Academic supervisors observe meetings every two or three weeks and are therefore able to monitor the situation and intervene if all is not running smoothly however on many occasions the mentor is left to take charge. Supervisors complete an appraisal checklist and discuss it with the mentor after each observation to provide developmental feedback and support. Supervisors provide a safety net and are ultimately responsible for both the mentors and the student teams including the assessment of both. The objective, however, is for mentors to be given responsibility and therefore to experience first-hand leadership and in the majority of cases supervisors feel able to stand back.

While the mentoring activity is central to the module, to realise the maximum benefit they also need parallel coaching in aspects such as chairmanship, project planning, time management, human resource management, team dynamics, leadership styles and motivation theory. Most importantly, they need the opportunity and encouragement to reflect on events and what are the causes of subordinate reactions in the wider context. A programme of seminars provides a weekly forum in which the mentors are encouraged to discuss and share their experiences and to learn new techniques. The taught element is 'activity based' borrowing most materials from staff training and development organizations.

When this module was first introduced, there was a lecture programme, however it was clear that, although the students listened politely, they had little real interest in non-technical topics taught in this way and, as a consequence, failed to really develop professionally or properly understand the mechanisms of human interaction. Hence, the lecture programme was replaced by the more effective workshops.

2.2 Module D517 'Teamwork and Leadership'.

This option is built around an outsourced 3-day residential Outdoor Management Course (OMC) currently provided by the Lindley Educational Trust. The Trust undertakes development activities with people of all ages and is experienced in constructing themed development courses for groups ranging from primary school children to senior company executives. This particular course was developed jointly by the staff of the Trust and the module leader at university. University staff accompany the students throughout the course acting as observers. Some of the topics that are fully explored and exemplified through outdoor activities are: the behaviour of individuals and groups, balancing the needs of the task, the team and the individual, leadership styles and skills, motivation and working under pressure.

In the weeks running up to the outdoor course, students attend just 3 seminars 'teamwork' leadership style' and 'motivation' and research appropriate theory such as John Adair's work on leadership and leadership styles, Tannenbaum and Schmidt's style continuum and Belbin's team roles. They research and present a case study as an oral report accompanied by a short written document. At this point, we believe that, although the students perform this task well, they are fundamentally unconvinced of the purpose or usefulness of such theory, nevertheless it provides a good foundation and all becomes much clearer during the reviews and feedback sessions that form an essential part of the residential course.

The course takes place in 'the Hollowford Centre: a purpose built training centre in the heart of the Peak District National Park in central England. This is a sparsely populated craggy mountainous region noted for outdoor leisure activities such as rock climbing, caving and hill walking. It is through this type of activity amongst others that we enthuse the students and empower them to develop their individual strengths, create positive relationships and construct effective work cultures. This type of course is popular with many commercial organisations for teambuilding and management development but rarely available as part of the engineering curriculum in British universities.

Fig. 1. Students tackling various indoor and outdoor challenges.

The intense activities are led by experienced professional trainers and begin with short ice-breakers, problem solving activities, and a raft building exercise. Teams are formed and each team earns virtual money through successfully completing exercises and the money is carried over to the next task. Each activity is designed to bring out a different aspect and the students are expected to take on different team roles. They all experience leadership in some form by the end of the course. Half way through day 2 a major 24-hour exercise begins. This runs late into the night with the teams only returning to the centre for a short sleep and then carries on into day 3. The exercise simulates a manufacturing construction business scenario; assembling a product, via the purchase of materials and components, and involves planning multiple tasks, working to strict time constraints, transportation and a whole host of manpower issues. Competing in teams up to 10 students are required to construct a model aircraft in the 24-hour period. They need to ‘buy’ their raw materials (the components of a plastic kit). Parts are ‘bought’ with virtual dollars that can only be earned by completing specified tasks such as abseiling, rock climbing, orienteering problem solving etc. The ‘tasks’ are situated at map references within a 20 mile radius and two minibuses with drivers/trainers were available for each company. Other centre based tasks such as hill walking, high wire activities or completing an obstacle course need to be completed to earn ‘fuel miles’ for the buses. Students must also feed their teams while out on activities and can earn points by cooking for the staff who are there to facilitate and observe the activities and ensure the safety of the teams. Students must decide what is done, when and by whom through careful planning and the appropriate division of manpower. In fact, the trainers will happily drive in the wrong direction or take the wrong equipment if told to do so by the students or will stop the bus if the teams miscalculate and run out of fuel miles. Under these circumstances, on a cold spring night, teams soon learn the importance of careful planning and thinking ahead. Plans are presented to staff at the outset for approval.

Notwithstanding the obvious attractions of the outdoor activities, the focus remains very much on learning with extended review and feedback sessions after each activity. Review sessions are led by the trainers and prove very effective at teasing out the important lessons embedded in the assignments. The trainers refer back to the theory studied before the course and it then becomes much easier to place these ideas into context. At first, the university staff were surprised at the intensity of these reviews, clearly brought about by such enthusiastic engagement.

a. Assessment

Table 1. Assessment details: each module has 3 elements of assessment.

	D500	D517
1	A structured essay, to encourage students to research and report on leadership techniques.	Pre OMC Case study comprising a short paper and oral presentation (small groups – peer moderated)
2	At the end of the project, mentors write up their experiences in the form of a reflective critique.	Individual report on OMC experiences
3	The progressive appraisal system identifies strengths, weaknesses and growth from the perspective of both supervisor and subordinates.	Team exercise – create a video documentary on a specific topic of teamwork and leadership.

3 RESULTS FROM THE SURVEY OF PARTICIPANTS

The novel methods used in both modules have created a lot of interest, not least from prospective employers. Graduates recount how prospective employers often appear disproportionately interested in hearing about these activities during job interviews and claim that taking part has given them an edge in the employment market. It is difficult, however, to be objective about how effective the modules really are in achieving the intended learning outcomes. From verbal feedback and end of module surveys, there is no doubt that our students think the opportunities are invaluable. Both modules operate on the principle that leadership cannot be taught but has to be nurtured through experience.

To compare the two methods, a year-group of students on both modules were asked to complete surveys of their attitude to leadership issues both before (anticipation) and after the courses (reflection). The same questionnaire was used with both modules. In total 65 participants took part in the survey.

General questions elicited written comments. When asked what they hoped to gain from the modules before starting, many hoped to gain confidence and personal skills while others looked forward to actually experiencing management skills and gaining organisation abilities. A number also hoped to gain in confidence for interview situations they would face in the near future. The reflection surveys seem to indicate that these expectations were achieved and in many cases, exceeded.

A set of statements focused on students' emotional reactions, they are listed below.

1. I like to encourage others
2. I feel comfortable as a leader
3. I like to work in teams
4. I like to work alone
5. I am good at decision making
6. I am confident in my abilities
7. I am confident as a person
8. I listen to what others say
9. I am an organised person
10. I plan before doing things
11. I pay attention to detail
12. I am patient
13. I like to get on with things
14. I reflect upon what has occurred
15. I review the work I have done

It is perhaps not surprising that a group of high-flying finalists should respond well to leadership; this is certainly no cross-section of the general public. The surveys were completed at different times, so most students would not remember their answers to the anticipation survey and have to answer truthfully when reflecting. Of course, different students participated in each module. The anticipation surveys for both modules shows relatively few apparently introverted individuals, reluctant to be involved but despite the relatively high 'anticipation' scores, the collective trend for both modules was to a further increase scores after the module.

There is insufficient space in this paper to discuss all the results in detail but the charts, below show selected highlights. Each chart shows the responses for the two modules side-by-side; the mentoring-based module with the light bars. The darker bars behind refer to the residential course module. Each bar represents the percentage of students on each module who either agree or disagree with the statement – in the Anticipation survey (A=left bar) and in the Reflection survey (R=right bar) so an increase in positive answers or a decrease in negative answers from A to R suggests development. In most cases one observes that the neutral or semi-negative scores fall as these people shift to more positive scores to the right.

Question 1 (figure 2) considers aptitude to working with others: both modules require the student to take an active interest in the work of others but there is a fundamental difference that in D500, the mentors are required to encourage a team of younger students while the team activities on the outdoor course are all within the same peer group. Both modules show some development but the improvement is stronger in D517. It appeared that some pretty strong and lasting friendships grew out of the OMC activities whereas mentors are, by their very role, expected to remain quite detached from their mentees. It is always easier to encourage a friend.

Question 2 (figure 3) asks whether individuals are within their comfort zone in a leadership situation. Again, the results are encouraging showing that the experience has led to an overall improvement in confidence. In this case, the mentoring experience shows the greater development. This may be because the topic of this module (an engineering project) is more familiar than some of the outdoor experiences that are designed to stretch the participants' achievements in new areas. Nevertheless, it is quite common for a student to admit some trepidation at the thought of taking responsibility for a second year team in D500.

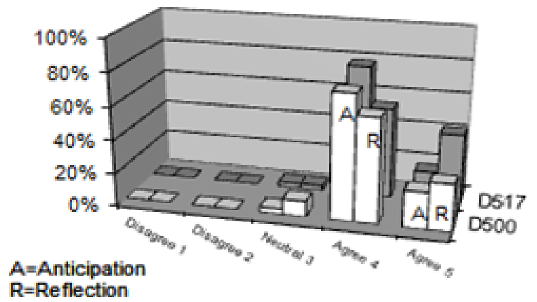

Fig. 2: I like to encourage others

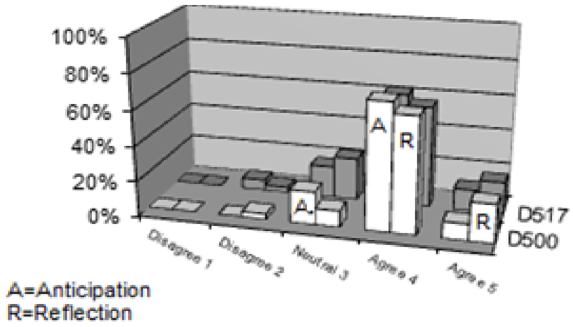

Fig. 3: I feel comfortable as a leader

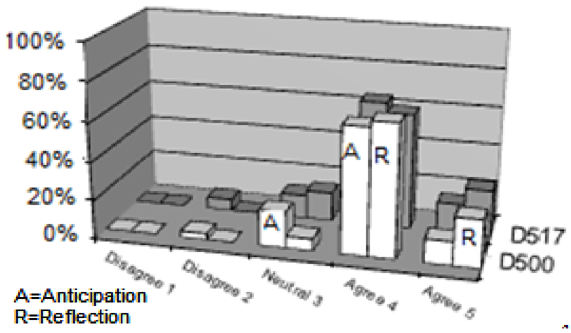

Fig. 4: I am confident in my abilities

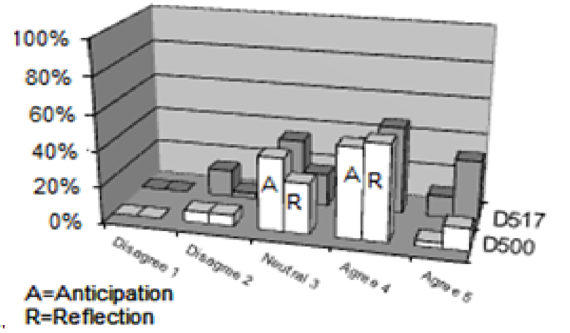

Fig. 5: I review the work I have done

Figure 4 looks at confidence; (question 6) Here again the mentoring module indicates the bigger gain. Perhaps there is truth in the anecdote that a person learns their subject well when they have to teach it to others, a feature of this module.

Question 9 (figure 5) shows the results for question 15 concerning the ability to reflect and review. The outdoor course seems particularly good at developing this important ability and approximately 20% of students recorded movement from one response category to the next. They reported that it was only after these sessions that their previous study on management topics back at university had started to appear relevant. One student commented in writing of the residential module "some of the most important and valuable lessons I have learned during my degree".

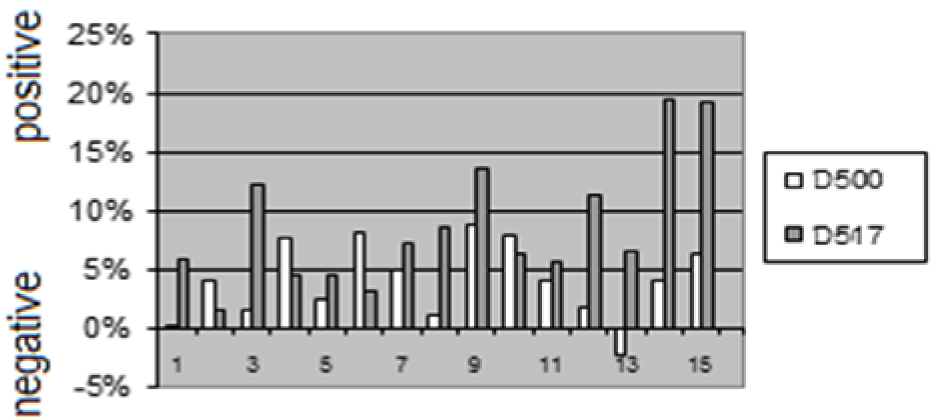

Fig. 6: Change analysis for all questions.

Figure 6 summarises the responses to all questions in numeric form where 5=strongly agree 4=agree, 3=neutral, 2=disagree and 1=strongly disagree. The chart shows the change in the group average scores before and after the modules. Of note, perhaps is one negative change for D500; question 13, “I like to get on with things”. There is no obvious explanation for this. The overall picture, however is of improvements across the board for both modules, which is very gratifying.

4 CONCLUSIONS

The world of employment training has proved an interesting and rewarding experience for both staff and students. There is no doubting the enthusiasm for this amongst these senior students who are focusing on their next career step into paid employments with considerable ambition. I doubt the courses would be so successful with a less well driven cohort. Indeed, one of the Lindley trainers commented that this group showed more enthusiasm than many groups of company executives.

The survey results suggested that both models are valuable. At present the two modules are offered as alternative options which are described to the prospective students in advance. Some people might find the content of one or other quite daunting and offering a choice prevents the possibility of an unhappy mismatch. While both modules appear to meet the objectives well, mentoring appears particularly strong in developing leadership and confidence while the outdoor management course excels in building teamwork and understanding theory through review and feedback; these, in fact were the areas that showed the biggest gains.

Furthermore leadership and team-building training provides a powerful added attraction to potential employers of engineering graduates.

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Teaching the art of communication through drawing

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ABSTRACT

Engineering drawing is a form of communication. Sketching skills are vital for communicating ideas, and understanding of the principles behind drawing conventions is needed to ensure clear communication between designers and fabricators. However, students are losing that ability to communicate as universities move towards CAD-only courses. What is needed is a course that reflects the real-world relationship between drawing, sketching and CAD: the modern engineer sketches an idea, takes it into 3D CAD, then produces 2D manufacturing drawings where necessary.

An exercise was designed in order to teach sketching and CAD skills to first-year engineering students at The University of Sheffield in an industrially relevant context, with the focus on communication rather than conventions. Students were given novel 3D-printed shapes and asked to sketch the part using standard drawing conventions so that someone else could reconstruct it.

Each student then created a CAD model from someone else's sketch, providing written feedback, and produced manufacturing drawings using SolidWorks.

The method described in this paper has been shown to be an effective and relevant way for students to learn the principles of engineering drawing, sketching and CAD. Peer feedback was shown to be an effective learning tool for both parties.

Conference Key Areas: Engineering skills, Curriculum development

Keywords: graphics, CAD, peer feedback

INTRODUCTION

"The single biggest problem in communication is the illusion that it has taken place."[1] Engineering drawing is a form of communication. Manufacturing drawings communicate a designer's intent to the fabricator. When an engineer wants to communicate an idea to another engineer, the first thing they reach for is a pencil. It has also been suggested that sketching is a way of offloading the visio-spatial working memory [2], allowing more space for design thinking. It is thus an integral part of the design process. Despite this, mechanical engineering programmes are increasingly moving away from hand drawing and teach little sketching [3,4]. Students are also coming to university with poorer hand drawing skills and performing poorly in drawing courses that do exist [5]. Communication has been identified as something students in group design projects struggle with, because of a lack of common “design language” and “communicative tools” such as sketching [3]. Stacey et al. noted that while “freehand sketches are a fast and powerful medium for expressing design ideas… misinterpretation of sketches is a major cause of communication failure in design teams” [6]. For this reason, teaching of hand drawing skills cannot and should not be entirely replaced by CAD-only courses.

The emphasis in traditional drawing classes has been on adherence to strict conventions such as line widths, text height and hatching types. As engineering programmes move away from teaching hand drawing to focus on drawing interpretation [7] and CAD skills, even with the introduction of modern interactive teaching tools [8,9], the key concepts for drawing identified by academics and industry experts [10] still focused around particular conventions such as orthographic projection, how to section, dimension and annotate. While these conventions are undoubtedly useful in forming a clear common language, it is important that the emphasis is placed on the communication itself rather than the conventions. With the advent of CAD and the rapid pace of technological development, engineers must understand the fundamental principles behind the conventions in order to be able to use them flexibly across different media and in interdisciplinary contexts. Otherwise, they are likely to discard conventions altogether and fall into ambiguous communication.

Both the traditional method and the CAD-only method fail to reflect the real-world relationship between drawing, sketching and CAD. Traditional courses tend to start with pencil drawing on drawing boards, with sketching and CAD introduced later, once “the foundations” have been laid down. The modern engineer sketches an idea, takes it into 3D CAD, then produces 2D manufacturing drawings where necessary. In this paper, it is argued that drawing and CAD teaching should reflect this process more accurately, rather than being taught in isolation, and should emphasise the development of communication skills. A prototype exercise is detailed and analysed.

1 BACKGROUND

In September 2016, the first cohort of a new MEng Engineering programme began their studies at The University of Sheffield. The programme was intended to be interdisciplinary, covering mechanical, civil, electrical and electronic, and chemical and biological engineering amongst others. This represented an opportunity to look again at the teaching of engineering drawing and computer-aided design (CAD). Through discussions with the relevant teaching staff across the faculty, it became clear that the main requirements common to all disciplines were for students to be able to sketch, to understand the relevant drawing conventions, and to be able to use CAD.

In the Mechanical Engineering department, the teaching had previously consisted of a series of lectures accompanied by hand drawing exercises, and a separate CAD course. This reflects historical engineering practice, where draftsmen would produce manufacturing drawings by hand (or later in 2D CAD) and engineers might separately produce 3D CAD models for use in Finite Element Analysis.

However, modern design and manufacturing tools, and the widespread availability of prototyping tools such as 3D printing mean that the modern engineer approaches the design-manufacture process very differently (see Figure 1). After an initial (sketched) concept, products may be directly designed within CAD, the idea taking shape as they are drawn; in civil engineering, the model may be created in Building Information Modelling (BIM) software so that it links with other design information; and crucially, parts can in some cases be manufactured directly from 3D models, bypassing the 'drawing for manufacture' process altogether. Where they are used, manufacturing drawings tend to be produced in CAD packages from the 3D model, and are increasingly used purely as a reference against which to evaluate the finished article, rather than the instructions on how to produce it. The use of templates for both drawing sheets and drafting standards has reduced the need for engineers to commit to memory entire drafting standards, allowing a focus on the fundamental elements.

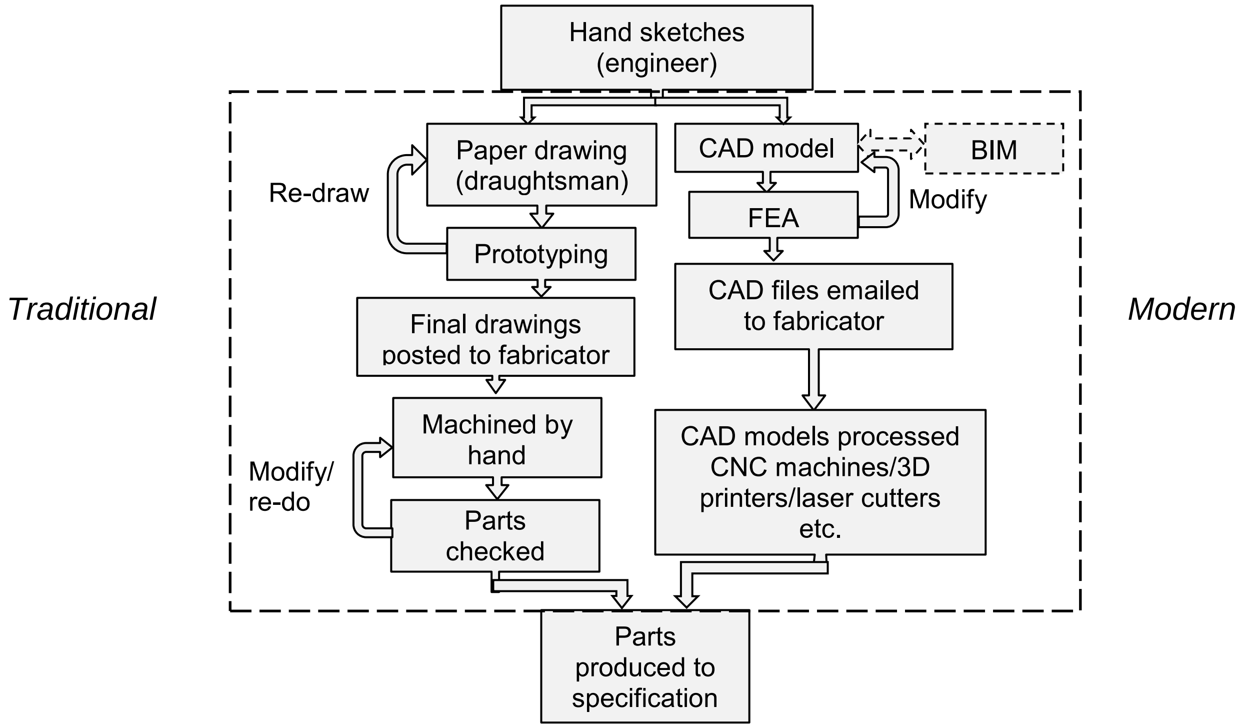

Fig. 1. Comparison of traditional and modern design processes

2 DESIGN OF LEARNING AND TEACHING ACTIVITIES

In order to more accurately reflect the interplay of sketching, CAD, and manufacturing drawings, and the importance of communication above the recall and application of specific drafting standards, an exercise was designed for 35 first-year engineering students at The University of Sheffield. By the end of the exercise, the students were expected to be able to:

- Communicate engineering concepts through sketching
- Use accepted drafting conventions to describe an object geometrically
- Interpret an engineering sketch and reproduce the object in CAD
- Produce part and assembly drawings in CAD
- Select and correctly mark appropriate tolerances for a hole and shaft based on a specified fit type

Each student was randomly assigned a 3D-printed part from a range of nine, consisting of three mating pairs and a three-part assembly. The parts are shown in Figure 2. Including physical interaction with machine parts in drawing classes has been trialled elsewhere [5, 11] and was found to improve students' spatial awareness and engagement. Each of the parts was a novel shape drawn in SolidWorks® using a combination of simple and complex operations. The use of novel shapes rather than existing components was intended to remove the ability of students to recognise the object and thus fill in missing information from memory. This simulates real-world conditions where a novel component is being designed.

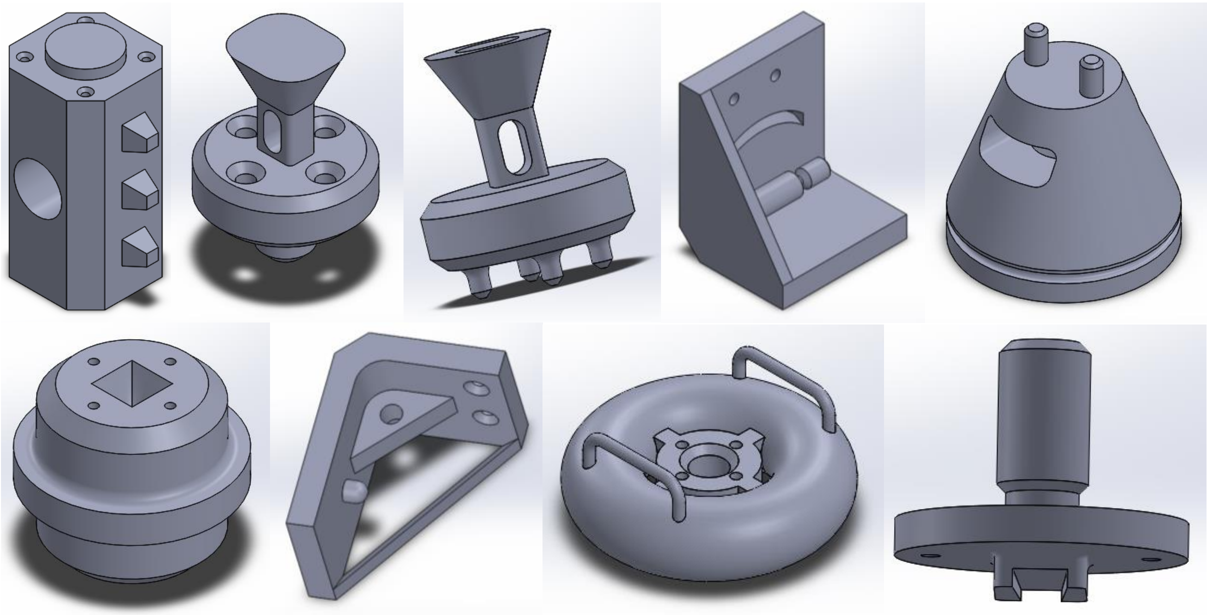

Fig. 2. CAD models of parts used in the exercise

Students were allowed to take the part away and told not to show it to anyone, but to sketch the part using standard drawing conventions and fully dimension it, using notes to clarify where necessary, so that someone else could reconstruct it. Students had previously attended a lecture and practical class where instruction on drawing conventions was given and students had an opportunity to practise sketching and receive feedback.

The students' sketches were collected and redistributed at random to those with a corresponding mating part. After some CAD tuition, they were asked to create a 3D model from the sketch and provide written feedback to the sketcher, focussing on whether the information had been communicated clearly. At this point, they were allowed to discuss the model with their partner and receive clarity on points of confusion. They were then asked to modify their model in light of the discussion and share the finished part with their partner.

Although some efforts have been made to integrate the teaching of hand drawing and CAD at other universities [5], this approach goes further, linking the two parts in a single exercise via an interpretation task that forces students to consider the viewpoint of those to whom they must communicate, and teaches the value of clarity and a common language in the form of conventions.

After further teaching on drawing for manufacture and basic tolerancing, they were each asked to produce manufacturing drawings of the two mating parts using SolidWorks, including an assembly drawing with a Bill of Materials. They were also given a fit for the mating hole and shaft (based on descriptions in [12] e.g. "loose running fit"), and asked to add appropriate tolerances to the relevant dimensions on the part drawings.

3 ASSESSMENT

Students were asked to electronically submit a portfolio containing their sketch, feedback on their partner's sketch, CAD models before and after discussion, and part and assembly drawings. The marking scheme is shown in Table 1. It can be seen that clarity and completeness feature prominently, and less weighting is given to adherence to specific conventions.

Table 1. Marking scheme for the exercise

Task	Weighting (%)
Sketch	**15**
How well does it convey the necessary information about the part?	
• Clarity	5
• Completeness	5
• Use of space	1
• Proportion	1
• Correct use of conventions (orthographic/isometric, sectioning, centre lines, dimensions etc.)	3
First model *How well does it represent the information in the sketch?*	**15**
Feedback *Does it identify all the issues with the part (clarity, completeness, use of space, proportion, etc.)?*	**10**
Second model	**20**
How closely does it replicate the part?	
• Basic features (extrude, revolve etc.)	10
• Holes (location, countersinking etc.)	5
• Complex features (loft/sweep etc.)	5
Detail drawings (each)	**15**
• Completeness (no. of views, hidden detail, full dimensioning)	6
• Clarity (details not overlapping etc.)	2
• Correct tolerancing of hole/shaft mate	5
• Use of space (sensible scaling)	1
• Title block	1
Assembly drawing	**10**
• Use of space	2
• Clarity	2
• Balloons	2
• Correct BOM	3
• Title Block	1

4 RESULTS

By the end of the course, most students were able to demonstrate an ability to communicate clearly and an understanding of basic engineering drawing concepts. Examples of original sketches and final CAD drawings are shown in Figures 3 and 4, along with the feedback provided by another student on the sketch.

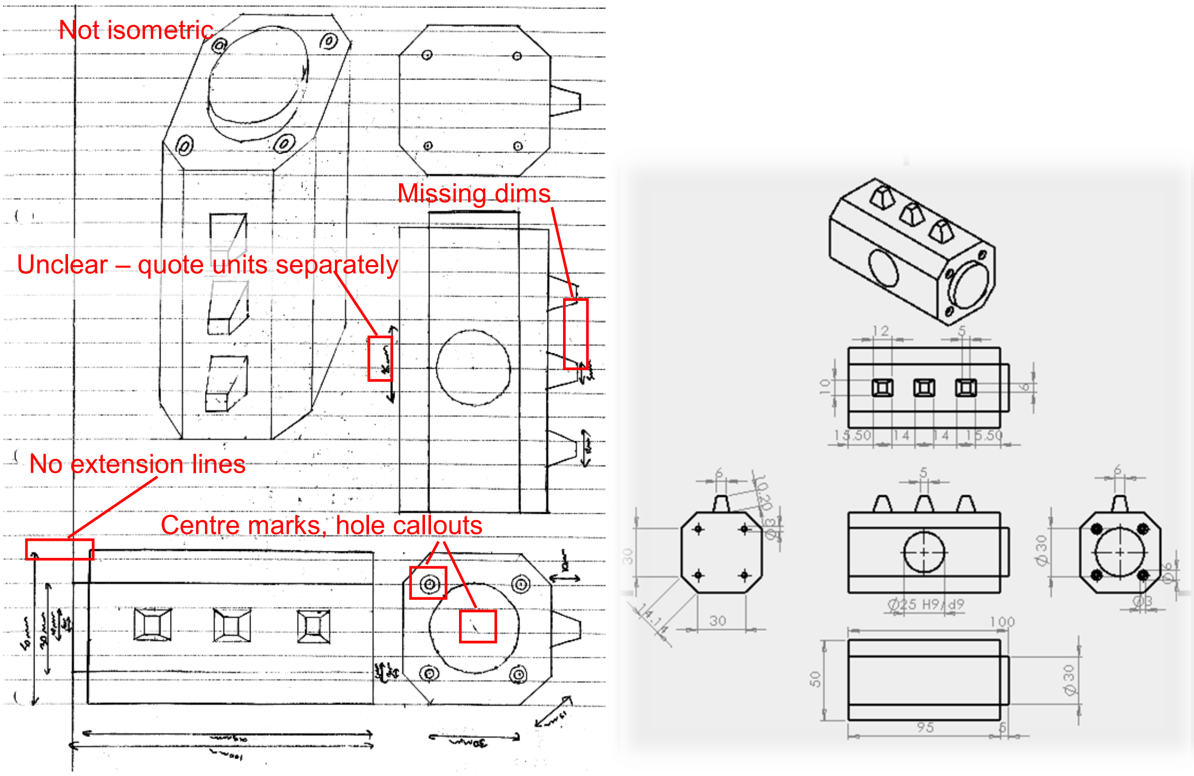

Fig. 3. (a) Original sketch with main errors shown; (b) final CAD drawing

Excerpts from the student feedback provided on the sketch (Fig. 3a):

"The sketch made the shape of the object clear… however whilst drawing I couldn't place the smaller details (the protrusions and holes) on the object due to a lack of centre lines and dimensions stating where on the object they should be. I had to guess where the holes went... Hidden lines would have helped identify how far the holes go into the shape along with their respective dimensions... Dimensions were sometimes ambiguous as some were similar and didn't have projection lines."

Excerpts from the student feedback provided on the sketch (Fig. 4a):

"… showed a clear understanding of how to… clearly convey how the object would look in real life… a good use of different types of lines to represent the interior detail… some confusion with the scale… and I had to estimate the distance of the innermost indents at the bottom of the shape… some issues with reading the measurements [which are not] connected directly to the ends of each part… some measurements were not provided… I would recommend double checking whether the dimensions at the top of the front-on view add up, labelling centre lines and the height of the cylinders on top of the shape as well as the distance between them, and including the dimensions of width of the removed square on the front view… rather than on the view from above… isometric view would be desirable, however it is not essential as the overall shape was clear. The information provided about [thread] proved to be especially helpful."

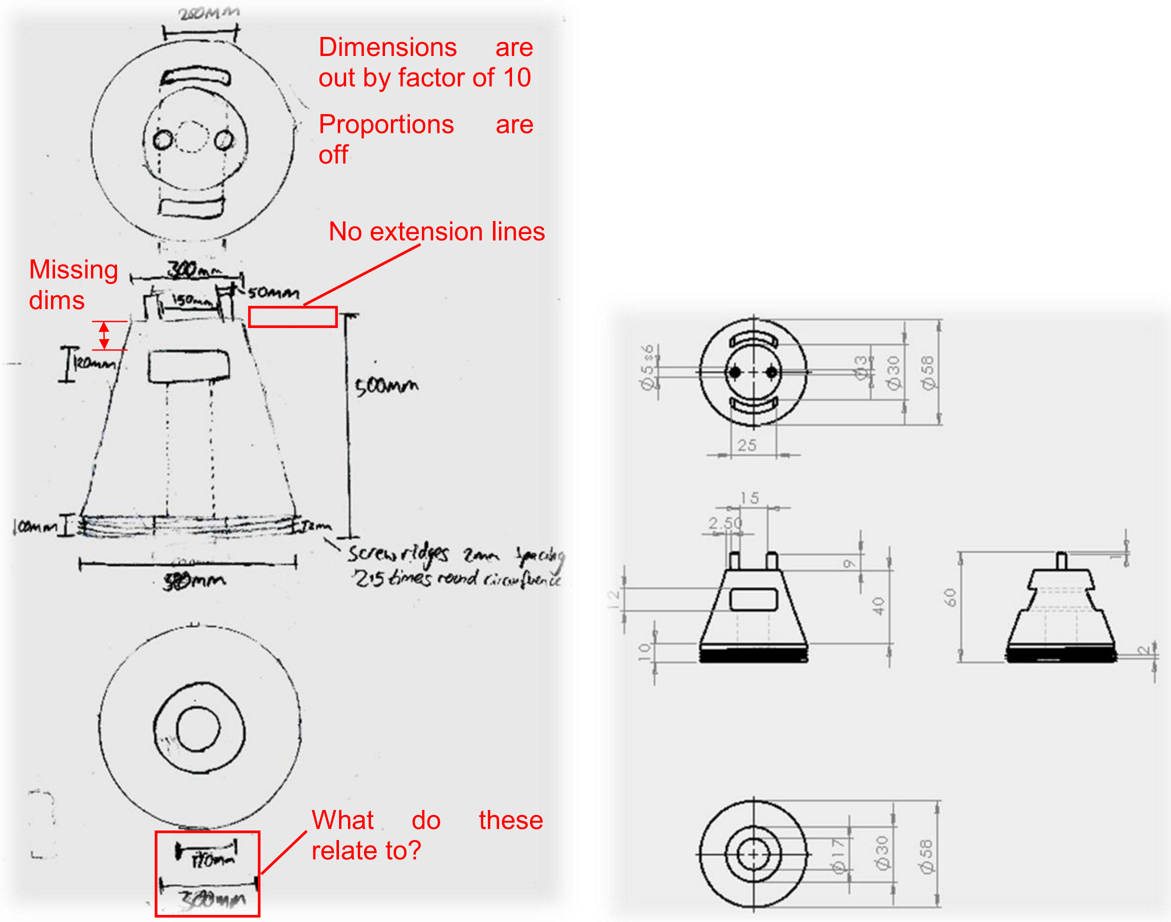

Fig. 4. (a) Original sketch with main errors shown; (b) final CAD drawing

It is clear from the improvement in clarity and completeness from the sketches to the final drawings (leaving aside the obvious advantages given by using CAD), that most students had achieved the intended learning objectives. The quality of feedback provided also shows that through the experience of using the sketches to create a CAD model, most students grasped the salient points of what makes a good engineering drawing and why clear communication matters when specifying for manufacture.

5 EVALUATION

This exercise reflects real-world use of CAD and drawing, and places the emphasis on developing the "communicative tools" and common "design language" [3] that students are missing. The use of sketching allowed them to focus on correctly using drawing conventions to communicate, rather than on drawing neatly or with the correct pencil. These skills should be transferrable to other standards (such as civil, chemical, or electrical drawing) since students understand the purpose of drawing rather than just memorising rules. The process of interpreting and feeding back on the sketches also gave the students the opportunity to understand the impact of good and poor practice on the effectiveness of communication, and to reflect on their own submission. The use of 3D-printed parts allowed the students to relate their drawings to a physical object, while also giving the flexibility to create complex, novel geometry that could not be replicated by traditional methods.

6 CONCLUSIONS AND FURTHER WORK

The method described in this paper has been shown to be an effective way for students to learn the principles of engineering drawing, sketching and CAD in an industrially relevant context. Peer feedback was shown to be an effective learning tool for both parties.

In the next iteration of the exercise, students could print parts from their models to be able to compare visually with the originals and understand how differences arose, which would be a useful form of feedback. Alternatively, augmented reality facilities at the University may be used to allow students to visualise the model in 3D and compare that way. This will additionally broaden the students' understanding of the uses of CAD modelling and increase engagement with the exercise.

The cohort used for this exercise was much smaller than those of Mechanical and Aerospace Engineering to whom such courses have previously been delivered. In order to roll out this exercise to those students, a peer review method for marking will be trialled.

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Entrepreneurship education for PhD students in engineering sciences

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ABSTRACT

In this article, we discuss the development of a specific entrepreneurship training programme and its integration into traditional doctoral education. We present a description and reflection on our new entrepreneurship training programme which is specifically designed for PhD students in engineering sciences. We propose a twofold approach: training programme development which takes into consideration, not only the initial skills level of participating students, but their future career perspectives as well. We define four skill development levels which are differentiated by specific requested learning outcomes. As a conclusion, we provide reflections on the future perspectives of entrepreneurship education in this specific context.

Conference Key Areas: Curriculum development, Engineering skills

Keywords: Doctoral education, Engineering science, Entrepreneurship training

INTRODUCTION

Doctoral students' education aims to develop highly specialised theoretical knowledge in students' research fields, as well as developing their skills and competencies in researching to help them better prepare their thesis [1]. These abilities are indispensable, not only to successfully complete their doctoral studies, but also for performing well in an academic career. However, only a minority of PhD students in engineering sciences will have the possibility to pursue an academic career in their research domain. According to the latest survey, the proportion of graduate engineering PhD students who started an academic career is in constant decline (from 52 % in 2010 to 43 % 2013) in France. The majority of them will make their career in industry and work in a business environment [2]. In this context, entrepreneurship education is viewed as a real facilitator in the transition of a constantly growing proportion of graduate PhD students from academic education to a work environment [3].

1 ENTREPRENEURSHIP EDUCATION

1.1 Entrepreneurship education for PhD students

Entrepreneurship education was introduced into the curriculum of French higher educational institutions relatively late, only over the past two decades. Its introduction was strongly encouraged and supported by the government in order to stimulate entrepreneurship activities and create employment [4]. However, the integration of entrepreneurship education in doctoral education programmes is still not generalised and depends mainly on institutional decisions. This is quite surprising despite the numerous benefits of these programmes for PhD students, industrial business organisations and higher educational institutions.

For PhD students, entrepreneurship education could appear as the cornerstone of their future employability: if they are to work in an industrial or business organisation, they have to possess not only well founded technical skills, but also business and entrepreneurship skills in order to allow them to operate successfully in this new environment. These ‘non-technical’ skills and competencies, often considered as secondary or complementary, have become vital for graduate doctoral students to acquire for when they start their career in industry. The possession of these transferable skills and competencies can give considerable advantages for them in the recruitment process.

For industrial organisations entrepreneurial skills and competencies have an important place in their skill requirements and are viewed as one of the key competencies nowadays. It is obvious that these skills and competencies are particularly important to build a solid entrepreneurial orientation which consists of innovativeness, proactiveness, risk taking, competitiveness and autonomy [5]. In a competence based market competition [6], employees’ competencies are considered as one of their most valuable assets for them to be able to develop new and innovative products. The lack of these skills and competencies could considerably reduce their economic performance and their capacity to attain sustainable competitive advantages. This is even accentuated in industry where engineers’ skills and competencies have a huge influence on the ability of organisations to create significant value added products and services.

From an academic perspective, the development of entrepreneurship education for engineering doctoral students has become an important issue. Several studies [7, 8, and 9] pointed out the positive effect of entrepreneurial education on the development of students’ business skills and competencies, and also on their innovation capacity [10, 11]. Entrepreneurship education has numerous short-term effects, such as the raising of entrepreneurship awareness, elevating the understanding about enterprises, allowing for the development of an entrepreneurial mindset or an awareness concerning the attitudes and intention toward entrepreneurship etc. [12]. Furthermore, there are several widely recognised positive long-term effects of entrepreneurship education on society, such as developing an idea and patents generation, allowing for enterprise growth and increasing job creation which motivates the expansion of entrepreneurship education [13].

1.2 Doctoral entrepreneurship education programme in France

Despite its long-standing needs, entrepreneurship education is a relatively new phenomenon in PhD students’ education in France. It was introduced into doctoral training only six years ago with the participation of a limited number of post-graduate engineering schools. With the support and encouragement of the government, it was launched by the CDEFI (Conference of Deans of French Schools of Engineering) in the framework of a specific doctoral training programme after a two year experimental period (from 2011 to 2013) when the programme was tested by nine engineering higher educational institutions [14]. Since its introduction, the number of participating institutions has seen an exponential growth, as 26 engineering schools and 30 doctoral schools participate in this programme today [15]. This doctoral programme is open for all doctoral students, independent of their scientific disciplines, and it is not reserved solely for engineering doctoral students. However, on the national level, 50% of the participants are doctoral students in the domain of engineering sciences. This high participation of engineering doctoral students is mainly explained by the fact that engineering schools in France traditionally have a strong relationship with industry which gives them a good vision about what the industry needs and its requirements for skills and competencies.

The main objective of this programme is the development of the skill and competency requirements which doctoral students need in order to improve their employability which will allow them to work in a real business environment. As we mentioned before, the majority of PhD students in France pursue their career in an industrial business environment. However, contrary to other European countries (e.g. Germany, UK), PhD graduation is not really recognised by French industrial business organisations. In this context, this doctoral training has a specific purpose of making the recruitment of graduate PhD students more attractive in the labour market. According to a recent study [16], graduate PhD students have difficulty identifying accessible positions and the skill and competency requirements of industry outside of their research and development activities. This programme could help them to better understand the concept and practice of industrial business organisations, and not only better identify the required skills and competencies of the industry, but to take advantage of them.

1.3 Skills development

The definition of the required skills was based on the referential list ‘DocPro’ which was co-created between the national association of PhD students (Association Bernard Gregory), the CPU (Conference of University Presidents) and the MEDEF (French Business Confederation) and included 24 skills over four domains [17]. There is a well-defined correspondence table between the referential ‘DocPro’ and the skill definition of the doctoral entrepreneurship programme [14:15] to help students in the evaluation of their skills.

The required skills in the doctoral entrepreneurship training are divided into four principal categories with several components in each of them (Cf. Table 1). The first category is related to the engineering PhD students’ ability to understand business concepts and practices. The second category is associated with project management and the capacity to work independently. The next category is composed of scientific and technical knowledge from the problem definition to the solution. The last category includes several social skills, such as interdisciplinary communication or language skills. For the obtainment of their certificate, students have to acquire at least 8 skills from these 15 skills by the end of the programme.

At the beginning of the training, as a part of the selection process, each engineering PhD student is asked to make a self-evaluation. Considered as the basis for the personalised programme construction, this self-evaluation is very important in defining what skills they need to develop. The result of this self-evaluation is very heterogeneous, as there is a huge difference in skill development in each discipline and even between the different fields of engineering science [18]. Furthermore, there are large divergences at a personal level, as each engineering PhD student has his own personal academic and work experience.

Nevertheless, the selection of candidates is not based on students' initial skills, but essentially on their motivation and their capacity to integrate into a business work environment. Also, the engagement of candidates on this two year doctoral entrepreneurship education training is an important criterion of the selection process. Given the fact that this is highly personalised doctoral training, it requires an important investment from the institutions. For this reason, requiring a high level of students' engagement could limit abandonment and failure.

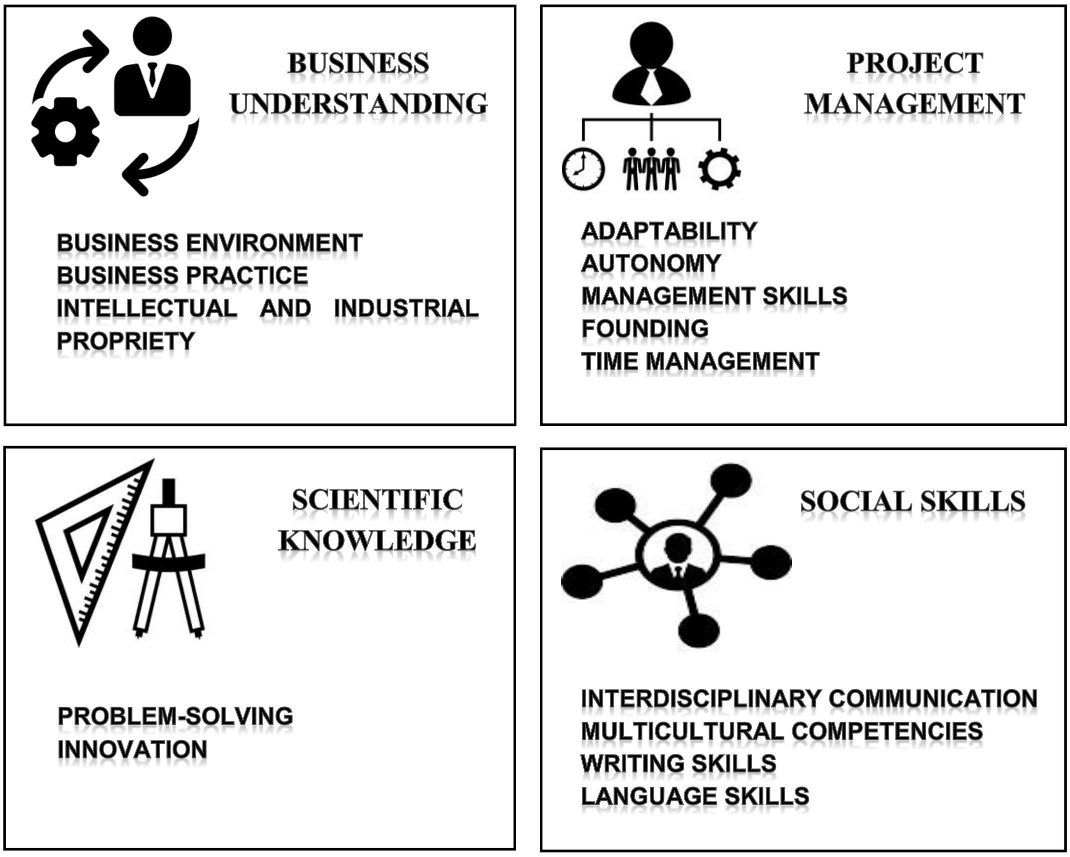

Fig. 1. Entrepreneurial skills development (Adapted from [14])

2 CURRICULUM DESIGN

In our engineering school, we have recently introduced a certified and adjusted two year entrepreneurship education programme. The curriculum development of the programme was based on the official recommendations of the CDEFI following the general framework of PhD programmes, which was designed to facilitate doctoral students' integration. This new entrepreneurship education programme is available for doctoral students who have successfully completed their first-year PhD studies and who have a proven record of engagement in their studies. We outline that students' engagement is particularly important in this programme for two main reasons: firstly, it is the longest doctoral programme proposed in our engineering school (lasting over two academic years) and secondly, it requires an important investment from our institution.

We have developed a highly personalised programme for our PhD students, which takes into account:

- Students' self-evaluation about their existing skills when they enter the programme and
- Their career prospects and the principal skills that they would need for their future professional activities.

As the participating PhD students are drawn from diverse engineering and scientific disciplines, they have very different skill sets when entering our entrepreneurship educational programme. Also, they have various career prospects depending on their personal preferences and opportunities. As we have a really heterogeneous participating population, we have applied a twofold approach (Cf. Figure 2) in the curriculum design, which simultaneously considers their initial skills level and their future working environment.

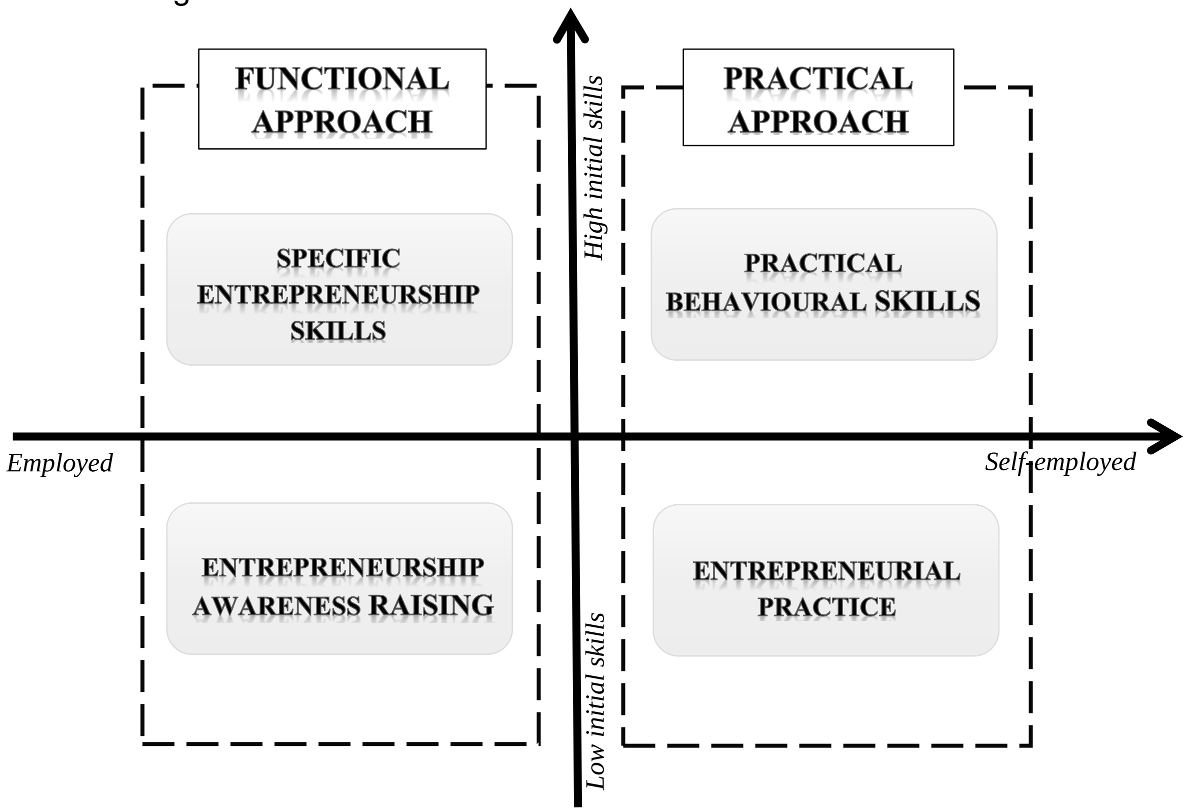

Fig. 2. Conceptual framework of the entrepreneurial programme development

2.1 Functional approach

We follow a functional approach in the curriculum design when participating students have a career desire to work in a business and industrial organisation. In this case, our main objective is the transmission of functional skills and knowledge to them. This approach is based on the development of general and specific business skills and depends on the participating student's skill development needs and requirements. Students have the choice of a large variety of modules which last a maximum of one semester and do not require long term engagement. We distinguish between two levels of skills development:

2.1.1. Entrepreneurship awareness raising

At the first level, we provide mainly theoretical knowledge and basic skills for raising their entrepreneurship awareness by giving them an insight into the life of businesses, in order for them to understand how it works. In this category, we have participating PhD students with a low level of initial skills on entering the programme. Typically, these participating students have a high level of scientific knowledge and skills, but have had a lack of opportunity to learn business subjects during their previous studies. For this reason, they generally need to acquire solid basic knowledge and skills to be able to understand and to be ready to work in a business environment.

2.1.2. Specific entrepreneurship skills

At the second level, we take into account students' special interests and preferences and aim to develop entrepreneurship skills and competencies by focusing on what would be principally useful for their future professional careers. At this level, we have participating doctoral students who possess strong basic business skills and understanding. They are interested to be involved in specialised modules relevant to their particular, and often well-defined, objectives. Usually, they are enrolled in this programme to acquire expertise in specific subjects, in most cases related to their scientific and research activities, in order to enhance their potential career opportunities.

2.2 Practical approach

For participating PhD students who have the intention, in their short or long term career, to set up their own companies, we applied a practical approach in the curriculum development. The principal objective of this approach is the transmission of practical and behavioural competencies in order to teach them how to develop entrepreneurial activities. We provide a highly specialised and individualised entrepreneurship learning programme which includes the creation of a new business by doctoral students. In this case, participating students have to undertake the PBL based entrepreneurship modules which are longer than the modules of the functional approach and need two to four semesters of continuous work and engagement. It is manifest that this practical approach requires a clear long-term vision, strong engagement and perseverance from them. They have to be highly motivated to accomplish these modules in parallel to their research and scientific activities, especially in the final year of their PhD studies. In this approach, we differentiate two levels of skill development according to the objectives of their entrepreneurship project.

2.2.1. Entrepreneurial practice

At the basic level, they are required to develop an entrepreneurial project as a member of a multidisciplinary team composed of graduate and postgraduate students of other engineering and non-engineering domains. The main objective of this entrepreneurial project is to learn how to create their start-ups. Despite the fact that every year at the end of the module some of these projects are transformed into a real business, the vast majority of them are only created to achieve the learning outcomes. Participating PhD students generally have a long-term career goal to create their own companies. However, they would like to start their career as an employee in an industrial business organisation in order to gain initial real work experience.

2.2.2. Practical behavioural skills

At the advanced level, PhD students develop their own business based on their technological invention or pattern. The principal objective of this level is not only to learn to lay the foundations, but also to create their real ventures. This level requires a particularly high level of engagement from participating students. At the end of our two year training programme, these students have the possibility, after finishing their PhD studies, to enter our engineering school's incubator and continue their project. During their entrepreneurship programme, they receive regular tutorials from the facilitator of the incubator. Also, they have the opportunity to participate in the diverse activities organised by the incubator which can facilitate their integration to the incubator's community.

As it was presented in the last paragraphs, we have designed the curriculum of our entrepreneurship education programme based on four differentiated learning objectives. The implementation of this programme requires the cooperation between teachers in management domains, research laboratories, our school's incubator and our industrial partners. Teachers in management and researchers in engineering were particularly involved in the development of the functional skills. The transmission of behavioural skills and competencies was carried out essentially by the help of our incubator and industrial partners.

CONCLUSION

Providing engineering PhD students with a well-adapted and valuable entrepreneurship education, alongside with its incontestable and numerous benefits, remains an important challenge today. Given the fact that the vast majority of PhD students will progress to a career in industry, entrepreneurship training opportunities for post-graduate students in engineering sciences will be in a growing demand over the next decade. However, the integration of entrepreneurship training programmes within the framework of doctoral education is not really prevalent, and only a very low percentage of engineering PhD students could benefit from it today in France.

Our engineering school has decided to take the lead in developing a tailored entrepreneurship training programme to increase doctoral students' employability. The introduction of this programme was appreciated not only by doctoral students, but also by their research laboratories, incubators and industrial partners and it has developed a thriving cooperation between them. Our first experiences confirm, from the abundant number of candidates, doctoral students' awareness of the benefits and usefulness of this programme. However, despite the raising need from students, it is available only for a limited number of doctoral students. As a future perspective, it would be beneficial to make it available for each motivated PhD student.

We have adopted a double approach in our programme which was useful for participating PhD students to receive a better adjustment and personalisation of their learning objectives. Students have a choice between four different learning objectives in relation of their future perspectives. It would be interesting to explore the applied teaching methods in each category and investigate what the most adapted methods are. It could provide us with useful information in choosing the best methods and ameliorate our curriculum.

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Improving innovation and multidisciplinary competences among bachelor of engineering students

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ABSTRACT

From society and industry, there are increasing requirements for skilled and well-educated engineers who can develop new solutions through innovation and this have pushed universities to meet these requirements by having an increasing focus on developing innovation and entrepreneurship programmes within Engineering Education. Furthermore, there is also a demand for the graduates to be able to work multidisciplinary and to be able to use generic skills in their work. In this paper, the research question is how to enhance innovation and multidisciplinary competences of engineering students? This is a central question in order to educate engineers that can create sustainable solutions for the environment, for products and to secure future workplaces. In this paper, a new mandatory course for Bachelor of Engineering students at the Technical University of Denmark (DTU) “Innovation Pilot”, will be described and how the challenge to improve innovative competences and the ability to work in multidisciplinary teams with engineers from other disciplines are solved. Results from a survey regarding the students’ innovation competences and interdisciplinarity show that we have succeed in creation of understanding of what innovation is. However interdisciplinary is still difficult for the students to handle.

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INTRODUCTION

From society and industry, there are increasing requirements for skilled and well-educated engineers who can develop new solutions through innovation and this have pushed universities to meet these requirements by having an increasing focus on developing innovation and entrepreneurship programmes within Engineering Education [11]. Furthermore, there is also a demand for the graduates to be able to work multidisciplinary and to be able to use generic skills in their work [2].

The aim of this paper is to address the research question "How to enhance innovation and multidisciplinary competences of engineering students?" This is a central question in order to educate engineers that can create sustain solutions for the environment, for products and for securing future workplaces. In this paper, a new mandatory course for Bachelor of Engineering students at the Technical University of Denmark (DTU) called Innovation Pilot, will be described and how the challenge to improve innovative competences and the ability to work in multidisciplinary teams with engineers students from other disciplines is solved.

1 BACKGROUND FOR FOSTER INNOVATION IN EDUCATION

Innovation can be defined in many ways and in general, innovation can be seen as the process of translating an idea into a products or service which creates value for someone or something. Business is an important factor as innovation includes an economical aspect and can be seen as the result when new ideas are matured and marketed by a company in order to satisfy the needs and expectations of the customers [9].

A number of conceptualized definitions and theoretical approaches have led to several attempts to understand innovation competency. However, the definition varied considerable with different perspectives and approaches [11]. Innovation competences involve a wide range of human abilities and processes such as personal ability (in finding real-life problems and formulating research questions), interpersonal ability (by being open and responsive to diverse perspectives and intentionally constructing collaborative relationships) and implementing ability (by effectively implementing their ideas in useful projects) [11].

Interdisciplinary competences are necessary to manage innovation activity as well as there is a need for the engineers to have knowledge and understanding of other professions involved in the creative and innovation process [7]. Nowadays it is a critical job requirement to be able to work on flexible and always-changing teams and furthermore also to have the capability to recognize an interconnection among a broad range of activities.

Working with innovation requires enhancing of the students skills in creativity but also to give the students higher confidence to deal with uncertainty, ambiguity, and risk-taking [4].

Active learning education aims at providing the students with the opportunity to think critically and through a series of activities that help them to prepare for challenging professional situations which may involve evaluation, problem solving and critical reasoning skills. Problem-based learning is a well-known approach by using a problem solving approach as well as motivating and engaging the student in the learning process [5].

1.1 CDIO as a teaching paradigm

In 2011, the CDIO (Conceive-Design-Implement-Operate) syllabus was updated to version 2.0 [1]. Particularly attention was given to innovation, invention, internationalization and sustainability.

In the Bachelor of Engineering educations at The Technical University of Denmark (DTU), the CDIO-approach to Engineering Education is implemented as the overall teaching paradigm [2].

In September 2014 the first version of the new developed CDIO-based diploma (B.Eng) programs were launched at DTU. The most significant new activity in the education was the introduction of a common 10 ECTS compulsory course in innovation in the later part of the programs named Innovation Pilot. The idea behind this course is to give students the opportunity to collaborate on inter-disciplinary real-life projects. This course strengthens not only innovation skills but personal and interpersonal skills as well [8].

2 THE COURSE INNOVATION PILOT

The outline for the course Innovation Pilot is that the students work in multidisciplinary teams with specific real-life challenges offered by the involved companies.

The companies provide open-ended projects which take a starting point in actual challenges observed by the company. The company is the problem owner and the students should involve the context reality of the company in solving the challenges. The students are responsible for finding ways to apply their unique skills and knowledge to create value in the projects.

The Innovation Pilot course is offered three times a year, twice in the semester periods of 13 weeks and once as an intensive summer course of 6 weeks. At DTU there are 17 study programmes involved and it is expected that approximately 450 students from these 17 study programmes will attend the course during each spring and winter semester. At the beginning of the course, the students are divided into smaller units of up to 60 students running in parallel. Teams are formed so they consist of 4-6 students within a minimum of two disciplines present. The teams are assembled with different competences to be used for the handling the challenge provided by a company.

There are no traditional lectures in the course so the students are expected to have prepared themselves before coming to the class by e-learning. The e-learning material consists of short videos, documents and papers all available at the course site. E-learning gives flexibility and removes the traditional lecture. This is to optimize the time the students have to work together (one full day a week) and to allocate time for facilitation. All the way through the course, the students work on creating prototypes in the university's workshops facilities.

The course Innovation Pilot is fitting nicely within the framework in CDIO. The course is given for the students during the last semesters of their education and combined their independent use of the disciplinary knowledge they gained with going through all the phases in the CDIO process; Conceive-Design-Implement-Operate. The last phases Implement and Operate in CDIO can be hard to address in an educational setting. In Innovation Pilot the students work also in those phases through the outline for the course where the students work in multidisciplinary engineering teams with a specific open-ended challenges offered by industry companies. The students involve the reality of the company when solving the challenges. Students are introduced to real life problem by direct involvement of enterprises which are engaged from the beginning of the course to propose challenges for the students.

The students attending the course come from 17 different study programmes and they have different experiences working in multiple disciplinary teams and with innovation. Depending on the case some students can easily adapt their educational background with the case work while others find it more difficult. From the course responsible there is focus on that the company challenges should be relevant for engineers and have a technical aspect. Furthermore, there is a focus how student with different educational backgrounds can use each other expertise and also use of generic skills in working with the company challenge.

The teaching in innovation pilot is based on the active learning method “problem based learning” with use of blended learning/flip the class room and workshops and team work. Furthermore, peer-feedback and pitches are used as part of the teaching.

2.1 Course design and learning processes

At the course innovation pilot, the Double Diamond model is used to support the innovation process. Double Diamond is a process model created by Design Council, a British organization, in 2005 [3] and it presents four main stages across two adjacent diamonds. The first diamond in the Double Diamond model concerns exploration of the problem and understanding of the problem. The second diamond is the problem solving phase. Each of the four stages is characterised by either convergent or divergent thinking. The four stages are:

- Discover –identify, exploration research and understand the initial problem.
- Define – limit and define a clear problem to be solved.
- Develop – focus on and develop a solution.
- Deliver – test and evaluate, ready the concept for presentation for the company

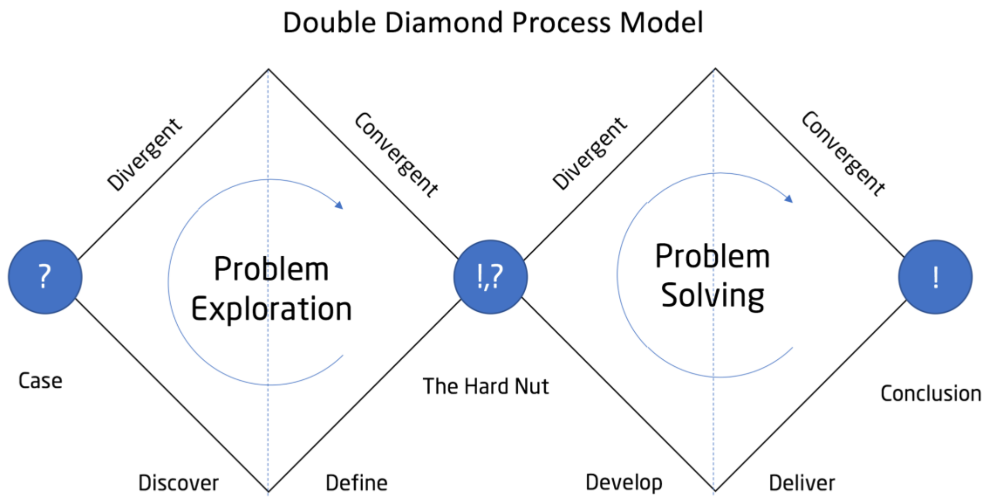

Fig. 1. Made by inspiration from the double diamond process model (Design Council, 2005 [3])

During the course, the students run the innovation process twice in two so-called loops, both involving company challenges. In both loops, the students conduct an innovation process structured according to the double diamond model (*Fig. 1*). The first loop takes four weeks and it is a training loop where the students get to know how to work with the double diamond process model with additional methods and tools. In the second loop, 2-3 teams of students work with the same challenge provided by a company and the process is structured as in the first loop, but it is now more up to students to plan their work. The second loop takes 8 week with 3 weeks dedicated to exploring and defining the problem (the first diamond in Double Diamond) and 5 weeks dedicated to problem-solving and prototyping (the second diamond in Double Diamond) [6].

3 APPROACH AND FINDINGS

Since spring 2016, the course innovation pilot has been running three times, and the number of students and company involved has increased over time. In spring 2016, the course ran for the first time and it was an elective course with 42 students. The second time the course was up scaled and had become a mandatory course with 233 students enrolled and at the third time, 272 students were enrolled. The companies involved in the course are mainly small-medium sized enterprises and typical engineering companies [6].

When the course was running in autumn 2016, a questionnaire was made to evaluate the students perception of innovation and interdisciplinary. The questionnaire consisted of questions with regards to innovation and interdisciplinary competences. For each question, there was a scale ranged from "disagree" to "agree" with the possibility to mark "do not know" for each question. In the interests of high response rate, the data was collected anonymously using the program "Surveymonkey" [10].

A link to the questionnaire was sent to the students at the beginning of the course and again after accomplishment of the course. After collection of the questionnaire data, the results were analysed.

3.1 Findings/results

In autumn 2016, 233 students were enrolled for the course and they were all invited to participate in the questionnaire. At the beginning of the course in autumn 2016, 184(79%) students filled out the questionnaire and after accomplishment of the last course 144(62%) students filled out the questionnaire. However only 182 and 175 students answered the questions regarding innovation and multidisciplinary, respectively in the first round and 137 and 132 students answered the questions regarding innovation and multidisciplinary, respectively in the second round.

There were three questions regarding innovation which the student had to answer and the questions were; “I know what innovation is”, “Innovation is important for an engineer“ and “I like to work with open problems”. *Fig. 2* show the results from the three questions from the first questionnaire at the beginning of the course and from the second questionnaire after accomplishment of the course - which can be compared.

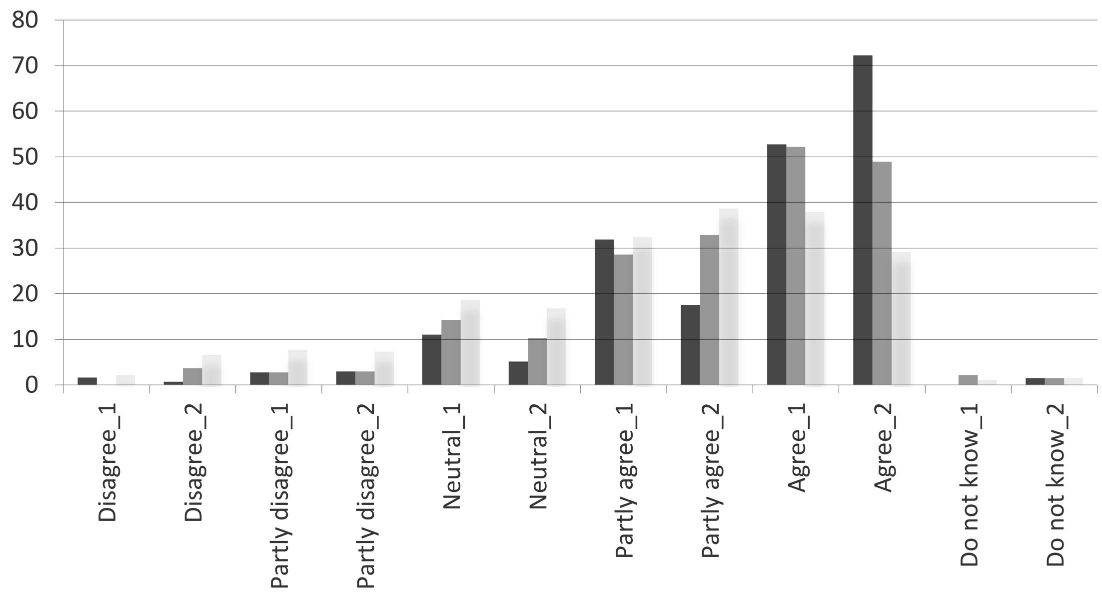

Fig. 2. Innovation: ‘I know what innovation is’ (Dark), ‘Innovation is important for an engineer’ (medium grey) and ‘I like to work with open problems’ (light grey). _1 represents the results from the questionnaire at the beginning of the course and _2 represent the results from the questionnaire after accomplishment of the course. Y axis is % of total number of answers.

With regards to innovation, more students agree that they know what innovation is and that innovation is important for an engineer after they have accomplished the course. However, there is tendency that there are more from agree to partly agree with regards to the question “I like to work with open problems”.

There were also three questions regarding multidisciplinary which the student had to answer. The questions were “I like to work with persons from my own education”, “I like to work with persons from other educations” and “I believe that multidisciplinary work is difficult”. *Fig. 3* show the results from the three questions from the first questionnaire at the beginning of the course and from the second questionnaire after accomplishment of the course - which can be compared.

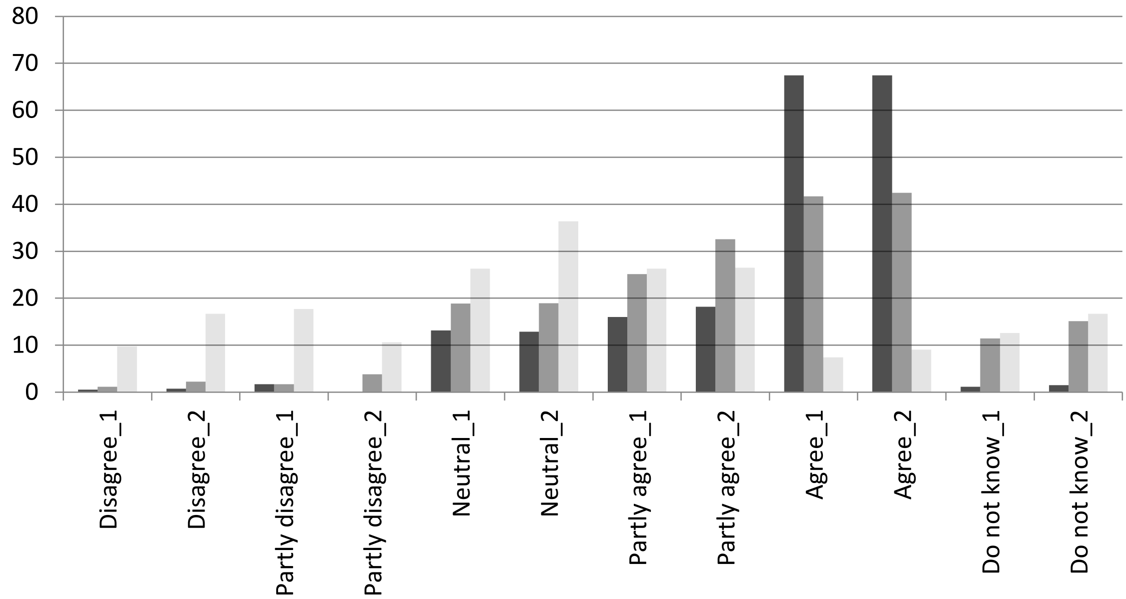

Fig.3. Multidisciplinary competences: “I like to work with persons from my own education” (dark), “I like to work with persons from other educations” (Medium grey), “I believe that interdisciplinary is difficult” (light) _1 represent the results from the questionnaire at the beginning of the course and _2 represent the results from the questionnaire after accomplishment of the course Y axis is % of total number of answers.

The results show that the students are becoming much more aware of what innovation is when they have finished the course. With regards to multidisciplinary, the picture is not so clear but a large part of the students believe it is difficult to work in multidisciplinary engineering teams after they have done it in innovation pilot. Our experience points to the observation (but no systematic investigation has yet been done in this area), that multidisciplinary is something the students in their study programs only have little experience with. The students ability to grasp the heterogeneity of the problems and their multidisciplinary facets, appear limited for the most parts. However, our expression is that many students really like to work with students from other programs and that they find it fun and motivating.

4 SUMMARY

Interdisciplinary innovation is important for the future engineers. In this paper, we have discussed how the Innovation Pilot-course defines a framework for collaboration between students from different engineering disciplines with aim of enhancing the innovation and multidisciplinary competences. The results from a questionnaire show that we have succeed in creating an understanding of what innovation is. However interdisciplinary is still difficult for the students to handle. In the future methods to learn and support student's interdisciplinary work need to be developed.

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Approaches to the Identification of STEM Key Competencies in European University systems

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ABSTRACT

The readySTEMgo project is a collaboration between six European universities: KU Leuven (Belgium), Hamburg University of Technology (TUHH – Germany), University of Žilina (UniZa – Slovakia), Budapest University of Technology and Economics (BME – Hungary), University of Birmingham (UK), and Aalto University (Finland). The prime objective of the project is to identify students with an increased drop-out risk before the start or throughout the course of the first-year in STEM (Science, Technology, Engineering, and Mathematics) study programmes.

Before providing an overview of the most salient project findings, we will first address some key issues involved in identifying key entry requirements for first-year science and engineering students in a European framework. A number of institutional (e.g., university entry requirements & secondary school curricula) and diagnostic (e.g., available tests) elements complicate a uniform approach in a diverse European consortium. Against this background, we present the most essential key competences followed by a detailed overview of a number of interventions aimed at at-risk students in the different institutions.

Conference Key Areas: Engineering Education Research; Attractiveness of Engineering Education; Skills and Engineering Education

Keywords: Study skills; Achievement; Skills, University entry systems

INTRODUCTION

1 UNIVERSITY ENTRY: INSTITUTIONAL DIVERSITY

1.1 Open admission versus highly selective culture

In general, university entry can best be considered as a continuum between open-admission institutions (i.e., limited entry requirements) and highly selective institutions. We characterize the diversity in university entrance requirements based on three dimensions: (1) Minimal entry criteria; (2) Timing of application, and (3) First-year drop-out rate.

In the readySTEMgo consortium, three universities apply highly selective criteria, namely University of Birmingham (UK), BME (Hungary), and Aalto University (Finland). First, in all three universities, high performance standards based on a nationally organised matriculation exam scores (or the equivalent such as IB and similar) are set as pre-requisites for applicants to be eligible to apply. Additionally, at Aalto University applicants' score obtained in a nationally organised entrance exam in math and Physics/Chemistry are considered whereas grades obtained in secondary school are taken into account at BME. Both Aalto University and BME may also admit applicants based on achievements in high-ranking academic competitions, or exceptionally high scores in the matriculation examination [1]. Second, a common feature of all selective institutions is the early application deadline. Applicants need to select the programmes they are applying for in January-March prior to the start of the academic year (BME & Aalto) or even earlier (Birmingham). In the case of Aalto University, secondary school students spend the spring semester working both on matriculation examinations in March and preparing for the entrance examination for university in May. At the University of Birmingham, applicants are even given a full year to work towards the required A-level scores. By the end of the previous academic year, UK students submit their application. Those students of interest to the relevant department are made a conditional offer of a place based on their chosen A-levels. By May of the year of entry students in possession of more than two conditional offers select one university as their firm choice and one, usually requiring a lower set of grades, as insurance. A student who achieves the offer from his firm choice in August of the year of entry has his/her place confirmed. Altogether, secondary school students in highly selective contexts are expected to display higher levels of commitment and goal-orientation in working towards a specific target (see below). Third, drop-out rates are generally substantially lower after the first year in highly selective institutions. For example, at the University of Birmingham less than 5% drops out. Analogously, at BME drop-out ranges between 10-20% over the different engineering programmes.

Medium selective institutions are represented by TUHH (Germany) and UniZa (Slovakia). At UniZa, the final mathematics and physics grades obtained in secondary school and participation in the matriculation exams for these subjects are taken into consideration (since 2008, no STEM subjects are obligatory in the matriculation exam). Applicants who did not participate in the math and/or physics matriculation exam and do not meet the minimal criteria for admittance are obliged to participate in a selection interview on campus. In practice, almost all of these students are accepted because of normative funding [1]. Analogously, at TUHH (Germany) students need to successfully obtain their Abitur matriculation certificate. In theory, admission to TUHH is nominally based on the applicant's results in the matriculation examinations, with a special weight for grades in mathematics. However, due to the legal requirement to not deny admission to anyone as long as the maximum number of students has not been reached (and to the relatively lower interest in engineering careers compared to other fields), admission is not competitive. As a result of normative funding (UniZa) and obligatory admission legislation (TUHH), there is a high degree of diversity in beginning students' prior exposure to instruction and in their skills in science and mathematics. The decision-making and application process takes place at a later stage compared to highly selective institutions (after the matriculation exams) and drop-out rates are higher. For example, for some programmes at UniZa, drop-out rates after the first year can get as high as 50%.

KU Leuven (Belgium) is a university at the open-admission end of the spectrum. In Belgium, only minimal requirements apply for entering a science or engineering bachelor. Any student with a diploma of secondary education is allowed to enrol in any programme they want (except for medicine), regardless of their prior achievements or educational background. The secondary school diploma is not obtained on the basis of a nationally organised matriculation exam but exam grades at the end of secondary school. As a result, a large number of students subscribe for a science or engineering programme only one or two months before the start of the academic year at KU Leuven. For example, in 2015-2016, 30% of the students made their final decision during the summer holiday prior to the academic year. The proportion of students who drop out after the first year lies around 30%, a number that is fairly stable over the last years.

1.2 Consequence of different admission criteria

The aforementioned institutional diversity in terms of entry requirements has important consequences for the realisation of the objectives of the readySTEMgo project. A uniform approach focusing on STEM course content is highly impractical because of the heterogeneity in first-year student populations: highly selective universities select a population of high-achieving students whereas at more open-admission universities there is a wider range of achievement levels of incoming students. A single scientific measurement in full alignment with the different secondary school STEM curricula at the partner countries is not feasible.

Therefore, we did not focus on cognitive key skills such as prior knowledge in the fields of mathematics, physics, biology and chemistry. There is ample evidence for the importance of prior achievement levels in these fields for student achievement in higher education [2]. Instead, it was decided to shift the focus to more non-cognitive skills that (1) have the potential to be a predictor of study success, (2) offer concrete targets for improvement, and (3) can be measured through existing validated instruments. In the following two paragraphs we give an overview of our results.

2 KEY COMPETENCES: DUAL APPROACH

All partners agreed that, irrespective of the context, first-year students are confronted with large amounts of challenging course material. Students are expected to be architects of their own learning process and to make use of the resources available to them to master the required knowledge levels. As such, we decided to focus on (1) incoming student's learning/study strategies and attitudes towards learning (KU Leuven, TUHH, UniZa, BME, and University of Birmingham) and (2) levels of conceptual understanding in the field of mechanics, a central topic in most engineering programmes (TUHH and UniZa). At Aalto University, we mainly focused on the evaluation of interventions which are aimed to support integration of freshmen into student and academic communities.

2.1 Learning and study strategies

At the start of the academic years 2015-2016 and 2016-2017, the Learning And Study Strategies Inventory (LASSI, [3]) was presented to 7168 first-year students at KU Leuven, UniZa, BME, and the University or Birmingham. Except for the latter university, we were able to link these test results to student's obtained grades after the first semester at university. Our results show that students' self-regulatory skills levels (e.g., time management, concentration when studying, and motivation/persistence) were all significantly related to student achievement. Fig. 1 presents the results for the time management scale. In all three universities there was a positive relationship between better time management skills and student achievement (expressed as the proportion of ECTS credits obtained) in the exams in January: students with poor time management skills obtain significantly less credits compared to students with better time management skills. Similar patterns were observed for the other self-regulatory scales.

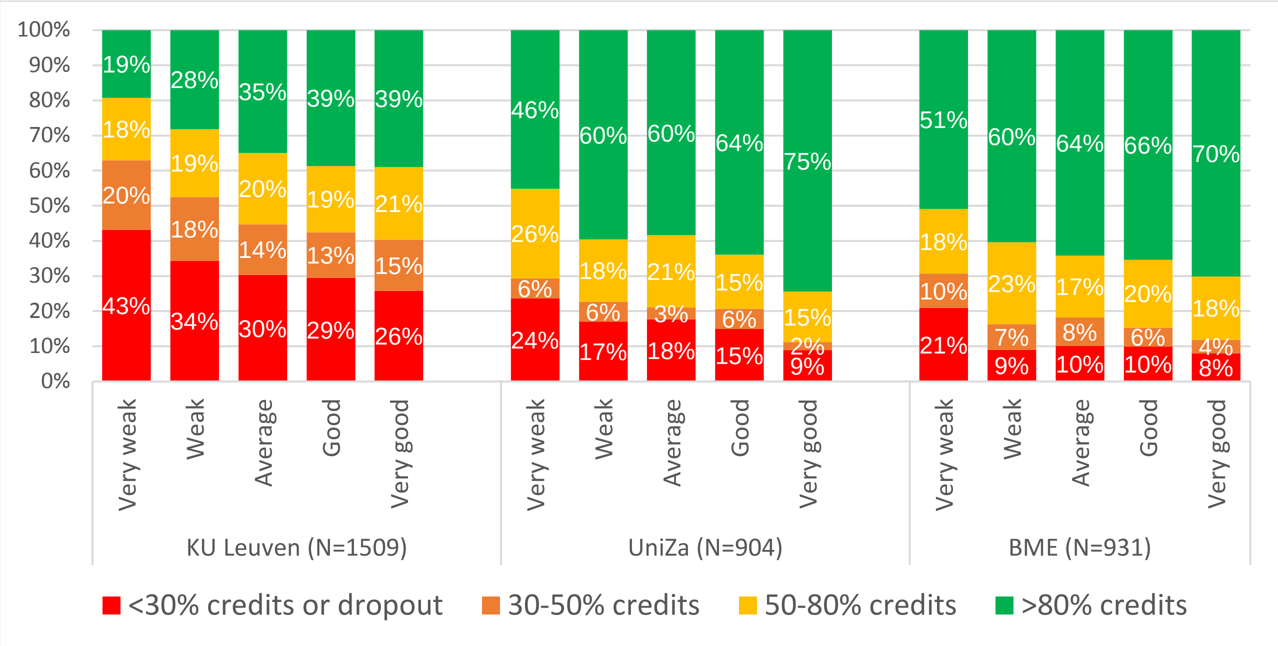

Fig. 1. Relationship between time management skills at the start and student achievement after the first examinations at university in 2016-2017 (KU Leuven, UniZa, and BME).

In sum, engineering students' self-regulatory skills levels at the start of university have important consequences for their achievement later on. Measuring the levels of self-regulating skills of incoming students may enable identification of students with an increased propensity to underperform or to drop out of the programme. Although this relation is supported in both open-admission (KU Leuven) and highly selective institutions (BME), this particularly applies for students from universities with a semi selective or open-admission culture since most of these students have not previously been required to attain externally set high level standards. In contrast, challenging target scores set by highly selective institutions require high degrees of self-regulation in the last stage of secondary school towards the matriculation exams. In order to illustrate this claim, the self-reported effort levels of students in secondary school in Belgium (KU Leuven) and the UK (Birmingham) are compared (Fig. 2). More specifically, during the first week of the academic year, students were requested to rate the following item on a 5-point Likert type scale: *"I had to work hard for my obtained study results in secondary education"*. 61% of the first-year students at the University of Birmingham agreed with this statement whereas for KU Leuven, this is only 13%.

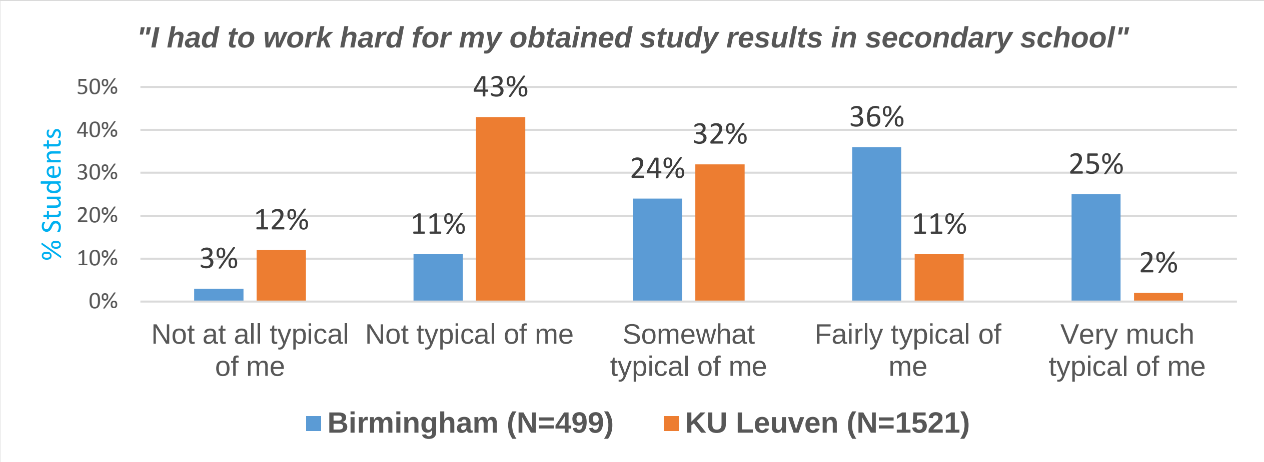

Fig. 2. Comparison of effort levels in secondary school in a highly selective (University of Birmingham) and an open-admission (KU Leuven) context.

2.2 Conceptual understanding

At TUHH and UniZa, a strong focus is on the conceptual understanding of students in the field of mechanics. It can be argued that students with a limited conceptual understanding at the start of an introductory Physics/Mechanics course are also at-risk. Both at UniZa and TUHH, rigorous pre and post test procedures (using the Force Concept Inventory and/or similar diagnostic tests), enable the determination of learning gains in terms of increased conceptual understanding after an introductory Physics/Mechanics course. Additionally, TUHH researchers examined the epistemological beliefs of first-year students about doing physics. For example, before the start of a large introductory mechanics course, 80% of the students indicated that they need to make sense out of formulas before they could use them correctly, and that they think it is useful to spent time on understanding where formulas are coming from.

In terms of learning gains in conceptual understanding, it was shown that interactive video teaching methods produced significantly higher learning gains compared to more traditional teaching methods.

3 INTERVENTIONS: A MULTIFACETED APPROACH

3.1 KU Leuven: Interactive student dashboard

At the start of the academic year 2016-2017, 1509 first-year students in the STEM field filled in the LASSI questionnaire regarding their learning and study behaviour in secondary school. Rather than only using the collected data for research purposes in the readySTEMgo project, it was decided to provide students with individual feedback on their personal scores on each scale. With the help of the researchers of the STELA project (www.stela-project.eu), an interactive feedback dashboard was developed with a central focus on actionable feedback (i.e., feedback that provides students with very concrete targets for improvement, [4]). The prime objective of this dashboard is to unveil information to first-year students on their personal self-regulatory skills (i.e., Concentration, Time management, Motivation/persistence, Anxiety, and Test strategies) and to stimulate a self-reflective process on their own learning behaviour. In order to avoid complex statistical interpretations, the dashboard uses simple visualizations complemented with textual explanations and concrete tips for improvement. 1406 students with a complete profile received an invitation by mail to consult their individual scores in the middle of the first semester. Altogether, 1135 (80.7%) of the students clicked on the link in the invitation email and entered the dashboard. 81.2% of the students that did click through, did so within three days. The proportions of students who consulted the improvement tips ranged between 15.2% (Performance anxiety) and 35.2% (Concentration). Additionally, the researchers found that students with a lower score on the five scales display higher levels of interaction with the platform (e.g., going back to an earlier page/tab, click on the improvement tips,…). For example, students with higher levels of performance anxiety consulted the improvement tips significantly more frequently compared to less anxious students.

3.2 UniZa: Physics summer course

In the framework of the readySTEMgo project, a summer course in physics was organised for the first time at Uniza. In this first edition, 87 students participated. In order to evaluate the effectiveness of the summer course, three evaluation criteria were put forward: (1) increased conceptual understanding of basic Newtonian Physics; (2) self-perceived usefulness in the short run; and (3) self-perceived usefulness in the long run (i.e., after the first semester). Of the 87 participants, 36 students participated in both the FCI pre and posttest. Statistical differences between the pre ($M=27.41$, $SD=10.69$) and posttest ($M=42.04$, $SD=12.27$) scores were tested using a t-test. The results clearly show a significantly higher post-test score after participating in the summer course $t\ (35)=9.76$, $p<0.001$. These results suggest that the summer course contributes to students' understanding of Newtonian physics. Second, in general, students reported high satisfaction levels with the summer course. On a 5-point Likert type scale, participating students consider the summer course to be very important ($M = 4.4$, $SD=0.81$) and useful ($M = 4.5$, $SD=0.55$). Even after the first semester Physics course, 78% of the respondents considered the summer course to be (very) useful and 69% of the respondents indicated that they were better able to check their prior physics knowledge.

3.3 TUHH: Tutorials & interactive teaching methods

Tutorials are defined as collaborative group activities that focus on instructional materials to target common misconceptions. In these tutorial sessions, a qualitative approach to problem solving is stimulated by trained assistants who guide a group of 20-25 students through the learning process by asking a number of specific questions. Evaluation of Tutorial instruction had begun prior to the start of the readySTEMgo project by collecting data on the level of expertise in the field of mechanics among incoming students. Through subsequent testing at the end of a first-semester Statics course, the effect of instruction with and without the use of Tutorials (for equal amounts of contact time) could be measured and compared. As the diagram of post-test versus pre-test scores from multiple years of instruction indicates, there is a statistically significant and practically relevant improvement of post-test scores for students of all levels of prior knowledge.

3.4 Aalto University: ABC-introduction week and student guilds

Prior to the start of the academic year, students at Aalto University are obliged to take part in a one-week intensive introduction course, which is later followed up by other supporting courses, such as the Academic Learning Community studies. Rather than focusing on the transfer of academic course content, the prime objective of this introduction week is to coach incoming students to adopt valuable learning and study strategies. Additionally, students are introduced to the student guilds and to their mentors at university. In the readySTEMgo project, we evaluated the self-perceived usefulness of the introduction week after two semesters at university. 46 out of 146 first-year students at the CHEM school filled in an online survey regarding the ABC introduction week and the student guilds.

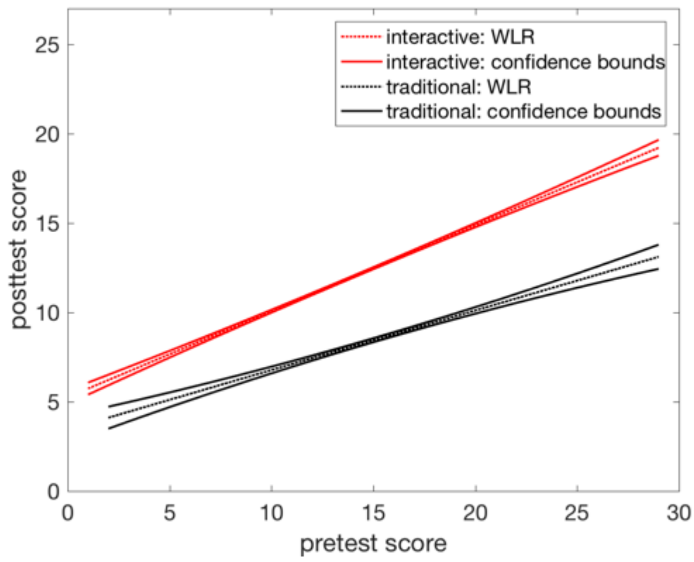

Fig. 3. Comparison of conceptual learning gains between interactive teaching methods (with tutorials) and traditional teaching methods at TUHH.

Altogether, 46% of the respondents agreed that the ABC-introduction week helped to them plan their studies. Only 13% of the students indicated that the ABC-introduction week has helped them to identify their strengths and weaknesses as a student. Peer support by the student guild showed to be an important resource for first-year students: 67% of the respondents indicated that the student guilds helped them to deal with school related pressure. Overall, it is evident that the peer support through social activities arranged by the guild, the mentoring system run by the guild and the extension into non-academic issues in student lives, identifies the student guild as a key element for student well-being. This has a clear positive effect on student attitudes towards tackling academic challenges.

3.5 BME: Math diagnostic test and bridging courses after enrolment

Since 2010, an obligatory math diagnostic test (‘*math zero test*’) at the start of the first semester (after enrolment), was introduced at BME. The need for the diagnostic test as part of the course requirements in first semester mathematics was generated by the current inconsistencies of the admission system of the Hungarian higher education, namely the weak correlation between admission points and diagnostic test scores [5].

Despite the high entrance score, many first-year students fail the math zero test. In the academic year 2016-2017, results of the readySTEMgo project showed that 23% of the students who failed the math zero test (N=380) obtained less than 50% of their credits after the exams in January 2017. For students who passed the math zero test (N=358), this number decreased to 8%. These results show that, even after a rigorous selection process, an obligatory math diagnostic test has added value in identifying at-risk students.

In order to support at-risk students in the transition to higher education, bridging courses in mathematics were introduced at all faculties. At the Faculty of Chemical Technology and Biotechnology, mandatory bridging courses in physics and chemistry (2 ECTS credits) were organised in addition to the bridging math course. Before the introduction of the bridging math course, more than 30% of the first-year students failed the “Mathematics 1” course. As a result of the participation in the bridging math course, the number of students who did not pass dropped drastically (below 20%). The effectiveness of both the bridging chemistry and physics course is similar: the failure rate dropped from about 50% to 25%.

4 SUMMARY

An important challenge for an international research consortium is the strict privacy legislation in some universities. In some cases, researchers are unable to gather data where student identity numbers would be matched with students grades through the official records (for example, Aalto University, University of Birmingham & TUHH). At the latter university, researchers administered an experimental approach with self-generated ID's in order to ask students directly for their self-reported grades (rather than access these data directly from the university records). Aalto University requires that use of data must be specified for a particular purpose, written consent is required, and data must be in a format that cannot be traced back to the individual. This is a challenge for studies which aim to follow progress of an individual student. Moreover, Aalto University collects an abundance of information at regular intervals for internal and external use. An attempt was made to collect data at Aalto for the present study, but the response of students in a highly complicated privacy setting in the present study, produced a very low response rate. As a consequence of these privacy regulations, we were not able to link the measured skills with students' actual performance in each university.

The common goal for all the partner universities is to deliver the best scientist and engineers by providing a study environment that (1) optimally supports the development of STEM skills and (2) engages into learning outcomes that lead to high employment of future graduates. On the other hand, even in the post-Bologna era, the readySTEMgo project has revealed that there are very divergent models and approaches for achieving learning outcomes in universities with very different institutional contexts. Each institution deals with its own challenges in a number of ways, ranging from a well-organised mentoring and guild system, an individual feedback system on learning strategies, interactive teaching methods, or STEM bridging courses. A thorough understanding of this diversity provided a number of interesting learning opportunities for all participating partners and helped to understand why successful educational recipes of one educational context cannot be univocally transferred to another.

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Connecting the world with Internet of Things

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ABSTRACT

Connecting the world sounds like a very challenging undertaking when it comes to gathering information, analysing and distributing data. *Internet of Things* is the concept of connecting any device to the internet while internetworking with devices. Possibilities for applications of *Internet of Things* are numerous to connect multiple systems while using the shared data for industrial and economic purposes or for empowering citizens and communities, among others. At Eindhoven University of Technology (the Netherlands) there are courses that aim at educating engineers to use applications for industrial purposes, but also for society and business solutions. The second year design-based learning sophomore course *Internet of Things* focuses on teaching students to solve open-ended problems both in industry or in hospital settings. . In this paper, we present the set-up of the *Internet of Things* project in which students explore different indoor localization scenarios. We explain as well the rational for the selected approach to teach this *Internet of Things* project. In addition, we give an overview of the main characteristics which feature the project, and we describe some expected benefits for the students.

Conference Key Areas: Curriculum Development; Skills and Engineering Education; Continuing Engineering Education and Lifelong Learning

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INTRODUCTION

Imaging a connected world is easy although the potential of the *Internet of things* (IoT) application is still to discover. Possibilities for applications are manifold to connect multiple systems while using the shared data for industrial and economic purposes or for empowering citizens and communities, among others. IoT is more than just a buzzer word that can be applied to a wide range of devices, technologies and situations. IoT is the concept of connecting any device to the internet while internetworking with, for instance, cellphones, connected vehicles, wearable devices or buildings by the use of sensors, actuators, and software of network connections [1].

At the Electrical Engineering (EE) department at the Eindhoven University of Technology (TU/e) the theme of IoT is starting to boom up. The rationale to integrate IoT in the EE curriculum is driven by the fact that IoT is quickly gaining an industrial foothold in the Netherlands and internationally. In addition, engineers with IoT knowledge and skills are already required by many companies. Furthermore, while a need for this expertise is evident, there are no hands-on specific courses or lab environments at the tU/e where students can be exposed to the IoT experience. The motivation for this project is to develop an IoT hands-on project within the EE curriculum in order to facilitate students gaining practical skills.

In this paper, we give first an overview of the IoT project assignment within the EE study program. Secondly, we also provide an outline of the multidisciplinary components of this project to develop new insights into possible business applications. Finally, we address the expected benefits of this pilot project.

1 THE CONTEXT OF *INTERNET OF THINGS*

1.1 The rationale for the development of a IoT project in *FLUX*

Internet of Things (IoT) is the internetworking of physical devices, vehicles, buildings and other items. IoT enable devices including electronics, software, sensors, actuators, and network connectivity modules in order to collect and exchange data. IoT is becoming a growing market making a stand in the industrial world in the Netherlands and internationally.

At the TU/e (the Netherlands) there are courses at the Computer Science and Industrial Engineering departments devoted to teach students the technological aspects of IoT, i.e., architectures, device classes, protocols, application patterns and application examples, among others. In addition, courses also focus on developing business models and business cases on the products students make. However, the industry needs engineers with hands-on skills able to innovate and implement applications to match customer value needs and businesses.

The second year design-based learning sophomore project course *Internet of Things* at the Electrical Engineering (EE) department aims at teaching students to learn to use the applications of IoT around gravel**/**net, the expandable wireless IoT network of 50 nodes deployed inside of the EE department, the ultra-modern and recently-constructed building *'FLUX'* (See Figure 1). Moreover, our purpose for the development of this hands-on project is to make possible to run new applications, hosting various sensors and other hardware. This network is the result of several past and ongoing research programs. However it is not yet big and mature enough to be used for educational purposes. It should scale, in principal, to 180-200 nodes and become robust and easy to use allowing both teachers and students to focus on learning objectives rather than on solving technical issues.

Within this project, students learn how to design wireless links (including basic concepts of antenna design), and to optimize end-to-end latency over an IoT network. Likewise, students become familiar with different wireless protocols while exploring the relation between signal noise ration and channel capacity, the design of low energy systems by the use of algorithms of localization.

The project has a multidisciplinary character as elements of architectures from the computer science field and the economic values from the business world are integrated in the cases of the students to complement the electrical engineering knowledge that students will gain throughout the implementation. In addition, students from other departments, mainly Computer Science and Innovation Sciences, work together with Electrical Engineering in teams.

1.2 The description of the IoT project and the use cases

The end purpose of the IoT project assignment is to have students to solve open-ended and realistic use cases as they would be tackling complex problems of a real world scenarios. The assignment is based on tracing people in a factory, or patients in a hospital, or expensive equipment in the university. All assignments have a common denominator, i.e. indoor localization functionality. However, each of these cases has different requirements. On the one hand, in an industrial floor with robots and humans, safety critical situations picked by sensors have to immediately be notified to the control room or robots in the vicinity. On the other hand, patients in a hospital need to be tracked either in a waiting room or through the thick walls of a surgery room. The students are challenged to select a scenario in which both a tracking system as well as designing a solution for it is needed.

Given a selected scenario (i.e. industrial floor or hospital setting) the students need to define the functional and non-functional requirements in order to prioritize them together with the stakeholders and product owners. The sort-listing of these requirements will guide the student to the design of the architecture and the integration of the different technologies at market level. That is why the students will hold several presentations to fine tune the prototypes according to the market demands. The stakeholders and product owners will be present to these presentations in order to give their feedback as soon as possible, enabling students to readjust prototypes in iterations. It is therefore an evolving design trying to continuously address exactly the customer demands.

The system under design is split into both hardware and software components. Each human to be tracked should be equipped with a small low-power device. In reality, it is that device the whole IoT system is tracking; for clarity, we call this device mobile. The system consists of several fixed small devices deployed in various spots in a building (e.g. ceiling, walls, windows, floor, tables etc). Through different communication techniques the fixed devices “see” the mobile ones and through triangulation they are capable of determining their exact position. There are multitude dimensions to be considered when designing such a system. Accuracy of localization, number of fixed devices, data collection for centralized management, and lifetime of battery powered devices to name a few. These are questions inherent to the assignment of the students. Answering those questions, always in view of the priorities of stakeholders, will help the students short-list the wireless technologies (ultra-wide band or ultrasonic), the hardware (low-power or resource-full) and software architecture (centralized, hybrid, decentralized) to be used.

Together with this design process, the students will be integrating the chosen combination of technologies and will be testing their choices. It is via reading, trial-and-error and consulting with experts and stakeholders that they will be learning concluding to the best product design. The validation of their project output will be done on a real IoT testbed (i.e. gravel/net) deployed in the department of Electrical Engineering, at the TU/e. The testbed counts for 150 fixed devices and around 30 mobile ones. All the devices are extendible with the combination of technologies students will integrate. The testbed is able to collect monitoring information and let the student download performance data of their experiments. Yet, it is up to the students to design their experiments and applications running on top. An illustration of gravel/net is given in Fig. 1, 2, and 3[2]. For instance, in safety critical use cases (factory) gravel/net will be able to inform the students of the delay of an alarm trigger from sensors in the field all the way to the control room of the factory. Symmetrically, gravel/net will notify the students when a human stopped being traceable either because left e.g. the hospital or got in a surgery room. It is up to the students to assess whether that was a desired performance or reaction to an event.

Fig. 1

Fig. 2

[2] All images in figures 1–5 belong to the author George Exarchakos (g.exarchakos@tue.nl)

Fig. 3

Moreover, for industrial applications with coordination with robots, these have to be coordinated precisely one product to the other. When it goes about robots issues such as people and safety or alarm are key important elements. At the end of the course, the students will demonstrate that their solution can indeed solve the challenge taking into consideration specifications such as speed and efficient use of energy.

1.3 The IoT assignment

The objectives of this DBL IoT project are:

- To optimized wireless links (including basic concepts of antenna design)
- To optimize end-to-end latency over an IoT network
- To get familiar with different wireless protocols
- To create and analyse relations between signal noise ratio and channel capacity
- To design for low energy systems
- To apply algorithms of localization
- To conduct analysis of large data sets
- To develop new insights into possible business application of the IoT case

The motivation behind this project course is to introduce students in the world of the *Internet of Things* by applying technology, architecture and business models by tracing people and objects in indoor localization functionally assignments.

Next to the technical challenges also the business aspects of the project will be explored within the students' groups. Students make use of a business case and models to notify in the production line. The added element of including business models and cases is to have students to get involved in real live assignments in which they have to gather information on crowd sensing applications to be able to understand how crowd works, for instance, for safety and business purposes while deploying the necessary application. The key element is that students see the product development part of such as real-life case as they may work in a small company with similar challenges.

The structure of the project consists of seven weeks and eight contact hours per week in which students carry out the project activities. Besides an introductory meeting on the *Internet of Things* assignments, students get two support lectures on the two main multidisciplinary topics in this project, i.e. architectures, and business models and cases. These support lectures are given by lecturers from the Computer Science and Innovation Sciences departments. In addition, the Electrical Engineering lecturers are also involved in the direct supervision of the teachers.

Following the educational principles of problem-based and project-based learning, students work in teams together throughout seven weeks. The groups are guided by a supervisor or project leaders. These are older bachelor or master students with broad knowledge on the *Internet of Things* as they have been involved in the construction of the network. The groups are made out up to 6 students and the tasks are divided among them.

The follow-up of the project activities and interim products is based on mid-term presentations in which students report about the progress of the project, main obstacles but also the challenges ahead and how these will be solved. In these mid-term presentations the interim products and prototypes, are assessed. Students receive feedback from the experts on how to make improvements including from a company in charge of providing proof-of-concept input. The presentations and final report are assessed against quality of final products.

2 INSTRUCTIONAL DESIGN IN ENGINEERING EDUCATION

2.1 The Design-based learning approach of the *Internet of Things* project

Design-based learning (DBL) is an active learning teaching method similar to Problem-based learning [4] and Project-based learning [5] engaging students in solving real-life design problems while reflecting on the design and learning process [6]. DBL was introduced at the TU/e in 1997 as an educational approach for engineering education. The unique element of DBL is that it is grounded in the *process of inquiry and reasoning towards generating innovative artifacts, systems and solutions* [7]. DBL emphasizes the engineering design process resembling authentic engineering settings in which students make decisions during the design cognitive thinking processes as they go through iterations in generating specifications, making predictions, experiencing and creating solutions, testing and communicating [7].

Resembling the DBL model from empirical literature, we have included the features of DBL [8], i.e., *open-ended, hands-on, authentic* and *multidisciplinary* aspects in the instructional design of the *Internet of Things* second year bachelor project. The *open-ended* character of the project is featured by the fact that students get a general description of the cases to explore from different perspectives. As an instance, students are to trace people in buildings, workers in a factory, patients in a hospital or just lab equipment. Besides the description of the use case with incomplete information and some specifications expected in the final systems, students' teams are to experiment iteratively with different architectures to be able to choose the appropriate one that matches the technology selected for the design. Within this experiencing phase and following the common engineering design process, students make a thorough out analysis of the use cases and requirements and choose some criteria to select the proper architecture. In addition, students' teams analyse the business aspects and make priorities of the requirements and features of the system to be developed.

As in the engineering design cycle, students formulate own design plan, and seek for alternatives in the design of the architecture and integration of existing architectures and communication technologies. In the integration process, the selection and assembly of the required hardware, installation of software, modules and libraries, etc., should be included. The next steps in the design process are to test iteratively the prototypes and experiencing repeatedly various architectures in order to design a minimum viable product, i.e. a prototype which is not the final product. The design and testing phases should be in iterations so that students can expand the design with different features of each specific case. A relevant element within the design process is the feedback to support the construction of a viable product so that this can be sold and become profitable. These project assignments provide students the opportunity to experience a typical production development process from the organization of working from a traditional waterfall production and design work into a much more *Agile* type of work consisting of short iterations allowing companies to realise new products in short time.

The fact that the assignments are embedded in *real life* industry tasks make the cases more *authentic* resembling jobs students might get in companies. The teaching staff from the Computer Science and Industrial Engineering departments will be also providing feedback as part of the customers' roles they will be playing. Moreover, the *hands-on* component of this project is actually inserted in the generation of knowledge from each iteration in the design process which is afterwards applied in a new iteration producing new information on the prototype to make.

In this *hands-on* project students are asked to work in *multi-disciplinary* groups to address a challenge concerning how a large pool of IoT devices connected to form an intelligent network can be used to solve practical engineering problems relating to emerging applications such as autonomous driving and in building navigation and localization. The rationale for multidisciplinary lies in that students from the different three departments, i.e. Electrical Engineering, Computer Science, and Industrial Engineering will be working together and share expertise from multiple domains i.e. design, integration-implementation, testing-deployment and business models. As a matter of fact the involvement of Computer Science in this project is related to the software architectures of a system, of Electrical Engineering to the hardware assembly and of Industrial Engineering to the value proposition and the business models.

3 INNOVATION SPACE AND THE ENGINEERS FOR THE FUTURE

The *Internet of Things* project is a pilot which has potential to expand and link with the newly initiated concept of Innovation Space at the TU/e. Since 2016 the idea of the TU/e Innovation Space (still under construction) is built upon the rationale to have students work on hands-on engineering assignments in multidisciplinary teams while dealing with challenging and *complex societal and industrial challenges, create prototypes and develop innovations in collaboration with researchers, businesses and other stakeholders...*[2]. The added value of this initiative is the strong scientific collaboration that the TU/e has with the surrounding industry, with researchers and businesses.

The concept of Innovation Space does not stand alone in the world. Looking at other initiatives overseas, for instance, the Design Factory at the Finnish Aalto University, this has been an inspiring example to adjust that model into the TU/e pattern. The experience of *Design factory* illustrates and leads the TU/e project to make possible and give form to a space in which the physical and mental working environment for product developers and researchers come together to encourage and to enable fruitful interaction between students, researchers, and professional practitioners. Following the already 10-year old Finnish model, the TU/e innovation space provides a setting to inspire teaching staff and students for which lectures and workshops are organized. In addition, the fact that the Innovation Space provides a scenario for the implementation of multidisciplinary engineering projects encourages the engineering thinking of creating prototypes and transforming those into products, services for the society in order to stimulate businesses. Compared to other models, the TU/e innovation space specific character lies on encouraging the cross-fertilization between departments as well as the cooperation with the business community. The operationalization of such an ambitious undertaking is actually a step ahead in realizing the vision of the TU/e to educate the Engineers for the Future [3].

4 DISCUSSION

The *Internet of Things* project is a pilot project that has been developed to introduce students in the world of communication technology and to learn them the application of technology, architecture and business models by tracing people and objects through indoor localization functionally assignments. The added value of this project is that is a pioneering course within the Eindhoven University of Technology as it is devoted to promote *hands-on* application of a connected world rather than in a lecture-type course. The relevance of this project is therefore twofold: first of all, the IoT project is aiming at promoting practical applications of content; secondly, the project aims at integrating different disciplines as a realistic scenario of what the engineers for the future will be dealing with in the industry in order to stimulate multidisciplinary projects.

It becomes difficult at this stage to sharply identify the benefits and students' gains of this project as it is now in a pilot phase. We foresee however some advantages and effects for students. First of all, the rationale for this project is based on integrating continuous iterations in the design process emulating the *Agile* method. By doing so, we expect higher quality of product design, in terms of accuracy of localization, measurements of distance, or in the optimization levels of the wireless network, among other performance items of the devices. Furthermore, the fact that students can choose different scenarios and perspectives to approach the problem solution will require creativity to combine technologies and architectures. We expect therefore new eye openers in the models students will design. A thorough out evaluation of results after the implementation of this pilot project will allow us to analyse students' gains in this IoT project.

The future challenges of this project will be to include elements of value for money in the design review in order to fine-tune the assignments and students' products according to the clients. In order to embrace the value for money component it will be necessary to make the project sustainable and gain financial support to be able to buy sensors, actuators and missing parts upon which students will make choices based on the technology and architectures they are planning to use. The need to link with the industry and with Innovation Space university project becomes also relevant.

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Design of a learning method based on Flipped-Classroom methodologies using SPOCs in an engineering course

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ABSTRACT

The actual development of communication and new technologies allows improving the pedagogy methodologies. In this work a new teaching methodology which combine online resources via Small Online Private Course (SPOC) with collaborative learning techniques is presented. This new methodology has been implemented in the course "Elasticity and Strength of Materials" in the Bachelor´s Degree in Industrial Technologies Engineering. As a benchmark of the methodology, 250 students and 6 teachers have been involved in the experience. The results of the study show how it is possible to improve the academic results with respect to the traditional teaching methodologies, improving as well transversal competences.

Conference Key Areas: Open and Online Engineering Education, Engineering Education Research, I want to contribute to solve local problems

Keywords: Learning design, Learning mark, Motivation, SPOC

INTRODUCTION

The technological development during the last decades, allows the teachers to employ new techniques based on online resources, adding value to the traditional teaching methodologies. Leading examples of this development are blended-learning (Bourne et al. 1996) and flipped-classroom (Kim et al. 2014). One of the main advances in these methodologies is the availability of moving part of the contents of the course to online resources, releasing time to apply other technologies in the classroom. The experiences during the last decades prove the improvements in engineering bachelors of collaborative learning, community learning and learning based on examples or projects (Smith et al. 2005).

Several studies show the improvements in the learning process of applying these new methodologies: Mendez and González (2011) balance the workload of each student based on its activity and its results using fuzzy logic techniques in a Control System course. The main conclusion of this work is the identification of the motivation as a driven parameter for the academic success. In other words, the use of online learning methodologies not only eases the learning process but also increases the student motivation.

Yigit et al. (2013) proved that the mark results of the students in a coding subject are similar between traditional teaching and blended-learning methodologies. Using flipped-classroom in 3 different courses of engineering, humanities and social studies, Kim et al (2014) allowed identifying the main standards or principles for all courses.

Blaeper et al. (2014) studied the effect of the reduction of the on-site time in the classroom (2/3 of the total) for online contents in a physics course. Moreover the class was moved to an active learning classroom. The student's knowledges of the subject were improved with respect to the traditional method. At the same time, the perception of the students about the course has been upgraded. Proving the efficiency of the active learning classrooms, although the number of students in a collaborative classroom is lower than in a traditional classroom, the achievements are greater, reducing the total time of learning process.

One of the disadvantages of the online contents is its dependence to the spreading of the internet access in the country. Banday et al. (2014) studied this effect in developing countries where the internet access is lower than in the occidental ones, and proposed tools to reduce the effect of these disadvantages.

The emerging of new technologies allows the teacher to apply innovative techniques in the teaching process, making the study time become a game. Bodnar et al (2016) presented a review of the gamification of different courses in engineering proving that this technique increases the motivation and improves the learning process.

This work presents the implementation of a flipped-classroom methodology in the course "*Elasticity and Strength of Materials*" in the Bachelor Degree in Industrial Technologies Engineering during the course 2015/16 at the University Carlos III of Madrid. The theoretical sessions were moved to a Small Private Online Course (SPOC) and the time released was used for a collaborative learning technique. The results of the final exam show that the new methodology could improve the students' academic results and simplify the learning process.

1 TEACHING METHODOLOGY

The teaching methodology designed should fulfil the criteria of the European Higher Education Area (EHEA) applied in Spanish universities. Moreover, it should be done in the actual classrooms, timetable and groups of the Bachelor Degree in Industrial Technologies Engineering at the University Carlos III of Madrid

Each group of this engineering bachelor has 2 sessions of 2 hours per week, the first one (Aggregated group) with a maximum of 120 students and the second one is a reduced group of 40 students. Usually the Aggregated group is used to explain theoretical contents and the reduced sessions are employed to solve practical exercises. Subsequently the students should study the theory and then try to solve the problems by its own. The number of students per year is around 250, which are divided into 3 aggregated groups and 7 reduced groups.

The implemented methodology is based on the idea of flipped-class-room, because some of the common tasks done by the students in the classroom in the traditional methodology, are moved to homework and vice versa. The learning process is as can be seen in Figure 1:

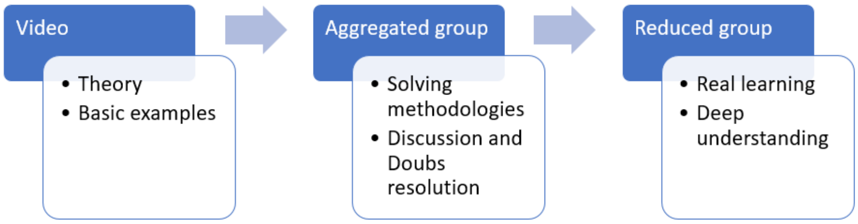

Figure 1. Learning process implemented in the course

- Theory contents are recorded in videos and uploaded into the SPOC platform. These videos should be attended/viewed as homework before the class in the aggregate group. Therefore the students, instead of listening the teacher in the classroom, view the video and hence they can decide the time and rhythm of the explanation and even repeat selected parts. Moreover the contents are multiplatform accessible, so the students decide the way to access to the information
- The aggregate group sessions are used now for discussing the theory in a more active way, from the students' point of view. Moreover different problems are solved and discussed, moving the task done in the traditional methodology of the reduce group to the aggregate one. The bigger number of students enriches the discussion and the possible doubts of the theory.
- Finally, the reduced groups are re-designed to accomplish a collaborative learning process. The group of 40 students was divided in groups of 5. Each odd week the group of 5 should solve by its own a problem, discussing the doubts with the teacher. The even weeks the groups present and explain the solutions to the other students, each team member should present at least 1 time the solutions and answer the doubts of the other students and the teacher's questions.

2 EVALUATION STRATEGY

The traditional way of marking consists of 60 % the final exam mark (4 different problems) and the 40% of the course mark correspond to continuum assessment. This continuum assessment was composed by a 15% the laboratory marks and 25 % the partial exams. Moreover it is required at least 4.5/10 in the final exam to pass the course.

The new evaluation strategy conserves the old weight between the final exam and the continuum assessment but, in this case, the 25% corresponding to the partial exams were assigned to the marks corresponding to the teamwork evaluation: 1/3 of this mark corresponds to the solving evaluation of the team (equally for all the team members), 1/3 corresponds to the evaluation of the presentation, and the rest (1/3) is the mark of the answers to the teacher questions after the problem presentation.

3 SPOC ENROLMENT

Most students attend the SPOC course. The SPOC contents are videos, self-assessment exercises and evaluation problems. After each video, the students should answer a series of questions designed to test the understanding of the concepts explained in the video, these exercises or questions are not taken into account for the final assessment. The evaluation exams consist on 6 questions or problems at the end of each week. The entire course was divided in 13 weeks and the final mark is the average of the marks of the 13 week's evaluation tests. Based on the results of these weekly tests, 83% of the students pass the SPOC course, 90 % of these obtain a mark bigger than 7/10 (mark grade B or A). Only 17% of the students did not pass the SPOC course, and 70% of this percentage gave up the SPOC course, hence they did not answer the tests. These results are considered positive, due to the fact that in all the courses there is a percentage of the students that give up the course without attending the final exam. This percentage (19%) was similar to the one of giving up the SPOC course.

4 RESULTS

The results of this work are compared with respect to the marks of the year 2014/15 and 2015/16 in the ordinary final exam of the course "*Elasticity and Strength of materials*". Besides the target population are different, the number of students involved is large enough to be considered as equally dispersed, 269 students in 2014/15 and 287 students in 2015/16. Moreover, the mean academic grading of both groups during the bachelor courses were similar. The mean academic grading of the student in 2014/15 was 6.19/10 and the grading of the students in 2015/16 was 6.05/10.

Table 1 shows the percentages of the total number of students that have passed the course, the percentage of students which pass the final exam, and the percentage of the students that have failed the exam (obtaining a mark greater than 4.5) but pass the course due to the continuum assessment mark. These results show that the percentage of the students who pass the course increase a 40% in relative terms, but the number of students with a mark greater than 5/10 in the final exam was increased in 78%. This means that a great number of students in 2014/15 did not pass the exam, but pass the course due to the continuum assessment mark.

	2014/15	2015/16	Differences
% Students pass course	47.21%	66.55%	41.0%
% Final exam positive	31.60%	56.45%	78.6%
% Students which pass the course due to the continuum, assessment.	15.61%	10.10%	-35.3%

Table 1. Percentage of students that pass the course in comparison with 2014/15

Table 2 shows the marks obtained by the students in the final exam for both 2014/15 and 2015/16 academic years. The number of students that give up the course decreased, which means that the number of students that considered that they were prepared for the exam increased. The percentage of students that did not pass the course decreased to a half in comparison with the previous year, and the percentage of passed increased. The more remarkable result is that only 3% of the students in 2014/15 obtained a B mark (7/10) and none of them an A mark (9/10). However, with the new methodology, 17% of the students obtained a B mark (7/10) and 6 % obtained an A mark (9/10). These results show that the knowledge acquired by the students can be considered remarkably better and it is translated into the marks of the students.

	2014/15	2015/16	Differences

Give up the course	23.79%	18.82%	-20.9%
Failed	44.61%	24.74%	-44.5%
Pass	28.62%	32.75%	14.4%
B mark	2.97%	17.07%	474.1%
A mark	0.00%	6.62%	
Total pass	31.60%	56.45%	78.6%

Table 1. Final exam marks distributions

Figure 2 depicts the distribution of the marks of the exam in the years 2014/15 and 2015/16, showing a normal distribution. In 2014/115 the normal distribution was centred in a mean value of 4.7 and a standard deviation of 1.39. Therefore the students did not pass the exam but passed the course due to the continuum assessment mark. The results due to the presented methodology, course 2015/16, shows a normal distribution centred in 5.89 with a standard deviation of 1.84. Most of the students passed the exam, and the number of marks higher than B increased.

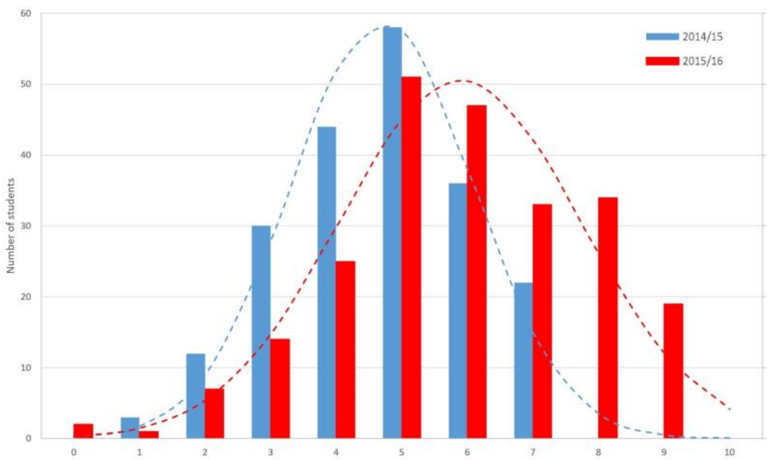

Fig. 1. Final exam mark distribution 2014/15 and 2015/16.

5 LEVEL OF COURSE SATISFACTION

The students from the University Carlos III of Madrid answer a satisfaction poll about the teaching methodology for every course and year. This poll has been used to evaluate the presented teaching methodology. It is important to remark that the students answer the poll before the final exam, so the answers are independent of the increased mean mark in the final exam. The course has 6 teachers in 3 aggregated groups and 7 reduced groups. Only 1 teacher was different between the 2014/15 and 2015/16 courses; that change affected only to the 30% of the students. The mean results of satisfaction of the students in 2014/15 was 3.51/5 whereas in 2015/16 was 3.6/5. There is a slightly rise in the satisfaction, but not significant to be considered. The significant change in the poll results was in the poll`s comments. In 2014/15 the students' comments or complaints were in the way of:

- The students considered that the number of problems were scarce

- The course syllabus is huge and each division is taught summarily
- The theory sessions are difficult
- The theory sessions are useless

In 2015/16 the comments or complaints of the students, can be classified also in:

- The students required more theory concepts in the on-site sessions
- There are weeks with partial exams of other subject that reduced the available time for the SPOC
- The students requested partial exams
- The presentations of the other students, explaining the problem resolutions are useless

The similar values of satisfaction in both years conclude that the new methodology has been similarly accepted by the students. Moreover there are different student profiles and some has better acceptance under new methodologies. In the traditional methodology, there is a group of students requesting more exercises, with the new methodology a new group appear requiring more theory weight in the on-site sessions, similar to the traditional method. The new method forces the student to learn out of his comfort zone, they are used to a passive learning in which listening to the teacher is the main task. In the new methodology they should study and prepare the subject by their own. The new method pushes the student to collaborate in team works and explain his results to the group by a public appearance, which usually turns out in complaints.

6 CONCLUSIONS

It can be considered the success of the new method, due to its results in comparison with the traditional methodology. Although a deeper analysis, including more polls and a bigger population is required to identify the aspects that causes the success, even so it can be identify possible success parameters of this experience:

- The blank sheet of paper magic: the most important time in the learning process is the one in which the students try to solve a problem by their own. Although the method assures that the teacher joins the students in this experience and serves as guidance.
- The relationship student-professor. The methodology implies a closer relation, which confers more confidence and reduces the expert syndrome in the teacher understanding the student point of view. This experience not only improves the learning process, but also gives to the teacher the opportunity of enhancing his explanations in the weaker knowledges points of the students.
- The spreading of enthusiasm. The effort and passion of the teacher is spread or transmitted to the students, and his answers to the teachers are an “extra” effort, trying to keep up with the professors.
- The task of every week homework. The demanding task of SPOC videos prevents to quit the course and enable a better understanding of every lesson. The success of the results is due to the fact that the students have worked more and better, because a better guidance in the learning process.
- The student behaviour depends on the environment. The traditional method used during decades, teaching by a passive listening, does not prepare the students for the professional career, where should be active and collaborative. This new methodology gives the principal role of the learning to the students.

- The new methodology is not only a success in the subject taught, but also increases transversal knowledges e.g. “the capacity to communicate its knowledge in public appearance” and “team working”

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Employability and the knowledge, skills and competencies of engineering graduates
Case Study of Finnish Engineering Education

ABSTRACT

This system paper will examine the amount and quality of work experience of newly graduated Finnish professionals from the field of technology and the knowledge, skills and competencies that the graduates have gained through formal engineering studies and through work experience gained during studies.

In the future world of work the ability to adopt and to apply new knowledge are crucial skills and enable life-long learning. New learning models such as problem-based learning, project-based learning, co-ops and CDIO are needed in providing engineers with skills and competencies they can utilize throughout their career. As the graduates have a significant amount of work experience it allows the universities to utilize the work experience and to recognize the competencies the students have gained outside the classroom.

Conference Key Areas: Skills and Engineering Education

Keywords: employability, work experience, graduates, skills

1 INTRODUCTION

Academic Engineers and Architects in Finland - TEK is a service and labour market organization for professionals and students in the area of engineering and technology. The 73 000 members of TEK mostly hold a M.Sc. degree in engineering, technology, architecture or natural sciences. In addition to labour market issues, TEK actively participates in the developing engineering education and further professional development. TEK works in close collaboration with universities, political authorities, representatives of working life and other relevant stakeholders. One of the main interests for TEK is to make sure that the Finnish Universities of Engineering and Technology will have the best possible funding and framework to provide top quality engineering education.

One of the practical tools used for monitoring the quality of engineering education is Graduate Feedback Survey which is directed at newly graduated M.Sc. engineers and architects. TEK and the Finnish universities of higher engineering education have conducted this joint feedback survey on a national scale for graduates since 2011. The main purpose of the feedback survey is to gather comparable information on the quality of the Finnish engineering M.Sc. degrees. Some highlights of the areas the survey covers are the quality of formal studies, the skills, competencies and knowledge gained by the graduates and their employment after graduation. This graduate feedback survey covers over 95 per cent of the Finnish M.Sc. engineering graduates. In 2016 the response rate was as high as 68 %.

In Finnish higher education it is rather typical that students gain a significant amount of work experience in industry during their studies. On average a graduate in the field of engineering and technology has more than 2 years of work experience of which 8 months is study related and equivalent to graduates level of education. Typically also the master thesis is done in industry which means that graduates have a strong professional network already at the time of graduation and they have demonstrated the ability to apply theory into practice.

This paper will present some recent findings from the data regarding employability and the knowledge skills and competencies the students gain from their studies and the work experience they gain during their studies.

2 THE FINNISH HIGHER EDUCATION SYSTEM

2.1 The Finnish higher education system in the field of engineering and technology

Finnish higher education system is based on a dual/binary system of higher education. The higher education institutions constitute of universities and universities of applied sciences (UAS). The members of TEK include professionals with at least second cycle university level degrees and students currently studying for second cycle degrees. Seven out of fourteen Finnish universities provide studies in the field of engineering and technology.

Finnish higher education system is not governed by any strategic policy papers per se at the moment as the policy paper system of higher education is currently under reform. The latest of the strategic policy papers called *koulutuksen ja tutkimuksen* *kehityssuunnitelma KESU* (education and research development plan) covered the development of higher education up until 2016. Currently the strategic goals of higher education are defined only in the government programme of 2015-2019 with four main goals for higher education: enhancing student selection processes, year-round study possibilities, digital learning environments and reviewing the eligibility demands in public positions.

Finnish higher education policy has aimed for decreasing length of studies for more than a decade. Regarding statutory developments, university students used to have unlimited time to complete their studies which has been limited to seven years since 2006. The public funding of universities is also strongly governing to faster completion of studies with amount of students achieving degrees and at least 55 study credits per academic year being rewarded generously. The universities are also governed for decreasing study times through university-specific negotiations arranged every four years.

The government policies aiming for shorter study times are justified with the aim to increase the amount of time population is active in the labour market. The long study times of Finnish students however seems not to decrease the length of careers at least in the field of technology: the study times lengthen mostly because the students are very active in the labour market already during studies. The culture of working alongside studies is also very beneficial for the students as explored further in this paper.

2.2 Monitoring the output: Graduate Feedback Survey

The graduate feedback survey discussed in this paper is a joint effort of TEK and those Finnish universities which provide education in the field of engineering and technology. The survey has been conducted since 2011 and it covers over 95 % of all graduates from academic studies in the field of engineering and technology. The response rate of the survey is very high, for example in 2015 the response rate was as high as 72 % of all graduates and in 2016 the responserate was 68 %. The survey is yearly open from the beginning of January until the end of December. The survey is rather extensive with 56 overall questions and an estimated response time of 45 minutes.

2.3 Culture of working along studies in Finland

Gaining work experience while studying is very typical in Finnish higher education system and Finnish labour market. Working during studies serves many functions for the students. First of all, the financial aid provided for students by the government is in many cases not enough to cover living costs. Secondly working during studies is regarded as a great way of enhancing ones skills, competencies and knowledge. Third, work experience is highly valued in the Finnish labour market, even if the experience is not from the field of studies or does not match the level of education. Work experience from ones own field of science also provides valuable contacts and networks to possible future employers. (TEK opiskelijatutkimus 2016) The percentage of employed university level students are presented in Figure 1.

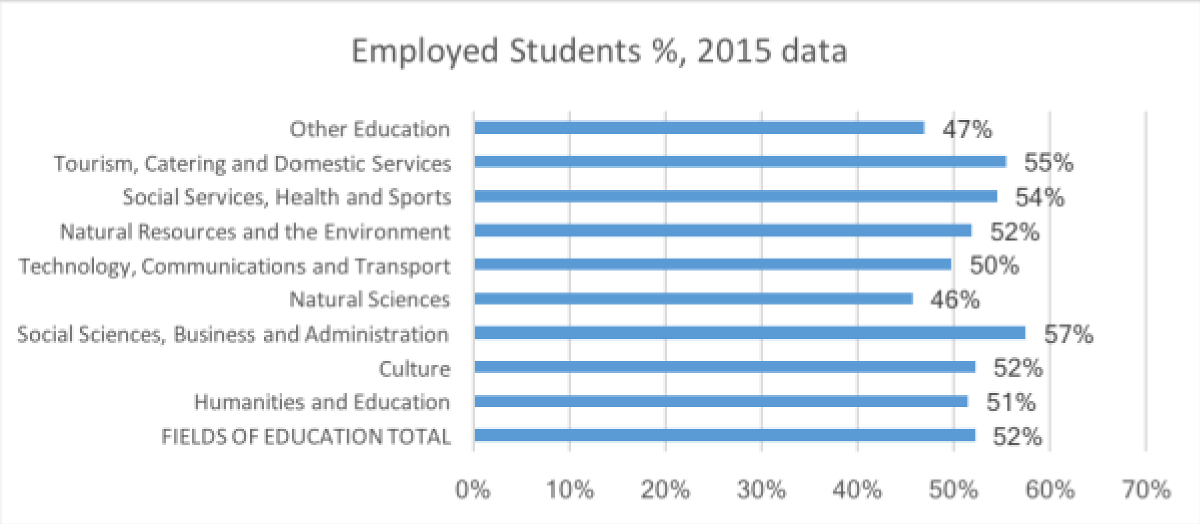


Fig. 1. Percentage of employed bachelor and master level students by field of education in 2015. (statistics Finland)

3 SKILLS, COMPETENCIES AND KNOWLEDGE GAINED IN STUDIES AND WORK EXPERIENCE

The skills, competencies and knowledge of Finnish graduates in the field of engineering and technology develop both through formal education and work experience gained during studies. The TEK Graduate Survey the development of 26 categorized skills, competencies and knowledge through both formal education and work experience. The results of the 2016 survey are illustrated in Fig. 2.

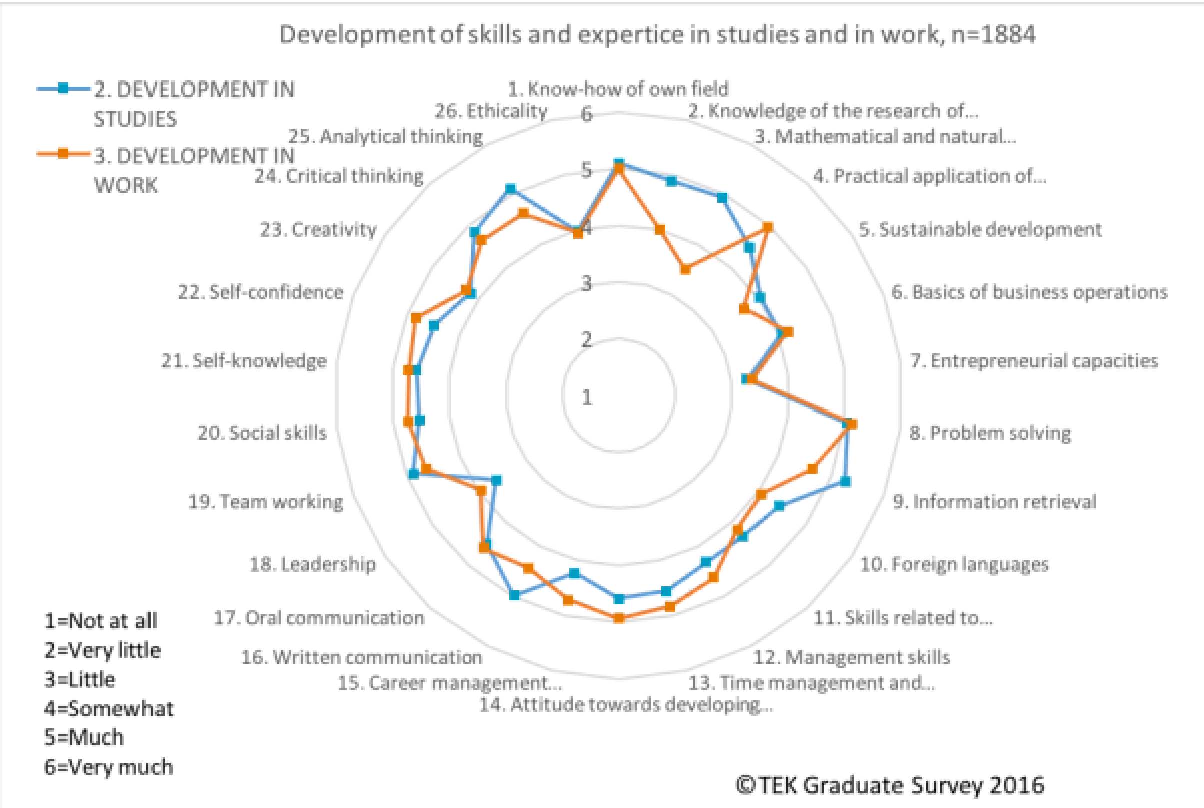


Fig. 2. Self-evaluated development of skills, competencies and knowledge of M.Sc. in

Tech graduates through formal education and work experience gained during studies in 2016. (TEK Graduate Survey 2016)

The differences in development of skills, competencies and knowledge however seem to emphasize the very hard to develop skills gained in formal education such as knowledge of research, mathematical and natural science skills, information retrieval skills and analytical thinking. Also the foundations for learning the skills are set out in formal education after which it is likely that further development of skills through work experience is easier.

While the differences of development the skills differ quite little between formal education and work experience, the differences highlight the importance of both factors in producing high-quality graduates in the field of technology. Many categories develop somewhat identically through both education and work experience but the differences are what matter the most. Formal education clearly lays the groundwork for further development by improving the core skills in the field of technology: mathematical and natural science skills, information retrieval and analytical thinking to highlight a few. Work experience also play a very important role by compensating where formal studies are fumbling: practical application of theories, attitude towards developing own skills and leadership skills to name a few.

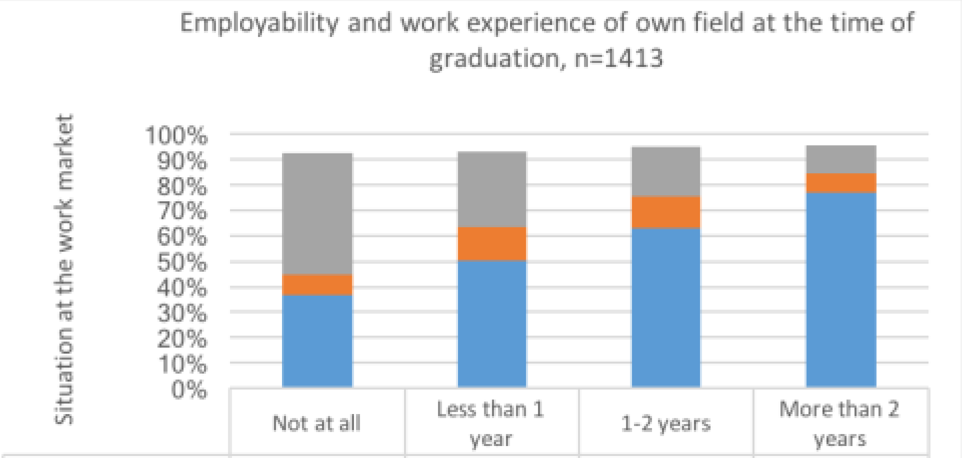
4 EMPLOYABILITY OF GRADUATES

The Finnish M.Sc.'s in the field of technology gain on average over 2 years of work experience during their studies However, the total study time of the respondents is approximately seven years with the target total study time being five years. According to the TEK Graduate Survey, the studies are delayed due to many reasons such as lack of motivation and lack of support and guidance in thesis work and/or studies. However the most common reason for delay in studies is working while studying.

Working alongside of studies provides a wide range of advantages for the students as explained in chapter 1. In addition to what we covered in chapter 1, work experience is also a source of motivation for studying as students get a better perspective and understanding on what kind of a career they would like to pursue. Working while studying also helps choosing courses and whole majors or minors according to interests discovered through work experience. Another perk of working alongside studies is that higher education degrees include mandatory or optional traineeships for which students also get study credits for.

The average 2 years of work experience is gained cumulatively throughout the studies. It is very common for the students to work during the summerbreak. Universities tend to provide some courses for summer for the students that fail landing a summer job or prefer studying in the summer. Spending the summer studying is however quite often a backup plan for students: in the summer of 2016, 82 % of students in the field of technology were employed. Students also work quite a lot during the semesters with 53 % of students in the field of technology working at least occasionally during semesters in the academic year 2015-2016. The summer jobs tend to be full-time and jobs during semesters tend to be part-time. (TEK Student Survey 2016) The M.Sc. thesis in the field of technology is mostly conducted in employment which also contributes an average of 8 months to the work experience of graduates. Only 19 % of 2016 graduates received no compensation for their masters thesis and 54 % conducted their thesis in the industry.

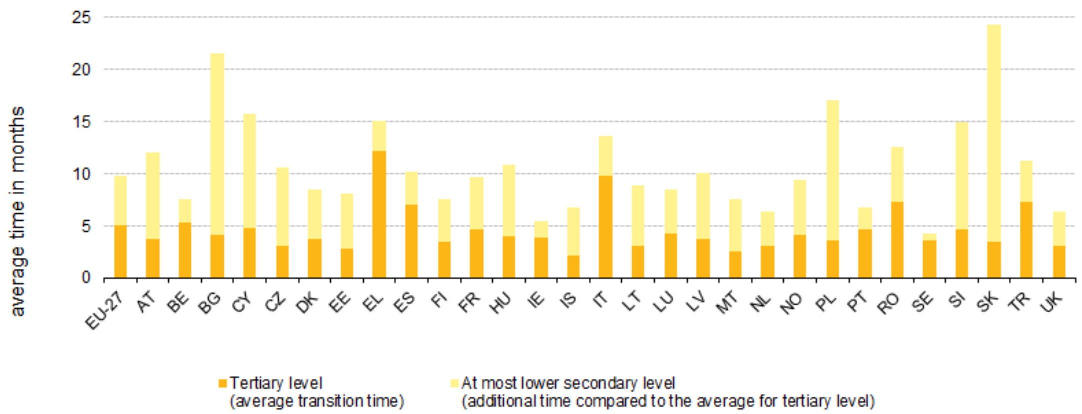
Finnish M.Sc.'s in Technology and Architects are mostly already employed when they graduate as seen in Fig. 3. The rate of employment is even higher if we account for agreed but not yet signed job contracts at the time of graduation. The total average rate of employment of graduates in 2016 was 68 % including the agreed job contracts. Fig. 3 also highlights the importance of work experience in enhancing the employability of graduates: the more work experience the graduate has gained during studies, the more likely they are to be employed at the time of graduation.



	Not at all	Less than 1 year	1-2 years	More than 2 years
Seeking for a job	48%	29%	19%	11%
Agreed workplace	8%	13%	13%	8%
Valid work contract	37%	50%	63%	77%

Fig. 3. Employment and amount of work experience (excluding M.Sc. Thesis work) gained during studies of M.Sc. in Tech graduates in 2016. (TEK Graduate Survey 2016)

One of the advantages of gaining work experience prior to graduation is the reduced transition time from education to work. As seen in Fig. 4, the Finnish average transition time from tertiary education to work is the seventh fastest of the EU-27 comparison (Finland average 3.5 months vs. EU-27 average 5.1 months). The reason for the swift employment after graduation is explained to a large extend by the fact that graduates get employed to the organization where they have worked during studies as seen in Fig. 5. More than three out of four employed graduates have worked during studies in the same organization where they were employed at the time of graduation.



Notes: Results are based on people who left formal education in the last five years.
BG, LT and SI data lack reliability due to low sample sizes for the category "at most lower secondary".

Fig. 4. Average length of transition from school to work by educational attainment level (Finland = FI), fields of science combined 2009. (Eurostat)

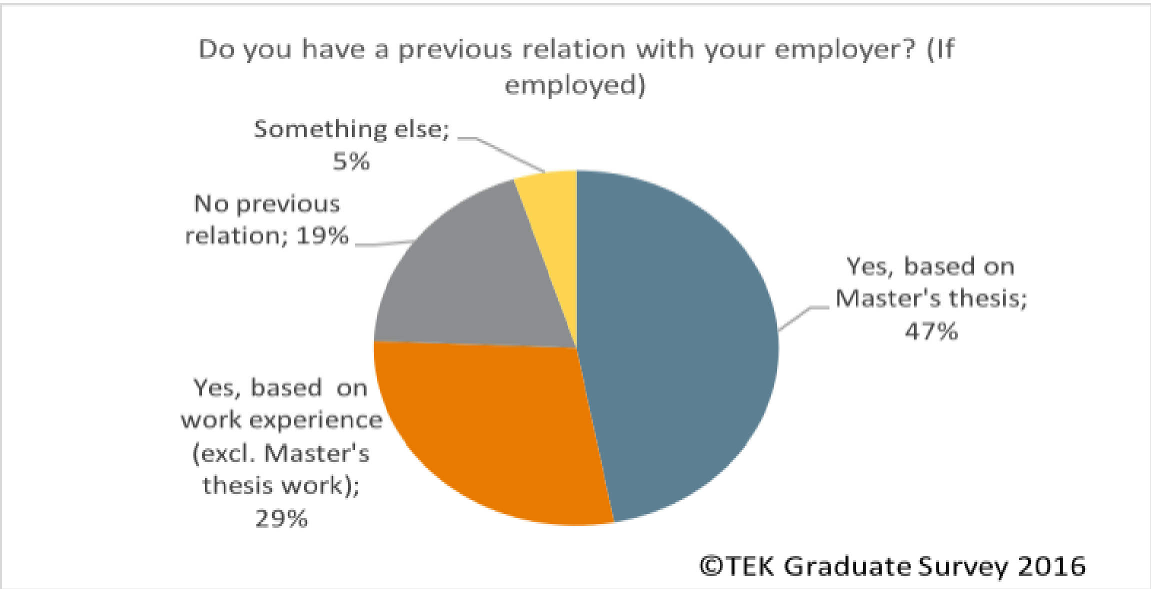


Fig. 5. Previous relation with employer, employed graduates 2016. (TEK Graduate Survey 2016)

The graduates also feel that the first position after graduation corresponds very well with their educational backgroud. Four out of five think that job corresponds either well or very well both with the graduates' field of studies and level of education. Due to intensive culture of working during studies, graduates tend to skip the trainee phase of employment after graduation as it is already taken care of alongside studies.

5 CONCLUSIONS AND DISCUSSION

In this paper we focused our study of work experience and employability in the graduates of engineering and technology. The amount of work experience gained during studies has a strong effect on the employability of graduates.

The Finnish higher education policy aims for shorter length of studies to lengthen the careers of graduates. That however seems highly unnecessary accoring to our data. The professional careers of graduates in the field of engineering and technology start already in the course of studies. The co-ops, CDIO concepts and traineeships are and can be embed in the engineering degrees through recognition of the skills and competencies gained outside of the classroom.

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Learning to be an Engineer: Implications for the education system

ABSTRACT

Previous research has reframed engineering as a series of six engineering habits of mind (EHoM). This was seminal for shaping thinking around what knowledge, skills and competencies young people need to develop if the UK wants to produce more engineers. *Learning to be an Engineer* explores the ways schools can create better and more engaging learning opportunities for would-be engineers and how engineering EHoM can be integrated in the real world of busy schools and colleges. The overarching hypothesis was that, while it is necessary to continue to value disciplinary knowledge and practical skills, it is also important to think more about the dispositions engineers need to acquire. To do this, dispositional teaching and its associated learning methods were carefully considered.

The research identifies some essential elements of the signature pedagogy for engineering: the engineering design process, 'tinkering', and authentic, sustained engagement with engineers. It also describes many positive outcomes for learners taught in this way, including: increased fluency in the key habits of mind and the development of 'growth mindsets'. Additionally, it finds benefits to the capability and confidence of teachers, in particular their engagement with practising engineers.

Conference Key Areas: Engineering Skills, Curriculum Development, Engineering Education Research

Keywords: Dispositions, signature pedagogy, education

INTRODUCTION

Learning to be an Engineer follows an earlier piece of analytic research, *Thinking like an Engineer: Implications for the education system*, which reframed engineering as a series of 'engineering habits of mind' (EHoM): systems-thinking, adapting, problemfinding, creative problem-solving, visualising, and improving [1]. The most important finding from this research is that the question, 'how do engineers think?', seemed to matter to teachers of engineering and is one which had not been discussed much previously. The teachers really engaged with this question and it was very effective at opening up discussions regarding pedagogy. Understanding more about how engineers think can assist teachers of engineering to construct appropriate curricula and select pedagogies and assessment methods which support engineering. Furthermore, understanding more about how engineers think may also provide clues as to how engineering careers can be presented more effectively to young people [1].

Drawing on extensive research and informed by discussions with experienced engineers and engineer educators, we suggested a number of signature pedagogies [2]. At the core of these is the engineering design process.

This research involves a small-scale intervention study and documents a proof of concept trial that sought to establish how schools can adopt the EHoM framework, which teaching methods are most helpful and the impact of adopting this approach.

The research began in late 2014 and was completed in summer 2016. It involved 33 schools and one further education college, 84 teachers and over 3,000 pupils. Three partners were involved in the research and each partner designed a programme of support for schools to embed EHoM using a range of different approaches.

During the research period, schools in England went through a time of considerable change, affecting their status, curriculum and accountability. A major review of the National Curriculum [3] was completed in England, which affected primary and secondary schools, as teachers engaged with, among other changes, computing as a new subject. At secondary level, the English Baccalaureate (EBacc) was introduced [4] and two new accountability measures, Attainment 8 and Progress 8, were introduced from 2016 onwards [5].

1. OUR APPROACH TO THE RESEARCH

1.1 Our theory of change

In moving from our conceptual research to a series of interventions we articulated a theory of change (TofC) in *Table 1*.

If we

- reframe engineering education to include desirable engineering habits of mind (EHoM) in addition to subject knowledge, and
- clearly articulate the principles and practices through which these EHoM can be cultivated in schools, and
- offer teachers targeted support for changing practices along with opportunities to co-design enquiries within the context of a reflective professional learning community Then
- we can better understand what school leaders and teachers need to do to change their practices to embed more effective engineering education

So that

- we can share this understanding widely and
- more effectively support the process of successful implementation of engineering education in schools

So that

- more schools embrace engineering and

- more school students have high-quality experiences of engineering education and
- more students choose to study engineering beyond school and, potentially, choose careers in engineering.

Table 1: Learning to be an engineer – a four step theory of change

Essentially we are suggesting that to overcome our current lack of engineers we need to do three things in schools:

- Move away from a focus on disciplinary knowledge (subjects such as maths) towards a better understanding of the ways engineers think and act (EHoM)
- Describe the teaching and learning methods most suited to cultivating EHoM, and
- Build teacher capability through professional development.

Our over-arching hypothesis is that while we need to continue to value disciplinary knowledge and practical skills, we also need to think more about the dispositions we want our engineers to acquire.

1.2 Research design and methods

The methodology for this small-scale intervention study was designed in line with our TofC model. We have previously identified the six EHoM and articulated possible approaches to their cultivation [6][7]. This report builds on this and presents the outcomes of a small-scale intervention study aimed at exploring the process of implementing EHoM in primary and secondary schools, and to a lesser extent with 16 to 19 year olds in further education colleges.

The schools and college participated on a voluntary basis and their teachers engaged in a small test of change to explore how they might expand engineering in the curriculum and cultivate EHoM in their learners. The majority engaged with this as a CPD learning project for which they adopted a participatory action research approach [10], evaluating the impact of their interventions on their learners, on themselves and on their school using a number of methods.

1.3 Evaluation methods

We used a number of qualitative methods to explore the teachers' intervention experiences to ensure as much triangulation of data sources and types as possible. This involved teachers' evaluations of their action research interventions, semi-structured interviews with teachers, and qualitative feedback via a questionnaire. We adopted an appreciative inquiry approach (AI) to underpin our philosophical approach to the whole study [9].

1.4 Data analysis and reporting

To understand more about the pedagogic processes underpinning the successful cultivation of EHoM in schools and to learn more about the impact that these interventions have on learners, teachers and engineers, we used a 'realist synthesis' approach [10] to identify why the teachers' interventions worked (or did not) and in what contexts. Analysis of the data using techniques associated with realist synthesis offered the opportunity of establishing not simply 'what works' but also 'for whom' and 'under what circumstances'. This perspective, with its explanatory rather than judgmental focus, also aligned with our AI philosophy.

We used thematic analysis [11] to code the data and produced a synthesis of the ways in which teachers had cultivated EHoM. We looked for patterns, identifying issues which were frequently repeated in the data but not specific to any one sector, such as 'learning from failure' or factors associated with 'growth mindset'.

Given the short length of time during which most teachers' interventions were carried out, and the variety of locations, there are inevitably limitations on the extent to which we can generalise from our findings. However, our use of realist synthesis allows us to offer an explanatory analysis of the degree to which the different interventions did or did not work and make some general remarks about these.

2. THE STUDY

2.1 Overview

The three partners each developed a distinctive approach to using the EHoM framework but all explored pedagogies for EHoM, curriculum development and teacher professional development. All the partners encouraged teachers to use participatory action research to structure and evaluate small tests of change in classrooms. The three projects undertaken were: Thinking Like an Engineer (TLaE), Tinker Tailor Robot Pi (TTRP), and Primary Engineer in Scotland.

2.2 Thinking Like an Engineer (TLaE)

This project embedded EHoM into the curriculum in a small number of schools and a college in England. TLaE developed teachers' understanding of EHoM, supported teachers in using signature pedagogies to develop EHoM and in creating schemes of work that included EHoM across science, mathematics, computing, D&T and art, and encouraged teachers to draw on the expertise of practising engineers. TLaE involved a blend of training, school support, curriculum development and action research as part of a professional learning community.

2.3 Tinker Tailor Robot Pi (TTRP)

This project investigated the development of an ethos of tinkering within computing, D&T and the science curriculum to promote engineering and EHoM with schools in Greater Manchester. TTRP explored how a pedagogical approach to primary engineering could be established within the mainstream curriculum. TTRP encouraged the sharing of professional practice between teachers and engineers, explored how engineers work and how learning related to engineering is taught in primary schools, and identified opportunities for incorporating engineering in primary schools through science, D&T and computing.

2.4 Primary Engineer

In 2015, work began to develop one of Primary Engineer's teacher development programmes into a GTC Scotland Professional Recognition Programme in Engineering STEM Learning which is now accredited by the University of Strathclyde as a Postgraduate Certificate. This third project supported the delivery of the course aimed at primary teachers in Scotland during 2015–2016. Nine teachers from eight primary schools in Glasgow and East Ayrshire completed four assignments, one of which involved interviewing engineers to explore the growth of their EHoM.

Figure 2 below shows the key features of the three interventions diagrammatically.

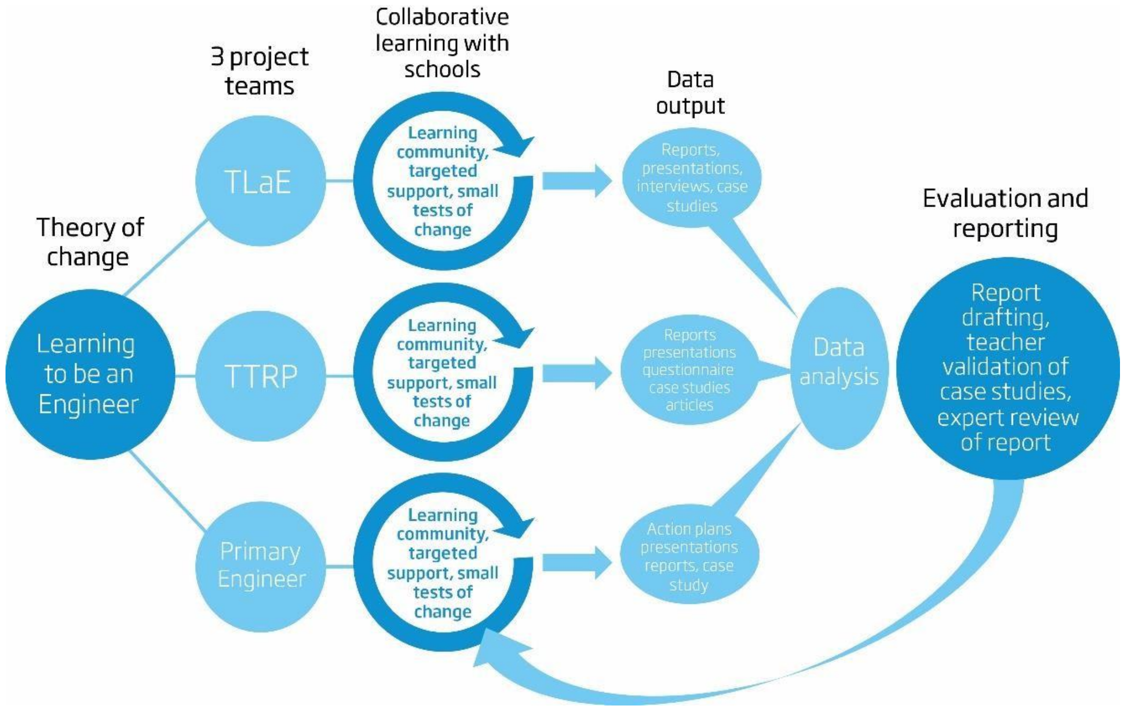

Figure 2: Overview of the three project interventions

3. CULTIVATING ENGINEERING HABITS OF MIND

Four pedagogic principles guided our cultivation of effective learning habits:

1. Teachers and learners need to fully understand the habit and recognise it when it is being used successfully.
2. Teachers must create the climate for a habit to flourish, including rewarding it.
3. Teachers need to choose teaching methods that facilitate the practice and transfer of the habit.
   One of the aims of our programme was to explore the value of 'signature pedagogies' in cultivating EHoM [2], teaching methods most likely to develop the desired engineering habits. The three elements of a signature pedagogy we explored were: the engineering design process, 'tinkering' (an approach to playful experimentation), and authentic learning with practitioners, such as professional engineers.
4. Teachers need to build learner engagement and commitment to the habit.

This research strongly validates the first step of our TofC. Teachers and engineers understood, approved of and used the EHoM model. They were able to connect EHoM thinking to their current practices and to the shifting external educational environment. They liked and used the signature pedagogy thinking. They responded enthusiastically to being part of a supportive professional learning community, were able to co-design different curricula using new pedagogies and were able to begin to make changes to their practices.

4. OUTCOMES FOR LEARNERS

In this section we describe the impact of teachers' interventions on their learners. We focus on the degree to which learners were able to use EHoM, the development of engineering mindsets, impact on literacy, numeracy and oracy, on classroom management and on learners' understanding of engineering.

4.1 Growth in learners' fluency with habits of mind Teachers observed growth in learners' fluency with the six engineering habits of mind: systems-thinking, adapting, problem-finding, creative problem-solving, visualising, and improving.

4.2 Evidence of developing engineering growth mindsets

In many cases, before the EHoM interventions, teachers said learners lacked resilience, perseverance and self-efficacy and were easily discouraged by failure, showing a fixed rather than a growth mindset. But as the project progressed, teachers reported that learners got better at using EHoM the more they practised them and that they demonstrated an increased growth mindset more generally. They also observed pupils transferring these skills in other areas of the curriculum.

4.3 Impact on literacy, numeracy and oracy

While we did not specifically aim to investigate the impact of cultivating EHoM on attainment in literacy and numeracy, some primary teachers noticed improvements in these subjects.

Teachers also reported that learners demonstrated an increased fluency in expressing ideas or opinions. Oracy, learning to talk well and learning well through talk, is regarded by many primary teachers to be of equal importance with literacy and numeracy in supporting attainment [12]. At secondary level, teachers noticed an improvement in learners' communication skills that was more employment focused. Learners demonstrated an increased confidence to network with employers and were able to talk in a more convincing manner to them when they went for job or apprenticeship interviews.

4.4 Self-managed learners and impact on classroom management

Overall, teachers reported that children were enthusiastic and motivated and that attitudes towards learning improved during the EHoM sessions. Teachers described how children had more opportunity to 'discuss, evaluate, analyse and problem solve' and that by working together on a 'level playing field' they were able to demonstrate EHoM. Some teachers found the approach took longer and noted that some more academic children found this type of learning challenging and struggled with the creating process. However, less academic children had a 'chance to shine' and demonstrate greater self-management.

4.5 Impact on learners' understanding of engineering

EHoM teaching that was reinforced through modelling by engineers enhanced learners' understanding of engineering and its potential as a career. The engineers' involvement in the curriculum showed learners how the content and skills they were learning were directly relevant to the real world.

5. OUTCOMES FOR TEACHERS

In this section we explore the impact on teachers' own habits and practices, as well as reflecting on the ways in which they engaged with engineers.

5.1 Teachers as risk takers and improvisers

It was evident that teachers found changing the habit of being 'in control of adverse events' and 'the expert' extremely difficult. Those who managed this shift found it to be very beneficial. More significant and riskier behaviour changes for teachers, such as admitting mistakes or being open-minded when receiving learners' ideas, were evidence of further development of the teachers' own growth mindset.

There were numerous occasions when teachers explained how they learnt alongside their students, particularly when they were addressing the meaning of the EHoM and attempting to transfer the use of EHoM into subjects other than engineering. They became more skilled at engaging in ‘cognitive apprenticeship’ style teaching techniques, such as modelling, scaffolding and coaching [13].

5.2 Teachers as collaborators

In most cases teachers were working on their interventions in pairs or groups, so had many opportunities to learn from each other. In secondary schools EHoM brought teachers from different departments together resulting in increased subject integration. Some teachers became recognised within and outside their school as ‘the expert’ on EHoM and on incorporating engineering into the curriculum, offering CPD sessions to their colleagues.

5.3 Teachers as reflectors

The action research approach underpinning the evaluation of the teachers’ EHoM interventions encouraged them to reflect on their methods. This led to further thinking about how to adapt their traditional teaching strategies, which was most evident in two areas: their increased use of facilitation techniques and the enhancement of their questioning techniques. Teachers also became more skilled at facilitating discussion and helping learners generate ideas through good questioning.

5.4 Teachers’ confidence in engaging with engineers

Though using EHoM, teachers gained knowledge that gave them confidence to make links between the subjects and skills that they were teaching and the world outside the school. Teachers’ growing understanding of EHoM also appeared to increase their confidence in approaching engineers about coming into the classroom and contributing to the curriculum.

The experience encouraged curriculum managers to be more direct with employers about how their involvement with a college can be mutually beneficial. Teachers also listened to what engineers were telling them about what it is like to work as an engineer and how teaching needs to change to cultivate this style of thinking.

6. CONCLUSIONS

This series of coordinated, small-scale interventions, piloted across a number of schools in three different regions of the UK, emerged from a reframing of what it is to be an engineer and research into how teaching and learning methods can best be selected to cultivate certain EHoM. Teachers undertaking these changes were given targeted support within a wider professional learning community in which there were opportunities for them to co-design new ways of teaching. In this section we draw conclusions from our evaluation of the teachers’ activities and discuss implications for different stakeholders.

Our ToC defined our overarching hypothesis that dispositional teaching using appropriate pedagogies could develop in young people the habits of mind most valuable for engineers. Furthermore, given targeted support for professional learning, teachers could adopt these pedagogies to enthuse young people about engineering.

Our findings suggest that within schools wanting to implement more engaging engineering education, the three elements of the first step of our TofC are valid:

a) The reframing of engineering education within schools in terms of EHoM in addition to subject knowledge is something that teachers like and understand.

b) It is possible to create the climate for EHoM to flourish at Key Stages 1, 2 and 3 using three elements of a signature pedagogy for engineering – the engineering design process, tinkering and authentic engagement with engineers – to cultivate the desired engineering habits of mind.

c) A professional learning community that offered targeted support for teachers to design, implement and reflect on the impact of small-scale curriculum interventions in a range of different subjects did begin to change their practices.

With reference to the second step of our TofC, we have begun to better understand what school leaders and teachers need to do to embed their practices. We draw the following additional conclusions:

1. EHoM approach – With support, all schools managed to use the four-step process for cultivating EHoM, locally interpreted and adjusted according to learner age and context. The least developed EHoM was systems thinking.

2. Developing as learners – As well as acquiring more confidence and capability in the target habits, there were significant improvements in terms of mindset (perseverance, learning from mistakes, playful experimentation) and the development of confidence as independent learners. The approach produced significant improvements in learners' understanding of engineers and engineering.

3. Professional learning – The mutually supportive environment of a professional learning community coupled with supported opportunities for the designing of smallscale tests of change was helpful in enabling teachers to begin to change their habits. But even in a supportive environment, teachers found it difficult to relinquish some of their former practices.

4. Leadership – The effective cultivation of EHoM requires a school culture supportive of exploring habits of mind and using interactive pedagogies, complementary summative and formative assessment practices, practical timetabling, appropriate physical space, available local engineers, and proactivity by senior leaders. Effective school leaders recognised the commitment and investment necessary to bring about a wholesale culture change.

5. Engaging with engineers – Engineers were most effectively engaged when they had an ongoing relationship with the school, which included extended conversations with teachers, working directly with young people, hosting visits for pupils and parents in their workplaces, and participation in the professional learning of teachers. Extended contact between engineers and schools makes learning relevant and provides adult role models to convince learners and their parents of the value of engineering as a career. In terms of the third step of our TofC, we have begun to document the extent of the challenge and understand how some external changes might facilitate progress.

In terms of the fourth step we still have a long way to go. Specifically, we need to understand more about successful models of the leadership of the necessary changes required at all levels of the education system.

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Students learning engineering skills together in cross-year-group integrated tutorials

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ABSTRACT

Through tutorials, students can develop their engineering and professional skills outside taught modules. We introduced a new integrated tutorial system in which students were taught in mixed year groups. Questionnaires and focus groups were used to investigate whether students preferred integrated tutorials or tutorials in their year groups. There was a clear preference for integrated tutorials, with students feeling that they provided improved pastoral and academic support and were more stimulating. They particularly appreciated the opportunity to mix with students from other years in a learning community. A minority of students felt that mixing the year groups meant that less material was relevant to individual students than in single-year group tutorials. Overall, integrated tutorials were felt to offer a more supportive learning experience than traditional year-group tutorials.

Conference Key Areas: Engineering Skills; curriculum development,

Keywords: Tutorials; learning communities; peer learning; engineering skills.

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INTRODUCTION

Tutorials provide an essential opportunity for students to consolidate knowledge gained in taught modules (sometimes referred to as courses or units) and to generalise their learning by discussing real-world engineering problems. Tutorials take many forms depending on the institution, the discipline and individual academics' preferences. Here, we define a tutorial as a regular opportunity for students to meet with staff for guidance on academic and personal matters that are broader than those discussed in individual modules. Our institution accepts that personal tutorials differ across disciplines; therefore, our tutorials focus on discussing employability skills, relevant resources and upcoming events.

Tutorials fill numerous overlapping roles including providing academic support, pastoral support, a learning community, peer learning, a social support network and so on [1]. Much of this could be provided by a tutorial system which is not discipline-specific. Indeed, the benefits of a learning community and social support network could even be enhanced by cross-disciplinary tutorials. However, discipline-specific tutorials can offer relevant advice which is consistent throughout an entire degree programme including the selection of optional components, specific advice on internships and careers, and the opportunity to develop professional engineering skills [2,3], as well as allowing open-ended student-led discussions about current engineering practices [4].

We recognise the broad range of activities which are referred to as "tutorials" and here take the opportunity to define our tutorial system. Our system is based on discipline-specific pastoral tutorials. Purely academic tutorials are given by subject-experts as part of taught modules. This ensures that all students on a module (who might come from different degree programmes in different departments) benefit from the same academic support. Here, we consider pastoral tutorials which are given in groups of about 10 students with a discipline-specific academic staff member. Where possible, the same staff member acts as tutor throughout the students' degree programme. We aim to have about 10 one hour tutorials per year, while encouraging students to arrange additional one-to-one meetings with their tutor where necessary. The topics covered are flexible but typically include professional engineering skills, preparation for employment, and revision and examination techniques.

In this paper, we compare two different tutorial systems, both following the general principles detailed above.

1 TUTORIALS AND LEARNING COMMUNITIES

1.1 The role of tutorials in an engineering programme

Tutorials provide an additional learning platform for students which complements more formal sessions, providing a further type of learning which goes beyond the formal lectures, project/problem based learning, and practical group work which take place elsewhere in an engineering programme. Students may be encouraged to discuss cross-cutting engineering themes which apply across subjects and which might be currently topical. They are informal and unassessed opportunities for students to engage in relevant topics [4] and they help to consolidate professional engineering skills such as teamwork, communication skills and an appreciation of broader contexts of engineering [5].

1.2 Learning communities for support and professional development

An important function provided by tutorials is the opportunity for students to develop a learning community [1,6,7]. This recognises that learners work together in a social group, gaining both social and academic support from each other whilst learning together. There is convincing evidence that “moderate to large academic benefits can be attributed to peer tutoring” [8]. Furthermore, newcomers to a group may gain particular benefit from working with established members of the group [9].

1.3 Integrated tutorials

In our previous tutorial system in a new 3-4 year biomedical engineering undergraduate programme, students were divided into tutorial groups, each of which consisted only of students from a single academic year. This brings undoubted advantages as the learning and interventions which students require tend to change year-by-year. All tutorials can therefore be focussed and are equally relevant to all students.

However, this system provided students with limited opportunities to *meet* with students from other year groups and almost no opportunities to *learn* with students from other years. Indeed, it was postulated that final year students underestimate their learning and maturity because they find it hard to compare their current level of knowledge to that which they had when they entered the programme. We decided to tackle this problem with a solution inspired by a local secondary school which has successfully introduced a “vertical”, mixed-age tutorial system which “encourages students from all ages and groups to mix and socialise well” [10].

In our new, “integrated tutorial” system, two to three students from each year group make up a tutorial group of about 10 students. The tutor acts more as a facilitator than an expert and can encourage conversation between the students. A few single-year-group tutorials remain where we need to address topics which are specific to a single year group. We assessed the impact of the integrated tutorial system using a combination of questionnaires and focus groups in a new collaboration between tutors on the biomedical engineering programme and the Institution’s Teaching and Learning Centre.

2 METHODOLOGY

2.1 Questionnaires

A questionnaire (*Fig 1*) was prepared, based on a 5-point Likert-type scale, designed to offer a quantitative comparison of students’ opinions of the new integrated tutorial system to their opinions of individual year tutorials. It included 12 questions designed specifically to assess tutorials (shown in Fig 1) and 10 more general questions aimed at assessing students’ opinions of the overall degree programme (not shown). Some questions were intended to be similar e.g. “how valuable are tutorials?” and “what is your overall view of tutorials?” in an attempt to provide some internal consistency check. The order of the five points on the Likert-type scale was randomised so that some questions were ranked good-bad and others bad-good. All were corrected so that 1 was bad and 5 was good before analysis. The questionnaires were anonymous, but students were asked to state their year group.

There is considerable controversy in the literature over the analysis of Likert-type data, depending on whether the categories are assumed to be equally spaced intervals, and if so whether the data can be assumed to be Normally distributed or not [11]. Here, we follow the lead of the UK's National Student Survey, where positive answers (e.g. "agree" and "strongly agree") are added together and expressed as a percentage "satisfaction" score.

Tutorials:

		1	2	3	4	5	
How many did you attend?	None						All
How useful were they academically?	Very useful						Not useful
How useful were they for personal development?	Not useful						Very useful
How relevant were they to taught material?	Highly relevant						Not relevant
How did they prepare you for scenarios, minors, etc?	Not at all						Fully
How useful were they for internships, careers advice, etc	Very useful						Not useful
How stimulating were tutorials?	Very						Not at all
Do you have sufficient academic support?	Yes						No
Do you have sufficient pastoral support?	No						Yes
Was your tutor available outside tutorials?	Yes						Hardly at all
How valuable are tutorials?	Not at all						Extremely
What is your overall view of tutorials	Very useful						Pointless

Fig 1. The Likert-type questionnaire which students were asked to fill in to assess their opinions of tutorials.

2.2 Student focus groups

Qualitative data provided cross-year focus groups to gain a deeper understanding of students' experiences of the new tutorial system. Five students took part in discussions in the focus groups, which expanded on the questionnaire responses in order to yield more information. One limitation of this study is the small number of students taking part in the study due to scheduling conflicts. While the number is small, our findings provide an initial cross section of feedback to be studied further.

3 RESULTS

3.1 Questionnaires

22 students completed the questionnaire for the single-year tutorials and 28 for the integrated tutorials (in the latter, 14 were from year 1, 8 from year 2 and 6 from year 3). The satisfaction scores (percentage of scores of 4 or 5) are given in Fig 2. Similar questions (e.g. Q11 and Q12), and another set of questions which on the same sheet but which were not intended to test for differences between the tutorial systems, had an average absolute difference between the systems of 7%, so this was taken to be a measure of the uncertainty and any differences between the years of greater than 14% was deemed worthy of further examination. These are highlighted in bold in Fig 2.

Two questions (Q1 and Q10) were rated more positively under the old single-year tutorial system, and the remainder were more positively rated under the new system. All of the changes >14% corresponded to improvements of the new system over the old one, with the average difference over all questions being 12%. Attendance was similar across both systems.

	Tutorials	Single-year tutorials	Integrated Tutorials
1	How many did you attend?	91	86
2	How useful were they academically?	**18**	**46**
3	How useful were they for personal development?	55	57
4	How relevant were they to taught material?	23	27
5	How did they prepare you for scenarios, minors, etc?	55	46
6	How useful were they for internships, careers advice, etc	**36**	**75**
7	How stimulating were tutorials?	**41**	**57**
8	Do you have sufficient academic support?	**62**	**86**
9	Do you have sufficient pastoral support?	**50**	**82**
10	Was your tutor available outside tutorials?	91	82
11	How valuable are tutorials?	45	54
12	What is your overall view of tutorials	52	61

Fig 2: Percentage satisfaction scores for two tutorial systems, with notable differences highlighted in bold

3.2 Student focus groups

When students were asked what is beneficial about the integrated tutorial system, their responses could be placed in two categories: academic and personal. Academically, students appreciated learning about modules and getting advice from students in other year groups. They saw other students as an unbiased source of information about modules and assignments. Personally, they saw the integrated tutorial as an opportunity to meet other students in the programme; it encouraged conversations between year groups and provided informal pastoral support. They particularly appreciated meeting like-minded students working in the same field.

Students suggested academic improvements that will be taken in to consideration (*e.g.* “more opportunities to talk to students from other year groups”), as well as practical issues around timetabling and very specific suggestions such as more assistance with writing job and internship applications. They particularly appreciated sessions that described practical engineering opportunities such as options for internships.

Overall, they felt that the integrated tutorial system led to more discussion among students, but a minority, particularly third-year students, felt that a reduced proportion of the time spent in tutorials is relevant to them, as much of the content might be relevant to students in other year groups.

4 DISCUSSION

On the whole, students preferred the new integrated tutorial system to the original single-year tutorials. However, their reasons were not those that we anticipated when we introduced it. The original aim was to provide students coming to the end of their degree with a comparison so that they could see how much they had learnt. This did not appear to be seen as relevant by either the questionnaire responses or the focus groups. Indeed, the main advantage was seen to accrue to new students who appreciated the opportunity to engage with and learn from more experienced students.

The results of the questionnaire showed that students did prefer the new system and felt it offered improved pastoral and academic support. They also felt that integrated tutorial conversations offered better advice on careers and internships. One of the strongest responses from the focus groups agreed with the response to Q7, namely that the tutorials were more stimulating because students engaged in conversation with each other. It is clear that students see the supportive, affective aspect of tutorials as very important – academic and pastoral support gained the highest satisfaction rating of all the questions. This aspect of community has been described in the literature [1,4,7] but its importance is perhaps under-recognised by practitioners.

There were substantial practical difficulties with the integrated system, mainly due to the challenging requirement to timetable sessions when students from all year groups can attend. It is also necessary to give more thought to planning and co-ordinating each session to ensure relevance to all students and so that all students receive a similar experience.

Advantages to staff of the new system include the transfer of expertise from tutor to student. The tutor's role has moved from being the source of information to a facilitator, encouraging students to discuss and solve problems themselves. This reduces the programme-specific experience needed for staff to get involved in tutoring and allows a wider range of staff to get involved.

One interesting suggestion which came from discussion with students is to allow them more influence over what topics are covered in tutorials. We will continue to develop our tutorial programme and encourage students to take an active role in planning tutorials as well as engaging in them.

5 SUMMARY

We have reconfigured the tutorial support system in an undergraduate engineering degree programme so that each tutorial group includes students from all years. Results demonstrated that overall students preferred the new tutorial system, though newer students were more in favour than students coming to the end of their programme.

We propose to continue to develop the integrated tutorial system, taking account of students concerns and suggestions as we do so.

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Same same but different:
Student views on the level of lecturer English and comprehensibility

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ABSTRACT

English Medium Instruction (EMI) is a commonly accepted and adopted approach to internationalization of universities. Internationalization involves both staff and students, as they both tend to benefit from the use of English in courses. This study compares two video-recorded lectures in an engineering master's program. These lectures were transcribed and student feedback was collected on paper-based questionnaires immediately after attending the recorded lectures. Students were asked to evaluate both their own English competency (self-evaluation) and their lecturers' English competency. This paper focuses on whether 1) the lecturer's English competency key to students' comprehension and 2) there is a link between student's English competency and their comprehension of these lectures.

The results indicate that the lecturers' English competency, as evaluated by the students, for these two lectures was almost identical. Despite this, the comprehension level of these lectures was notably different. Nevertheless, students' self-evaluation of their English competency did not appear to be a distinguishing feature regarding lecture comprehension. Closer examination found more use of interactional features in the better comprehended lecture. While research is attempting to find the "good enough" level of English, the lecturers should focus on implementing enough interactional features when lecturing for better comprehension of their lectures.

Conference Key Areas: Engineering Education Research, Skills and Engineering Education, Curriculum Development

Keywords: English Medium Instruction, English competency, lectures

INTRODUCTION

English Medium Instruction (EMI) is a commonly accepted and adopted approach to internationalization of universities. Internationalization involves both staff and students, as they tend to benefit from the use of English in courses. These benefits may not be evident at the point when lecturers are converting and developing their courses and their materials into English and, especially at the beginning of EMI, need to use more time on course work than when doing it in their native languages. What level of English, then, is "good enough" for lecturers? Students, naturally, have to take TOEFL or other standardized exams to show their ability to study in English before acceptance to a study program. Usually lecturers are not required to do so, especially if they already have their permanent positions and if they have established themselves as experts within their field of study.

Since acquiring knowledge on EMI in engineering education, [1] found benefits, such as more immediate and concentrated focus on the subject matter as well as concentration in general, for lecturers and students. The present study compares two video-recorded lectures in an engineering master's program. These lectures were transcribed and student feedback was collected on paper-based questionnaires immediately after attending the recorded lectures. Students were asked to evaluate both their own English competency (self-evaluation) and their lecturers' English competency. This paper focuses on whether 1) the lecturer's English competency is a key to students' comprehension and 2) there is a link between student's English competency and their comprehension of these lectures. The study attempts to see what other issues may influence the level of comprehension, although it avoids a more thorough linguistic analysis as that would be beyond the scope of this particular conference.

1 INTERNATIONALISATION, ENGLISH, AND COMPREHENSION

1.1 International universities

Currently, most European universities (of technology) have much of their courses offered in English [2]. It is one way to attract both international staff and students which is evaluated positively in the university assessment in reference to the level of internationalization of the university. When this trend was initiated at the beginning of the current millennium as part of the Bologna process[1], discussions varied from students not being able to learn through English to how they will learn both the subject matter and English simultaneously. Some student unions highly criticized the courses being offered in English only rather than in both English and in the major native language of the university in question.

Today Master's Programs in English are the norm and even some Bachelor's Programs, or at least courses, are operated in English in countries where English is not considered the native language. Despite this, many non-native English speaker lecturers still feel unsure of their language abilities and have concern whether their students understand them when they use their "broken English" in lecturing.

1.2 English as a Lingua Franca (ELF) and lecturing

Lingua francas have been used at least from 1200's when the Arab-speaking traders had to communicate with "Franks", i.e. the Europeans to conduct business. The developed "language of the Franks" (=lingua franca) enabled these business transactions to occur [3]. Since this original *lingua franca*, the term has been reserved to those native languages which are used as a vehicular language in situations where no other common language is found.

According to Seidlehofer [4], non-native speakers of English use ELF mostly with other non-native speakers of English. These non-native speakers of English have outnumbered the native speakers already for decades [5], [6] and English is the language of science, academia, business, and (popular) culture. Usually the situations in which English is used, are high-stakes situations in which participants aim at comprehensive communication regardless of the potential obstacles.

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[1] See, e.g. http://www.coe.int/t/dg4/highereducation/EHEA2010/BolognaPedestrians_en.asp#P132_13851

Lecturing is a good example of a high-stakes situation and, no matter what we may think of the efficiency of lecturing as pedagogical means to learning, still a major part of instructional activities at universities [7]. With the internationalized universities, these lectures are most often held in ELF with audience whose native languages vary. In addition to the most obvious function of a lecture, relaying information, it also has other functions, such as focusing on a common goal, preparing for working life, as well as socializing students into the scientific community and even preparing them for working life [8], [9], [10].

1.3 Lecturing and Comprehension

Measuring comprehension is a difficult task. Tests, if designed properly, show what students know. The testers cannot know, however, where and how this knowledge was acquired and whether that knowledge relates to comprehension of prior lecturing.
What is known, though, is that reading written text aloud is usually more difficult to comprehend than spontaneous spoken language [11]. This explains the promotion of the so-called conversational style lecturing [12] – also called fresh talk [13] and open style lecturing [14] – in order for the audience to be able to follow and comprehend the lecturing. This type of lecturing is close to spoken language rather than written text and even allows better activation of the audience, another means to aid comprehension.

According to [15], lectures in the English-speaking universities are becoming less formal and more interactive and the role of the lecturer is more of a facilitator. [16] recommend lecturers to encourage their students to be active rather than passive. These approaches, regardless of the language used in lectures, helps students to comprehend the lectures.

When lectures are in English, which is neither the lecturer's nor the student's native language, the assumption is that communication is not very fluent. Nevertheless, [17] and [18] found that ELF speakers tend to use communication strategies to explicate their message. This, in addition to other EMI features would support the learners when attending lectures conducted in English as a *lingua franca*. In other words, lecturers may subconsciously be using strategies to help their audience to comprehend their messages.

2 CASE STUDY ON LECTURES IN ELF

2.1 Background to the study

When universities modify anything, very often the first reaction of both staff and students is resistance to changes. When a Master's Program is reformed to be in English instead of the native language as it used to be, opposition is evident. Seasoned professors together with students who had been studying their Bachelor's Degree towards that particular Master's Program only to hear they will have to use English instead of their native language created a somewhat tense situation.

In order to determine students' perception of the new situation and the use of English, 22 lectures were video-recorded 2005-2006[2] with student feedback on paper-based questionnaires collected after each of these lectures [19]. Specific lectures were later chosen for closer scrutiny and transcribed. This paper focuses on two of the transcribed lectures and explores the feedback gathered on them.

[2] The material was collected over ten years ago and the situation currently may be somewhat different. Nevertheless, data itself is still useful and not outdated and, thus, provides valuable information when studied from various points of view.

Since the study is on a Master's Program in a somewhat small department, the lecture attendance was fairly low. Despite the low number of respondents, the questionnaire answers were able to shed light on the most intriguing lectures which then were studied further. The attendance influences the results of the study mainly in their generalization, but provide student point of view on the situation together with information on lecture comprehension.

2.2 Questionnaire

The entire questionnaire is available as Appendix 1. In addition to the statements regarding the respondent self-evaluated English skills and the perceived English skills of the lecturer, this paper focuses on the statements regarding comprehension listed in *Table 1* below.

Table 1. Questionnaire questions included in evaluation

		Agree	Somewhat agree	Somewhat disagree	Disagree
7.	I understood the contents of the lecture well.	1	2	3	4
8.	I did not understand the main contents of the lecture.	1	2	3	4
15.	It was easy to follow the lecture.	1	2	3	4

Although statement number 15 in Table 1 does not specifically mention comprehension, the ease in which student follows the lecture is seen as relating to the experience of understanding. Students also had to choose what they felt was their own level of English skills as well as those of the lecturer the lecture of which they had attended immediately before filling out the questionnaire. The scale for English skills was excellent, good, fair, and poor.

This paper explores the questionnaire responses and transcriptions of two lectures that were found to be the outliers of the lectures in a larger study [19]. Based on the comprehension values and perceived English skills calculated from the questionnaire responses, lecturers in Lectures 02 and 21, discussed in this paper, had almost identical English skill levels as perceived by the respondents while the comprehension levels differed quite notably. This difference intrigued closer inspection of these particular lectures.

2.3 Results

Lecture 21 had 19 participants, one of which did not complete the questionnaire completely and had to be disregarded. Lecture 02 had 9 participants, all of whom completed the questionnaire. The numbers are used only to show trends and to provide some basic information, naturally this is not a quantitative study as the quantities are so limited. Nevertheless, numbers and their analysis shed light on how students as a group of respondents reacted to the questionnaire statements.

Table 2 below shows the respondents viewed their own English skills and their lecturers' English skills. The group of respondents is different in these two lectures, but the responses regarding English skills is quite similar.

Table 2. Perception of English skills in two lectures

Lecture 21

Responses	Student Own English skill	Lecturer English skill
2	Excellent	Fair
6	Good	Good
8	Good	Fair
1	Good	Poor
1	Fair	Good

Lecture 02

Responses	Student Own English skill	Lecturer English skill
1	Excellent	Good
2	Good	Good
3	Good	Fair
1	Good	Poor
1	Fair	Fair
1	Poor	Fair

Most of the students self-evaluated their own English skills as being "good" while the English skills of these two lecturers were mostly assessed as being "fair". In Lecture 02, one student perceived their own English as "poor" while perceiving the lecturer's English skills as "fair".

Lecture 22 also had one student with "fair" skills but in this lecture the lecturer's skills by this student were perceived as "good". In Lecture 02 both the participants and the lecturer's English skills were perceived slightly worse than in Lecture 22. In both lectures those students who evaluated their own English skills being lowest in the group ("fair" or "poor"), both perceived their lecturer's skills one category higher than their own. However, those students who had self-assessed their own skills as "excellent" perceived their lecturer's English skills at least one category lower than their own ("good" or "fair").

How do the English skills reflect on comprehension of these lectures? Table 3 below shows participant responses to the chosen comprehension-related statements and the findings show more differences than those regarding English skills.

Table 3. Comprehension-related responses of lectures in percentages

		Agree	Somewhat agree	Somewhat disagree	Disagree
	Lecture 21				
7.	I understood the contents of the lecture well.	61	39		
8.	I did not understand the main contents of the lecture.			6	94
15.	It was easy to follow the lecture.	44	50	6	
	Lecture 02				
7.	I understood the contents of the lecture well.	22	56	22	
8.	I did not understand the main contents of the lecture.	11		22	67
15.	It was easy to follow the lecture.	22	45	33	

The first statement*, "I understood the contents of the lecture well"* had no respondent in Lecture 21 even somewhat disagree while 22% of the respondents somewhat disagreed with that statement in Lecture 02. Furthermore, even those respondents who were on the positive end of the scale, in Lecture 02 more "somewhat agreed" rather than agreed. This indicates the comprehension rate was notably higher in Lecture 21.

None of the respondents in Lecture 21 "agreed" or "somewhat agreed" on *"I did not understand the main contents of the lecture"* while 11% of the respondents in Lecture 02 "agreed" with that statement. In Lecture 21, 94% of the respondents disagreed with this statement and in Lecture 02 this number was 67%.

Statement *"It was easy to follow the lecture"* divided the respondents' opinions more in Lecture 02 where the responses are fairly evenly spread between "agree", "somewhat agree" and "somewhat disagree". In Lecture 22 only 6% of the respondents "somewhat disagreed" with that statement and 56% somewhat agreed.

Based on these responses, Lecture 21 can be viewed as a better comprehended lecture, although the English skills of both of the lecturers were assessed to be quite similar.

As with any study, outliers raise interest. In both explored lectures, there were those respondents who assessed their own English skills lower than those of the lecturers. When looking at their responses regarding comprehension, the responses are identical and not at the far ends of the scale. Both agreement and disagreement were "somewhat", as Table 4 indicates.

Table 4. English skills vs. comprehension

Lecture	Own English	Lecturer English	Understood well	Did not understand	Easy to follow
21	Fair	Good	2	3	2
02	Poor	Fair	2	3	2
21	Excellent	Fair	1	4	2
02	Excellent	Good	1	4	1

Scale: 1=agree, 2=somewhat agree, 3=somewhat disagree, 4=disagree

When looking at those respondents who assessed their own English skills as excellent, both felt they understood their lecturers well and disagreed with the *"did not understand"* statement. The respondent who perceived the lecturer's English skills as "Fair", found that lecture somewhat easy to follow while the respondent in the other lecture, who assessed the lecturer's English as "Good", found that lecture easy to follow.

These results indicate that the English skills of neither the lecturer nor the student. This demonstrates that comprehension at this high level of abstraction is based on many aspects of the message as well as on the participants' prior knowledge on the particular subject.

Although beyond the scope of this paper, it has to be mentioned that the transcriptions of these lectures show differences in how the subject matter was discussed in them. Lecturer in Lecture 21 was able to narrate and create a story rather than just stating facts. This lecturer also used many interactional features during lecturing to make the audience think about the subject: questions, repetition and directives[3] helped in that.

[3] statements such as "You have to remember!"

3 CONCLUSIONS

3.1 Research questions – answers?

As the results shown above indicate, lecture comprehension is dependent on other issues than English skills. The questions this paper set out to explore: whether 1) the lecturer's English competency is a key to students' comprehension and 2) there is a link between student's English competency and their comprehension of these lectures, thus have to be answered simply with "no" to both of them.

Nevertheless, it would be worth a further study to see what makes students evaluate their own English skills as "poor" or "fair" when they are using their English to study highly complex issues at a highly abstract level. What makes students' language identity [19] to be lower than what it actually is and is there a way to improve that self-image regarding English skills?

Another question is, whether lecturing should still be part of university studies. Similar aspects that influence lecture comprehension, however, are in effect also in any on-line materials, even when technology is called on to solve these issues.

Further studies on various aspects of comprehension and on English in Academia are needed as the way universities operate is constantly changing. Despite these changes, lectures have remained almost identical throughout decades – should they be modified somehow?

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Appendix 1: Questionnaire

Please circle the correct alternative or write your answer in the space reserved for it.

1. I am 1 Male 2 Female
2. I was born (year) ____________
3. My native language is 1 Finnish 2 Swedish 3 Other, specify ____________

Please circle the most appropriate alternative. One response per question.

4. I speak English
   1 Daily
   2 Weekly
   3 Sometimes
   4 Hardly ever
5. I acquired English
   1 At school (general studies in native language)
   2 In an English-speaking country
   3 In a school where teaching was in English (with native language surroundings)
   4 Elsewhere, specify ____________
6. The level of my English skills in my opinion is
   1 Excellent
   2 Good
   3 Fair
   4 Poor

The following questions pertain to the lecture you just attended.
Please circle the alternative corresponding to your opinion.

		Agree	Somewhat agree	Somewhat disagree	Disagree
7.	I understood the contents of the lecture well.	1	2	3	4
8.	I did not understand the main contents of the lecture.	1	2	3	4
9.	Most of the lecture remained unclear to me.	1	2	3	4
10.	The atmosphere during the lecture was relaxed.	1	2	3	4
11.	The atmosphere during the lecture encouraged to question and to discuss the topic.	1	2	3	4
12.	I would have understood the lecture better in my native language.	1	2	3	4
13.	The topic of the lecture was so challenging that the language used would have not influenced my understanding of the lecture.	1	2	3	4
14.	The contents of the lecture were presented logically.	1	2	3	4
15.	It was easy to follow the lecture.	1	2	3	4
16.	The contents of the lecture remained secondary since I concentrated on the language so much.	1	2	3	4
17.	It was difficult to follow the lecture, but it had little or nothing to do with the language used.	1	2	3	4
18.	I felt uneasy for the lecturer while he/she lectured in English.	1	2	3	4

19.	I would prefer a native-speaker of English as a lecturer.	1	2	3	4

The following questions pertain to the lecturer's English skills.
Please circle the alternative(s) corresponding to your opinion.

20. The lecturer's language skills in my opinion are
    1 Excellent
    2 Good
    3 Fair
    4 Poor

21. The lecturer's language skills lack in
    1 Vocabulary
    2 Fluency
    3 Intonation (=melody of speech)
    4 Pronouncing single sounds
    5 Other, specify ___________________

22. Further comments:

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Thank you for your responses and for your help!

Improving students' critical thinking and communication skills

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ABSTRACT

University engineering faculties, professional engineering institutions and industry increasingly recognize that higher education should support students to develop key professional skills such as critical thinking and communication skills. This paper examines three activities aimed at teaching these skills, i.e. practical open-ended group activities; discussion with experts or as experts; and peer assessment. These methods were assessed in terms of student and staff opinions, but also practicality. Our research indicates that it is beneficial to integrate and balance these three types of activities within engineering degrees as they complement each other. Our findings and conclusions can be applicable to any engineering degree, whether the aim is to incorporate the teaching of these skills in a small activity within a module or a full programme of studies.

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Conference Key Areas: Engineering skills, Continuing Engineering Education and Lifelong Learning, Curriculum Development.

Keywords: critical thinking, engineering skills, peer assessment, research-based education.

INTRODUCTION

Engineering employers expect graduates to have a good knowledge of their field of study, as well as workplace skills such as critical thinking and communication skills [1,2]. Universities and professional engineering institutions increasingly recognize this need and incorporate the development and assessment of professional skills within their accredited curricula [3-6]. In general, practitioners acknowledge that these skills must be built over time, and therefore must be integrated throughout the programme of study. Different methods are used in the literature. This paper focuses on 3 generic overarching teaching methods, i.e. (i) open-ended practical activities and research based education, (ii) discussions with a range of experts and sectors, and (iii) critically analysing other students' work with peer assessment.

Open-ended practical activities and research based education provide students with "real-life working scenarios" where they apply and reinforce their technical knowledge, critical thinking and problem solving skills, as well as communication and team work. Employers are looking for graduates with this type of experience [2]. Students often find these activities challenging but often engage and learn with them.

Engineering students benefit from interacting with a range of audiences and experts, preparing them to communicate effectively in a range of roles relevant to industry, such as speaking with clients, experts, peers, etc. [1,2]. Furthermore, dialog with experts within and beyond academia challenge the students and supports their critical thinking development; while taking the expert role and engaging with less technical audiences -e.g. peers and junior students- develops their confidence and knowledge further [7].

Finally, peer assessment is increasingly applied in higher education because it enhances students' learning and development of critical skills [8,9] among other benefits [10,11]. However, there are concerns that students may not engage with peer marking [9,12] and may not trust peers to make fair judgements [12]. This can be mitigated by using the 360-degrees peer-assessment method (360PA) where students are assessed in part on the quality of feedback that they provide [13]. The use of peer assessment gives the students an opportunity to learn how to express feedback in a constructive and tactful way.

This paper describes and compares these three different educational activities to foster the development of critical thinking and communication skills. Evidence was obtained from teacher observations, discussion with teachers and student, and anonymous questionnaires filled out by students. Some examples of implementation and final recommendations to practitioners are provided.

1 PROJECT METHOD

1.1 Overview of activities incorporated within the programme

A range of "non-traditional" activities were incorporated within the BEng Biomedical Engineering programme (BME) (https://goo.gl/pfMTPa), part of the Integrated Engineering Program at UCL, UK. These complement traditional lectures, tutorial sessions, and traditional practical sessions often incorporated within modules where students carry out a set of defined instructions, e.g. an experiment, or certain routines in a piece of software. We investigate activities grouped into three general categories:

(A) Open-ended group activities: These are long practical activities where students are presented with a problem that they need to solve, or a research question that they need to investigate, but are given freedom in what the end-product should be or how to reach it, hence 'open-ended'.

We examine various instances of these open-ended group activities: (i) six so-called 'scenarios', which are one intensive full week activity covering a range of topics such as programming, electronics, mechanics, design, etc; (ii) research activities, typically spanning up to a term, where each group defines and solves its own research question, e.g. first year students investigate the mechanical properties of a material using the Instron E3000 [14], and present their results via poster in a conference-type setting; (iii) large design group project in the 3rd year.

(B) Discussion with experts or as experts: Meaningful learning requires that students are not passive receivers of information. Academic discussion with lecturers is a common practice in Higher Education and an excellent way of challenging students, widening and reinforcing their knowledge. Additional approaches investigated in this paper, are: (i) frequent exposure of students to non-academic experts, e.g. from industry or the health system including visit and shadowing clinicians at hospitals, and patients; (ii) students present and discuss their results to a range of experts in the field as part of the assessment; (iii) students are encouraged to engage with younger students and act as experts, e.g. supporting the teaching in a given practical, or discussing and giving formative feedback to 1st year students.

(C) Peer assessment (PA): PA is used in many modules across the degree, in a range of assignments such as reports of experimental work, video, a section of the final year project dissertation, presentations, and mathematical assignments.

1.2 Assessment of impact by students

Third year students were invited to complete an anonymous questionnaire. This questionnaire looks at how confident students are with respect to 4 specific skills, defined as S1 to S4 below, if they developed such skills since the start of their degree, and how the types of activity A, B and C (as defined in section 1.1) contributed to such development. All questions have a 5-point scale. Student's quotes are also provided. The skills investigated were:

- S1: Critical thinking
- S2: Communication with a range of audiences and different situations
- S3: Critically analyse someone else's work
- S4: Constructing feedback for peers or junior students.

1.3 Assessment of impact by staff

Similarly, interviews were conducted with members of staff to investigate the effect of activities A, B, C on the development of students' S1-S4 skills. Those staff members selected had contact with the students at different years during their degree. They were asked the following questions:

- Since the students started their degree, have you observed an improvement in their abilities with regard to S1, S2, S3 and S4? :

- If so, how did you observe these changes?
- What do you think has caused these changes?
- Have students changed their approach to scenarios?

1.4 Other factors

Also considered in the assessment is staff time and resources needed.

2 RESULTS

Students' feedback via questionnaires is presented in *Table 1*. A sample of students and staff point of view on these three activities is given in *Table 2* and *3* respectively.

Table 1. Third year students' responses to questionnaire (N=9, 90% of the class). Scale: 1- not at all, 2- not very, 3- fairly, 4- significantly, 5-very. Mean (SD)

	S1	S2	S3	S4
Current confidence in your ability?	3.9 (0.7)	3.9 (0.7)	3.7 (0.5)	3.9 (0.6)
Has it developed during your degree?	**4.4 (0.7)**	**4.1 (1.0)**	**4.2 (0.7)**	**4.1 (0.8)**
Has this type of activity helped you to develop it? (A) Open-ended group activities	**4.1 (1.1)**	**4.7 (0.5)**	3.7 (1.1)	**4.0 (0.7)**
(B) Discussion with experts or as experts	**4.4 (0.5)**	**4.3 (0.9)**	3.2 (1.3)	3.7 (0.9)
(C) Peer dialog and peer assessment	3.1 (1.3)	3.0 (1.1)	**4.0 (0.7)**	**4.0 (0.7)**

Table 2. Quotes from students (representative sample)

Student 1: *"Open ended activities have helped me improve my skills in communicating with team members and motivating each other to work well together to produce a good piece of work, towards a strict deadline. It's really helpful as it helps you understand what it's like to work in a team environment, especially for working in companies in the future.* *Discussion with experts helped me to improve my communication skills also, especially learning to be empathetic towards patients and what examiners want.* *Peer assessment helped me learn how to critically analyse someone else's work and ensure I give good feedback, as well at utilising the feedback I was given."*
Student 2: *"Discussion with experts: Good for constructing feedback as you learn the opinion of people with experience in a particular area, and you can apply this to your feedback for others. […]* *PA: Gives you more time to think about how to word your feedback, but quite frustrating if those who are giving you feedback do not put effort into it."*
Student 3: *"Being pushed to engage in the activities [A, B, C] meant there was a need to refine my skills in these areas."*
Student 4: *"[…] I think my critical thinking was developed most with the expert discussions as they would ask questions that make you think deeper about the topic, which I found challenging but good.[…]"*
Student 5: *"Open-ended group activities such as scenarios have greatly improved my critical thinking skills to solve new problems in a creative way. They have also improved my communication skills when working in a team with colleagues, lecturers and area experts. […]*

PA activities have improved my ability to construct feedback and shows you how other people think which can improve the way you critically think yourself.   *[Recommendations for the future] Continue to combine the talks with experts with the open-ended group activities. Peer assessment is helpful but is also time consuming […]. All these activities [A, B, C] are important and should be incorporated in the Biomedical degree."*

Table 3. Quotes from members of staff (representative sample)

EH, Laboratory Technician, supports students during practical activities and scenarios in years 1 to 3:   *"Yes, [I have observed an improvement on the students' abilities to S1 and S2].*   *S1: Students were made to think critically of their strategy in Scenario 2. [At the end] the students were asked to contribute one thing they had learnt […], some students were incredibly reflective realising their downfalls in planning at the beginning led to a poorly constructed investigation.*   *S2: Throughout scenarios students have needed to present their work to scenario leaders and experts, […] work as teams and communicate their ideas effectively. I have seen students greatly improve their ability to work in a team; some students start the first year scenarios afraid to speak their opinions to their team mates and are more confident in doing so by the scenarios in the second year.*   *[In] scenario 6, students get to experience contact with a 'patient' to test their device, this gives them chance to learn a vital skill in communicating at a completely different level to the common student- teacher interactions […].*   *In general: For some students failure has been the predecessor for change, learning from mistakes of previous scenarios.[…] By the second year students become much more familiar with the concept of scenarios and how to deal with them, they are happier with the freedom to plan and construct their own ideas. They do not ask for help as much, they come up with ideas within their groups and do not need constant affirmation."*
JG, Principal Teaching Fellow, lecturer in year 1 and lead of 2 scenarios: *"S1: It's difficult to say as I see just a snapshot of them. However I believe that the students' critical thinking improves during the week of the [3rd] scenario when they have to actively problem solve in order to get to the end point.*   *S2: Communication definitely improves throughout. First year students are usually quite nervous about presenting, but by the time they get to the [5th] scenario, they are almost all confident about presenting to what is actually quite a scary audience.*   *S3: Again, I've not seen the students analyse much of other's work – just really in Dragons den. This year, a couple of groups were able to comment on and consider whether or not they actually believed that the technologies given to them would be good in the market place. It takes a certain amount of confidence to speak up when presented with an academics' research work.*   *S4: I've not had the opportunity to see this in action.*   *In general: Giving them opportunities to attempt all these skills regularly, combined with a mixture of feedback and constructive praise [is what has caused this development on the students]."*

3 DISCUSSION

Engineering students and staff (including the authors of this paper) believe in general that the types of activities under study (A, B, C) did help to develop critical thinking and communication skills (S1-S4) of engineering students. A comparison between the 3 types of proposed activities is summarized in *Table 4*, and discussed below.

Type A activity, i.e. open-ended practical activities, seems to give the engineering students the chance to use - and the need to develop - the full range of skills (votes range 3.7-4.7/5) in general, and are recommended by staff for the training/learning they provide. According to the student questionnaire, S3 (critically analyse someone else's work) is perhaps the skill accomplished to the least degree with this activity, demonstrating that although students are working and assessed in groups, they are still not ready/inclined to analyse and criticize the work of their peers. But overall, the students enjoy and appreciate open-ended group activities. For instance, during one open-end research activity the 1st year students (N=23) claimed that they learnt a lot (mean vote = 3.8/4), and that it was a valuable learning experience towards their future (mean vote = 4.0/4). However, setting up, resourcing and running this type of activities can be highly time-consuming and costly.

Type B activity, i.e. discussion with or as experts, is very popular among students, getting a high mean score for S1 (4.4/5) and S2 (4.3/5). Students learn how to critically analyze and interpret information by discussing with experts (lecturers, researchers, industry, medical doctors), and learn to communicate with different audiences (including non-technical people e.g. patients). Part of this is done within classes and support sessions, which it is the least time-consuming and most economical option. However it is also good for the students to have the chance to share their thoughts with experts while working on engineering (open-ended) projects. These personal discussions are of high value as the student has a good understanding of the project at hand, allowing the questions/discussions to be deeper. If organized into timetabled sessions, these one-to-one discussions are feasible. However, the total number of staff hours increases with the class size.

Type C activity, i.e. peer dialog and peer assessment, seem to address the development of skills S3 and S4 according to the students, with scores of 4.0/5 in both cases. Many students see and comment on the benefits of this activity; however some are still skeptical and might not engage with it as much as they should because they consider it as something extra rather than part of the assignment. The use of the *360 degrees peer assessment method* partially solves this problem, while allowing staff to measure and assess the ability of students to construct feedback. It requires the students to critically analyze the work of their peers and engage with the feedback received – both of which they might not do otherwise even if working in groups! This type of activity is the least sensitive to class size, in fact allowing a large class to get feedback on their work in a relative small amount of time with minimal staff involvement and resources. Staff using this 360PA method thought that the feedback provided by the students was thoughtful, of good quality, and more extensive than that provided by staff [15]. Activities type B and C seem to be complementary to one another.

By the end of the third year of the programme, students were still not quite confident of their critical thinking and communication skills (S1-S4) with scores between 3.7-3.9/5. This is surprising, considering that activities (A, B, C) have been integrated across the programme in part with those aims, but reinforces the need to support the students in the developing of these skills as to be ready for their professional lives. However, it seems that the proposed activities work, with students acknowledging that they have significantly developed skills S1-S4 during their degree (average ranging

4.1-4.4/5). Students' preference and perceived benefits among these activities vary, further supporting that they are used in combination.

Table 4. Comparison of the proposed types of activities

Activity type	Students	Staff	Resources
(A) Open-ended group activities	High engaging, significantly develops skills S1, S2 and S4.	Develops S1 & S2, might help S3-S4 but no evidence. Very useful as training for engineering.	Highly demanding: space, equipment, staff-time for preparation and support
(B) Discussion with experts or as experts	Very useful for S1 and S2	Can be more easily incorporated in different parts of a module. Useful. Students might engage differently.	Staff time: medium No cost or lab requirements.
(C) Peer dialog and peer assessment	Significantly useful for S3 and S4. Not all students like it.	S3 and S4 can be assessed. Prompt and good quality feedback, more detailed than staff can provide.	Staff time: low No cost or lab requirements. Easily scalable with class size.

4 CONCLUSION

This research looked at 3 generic types of activities, and seem to be in agreement with other studies in the literature that claim the benefits of using active learning methods such as project-based learning [3, 5] (type of activity A) and outfacing assessment to High School students [6] (a form of activity B). It also covers the evaluation of peer assessment (type of activity C) that was identified by Llorens [3] as something that had to be investigated.

Our practice suggests that it is beneficial to integrate in the programme a range of practical open-ended and research-based activities, dialog with a variety of experts and sectors, and the use of peer assessment for various elements. A balance between these options is desirable, as the first two are demanding in terms of staff-time and resources, while peer assessment can be more scalable. The combination is able to cover the development of the studied skills, i.e. critical thinking and communication skills. Our approach is relevant to teaching critical skills, either in a small activity within a module or a full programme of studies.

This research should continue to proof its reliability, involving larger classes and perhaps looking at student and staff perception after the 1st and 2nd year of the degree.

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Exploring the Influence of Cohesion on Team Performance Behaviors in Software Engineering Education

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ABSTRACT

Nowadays it is generally recognized that in order to be an effective software engineer one requires skills for performing in a team. Therefore, research on team working skills in software engineering education has been gaining more attention. Most of the studies have focused on how a certain learning-teaching approach impacts team work. Despite these efforts, human aspects haven't had the attention they deserve to better educate software engineering students. This work shows the results of a pilot study in software engineering education related to the influence of cohesion on team performance behaviors. The relation between these variables is looked at through the lens of an IMOI (Input Mediator Output Input) model. Team cohesion acts as a *mediator* to improve team performance behavior *outputs*, whereas the intervention on cohesion is seen as the *input.* After some appropriate training on team working skills, students have to establish team rules on communication and conflict management. We assume that this will improve the team cohesion, and lead to more effective team performance behaviors. Improvement of the rules (*input* again) is then based on tracking the behaviors of individual contributions to the team work. The study presented here was performed in the software engineering program at University of Holguin in Cuba.

Conference Key Areas: Engineering Education Research, Engineering Skills, Curriculum Development

Keywords: team work, software engineering education, cohesion, team performance behavior

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INTRODUCTION

Engineering education is critical for the development of industry and hence of society in general in any country. Preparing engineers for the future, [1] includes training them on technical and professional skills closely related to team work, like project management, leadership and communication skills. The ability to work as an effective member of a development team is a primary goal of engineering education [2] and is also included in the ABET students' learning outcomes criteria for accrediting computer programs [3].

Team work is especially important for software engineers due to the complex socio-technical nature of their profession, broadly recognized by authors like [4]–[7]. IEEE defines software engineering as "the application of a systematic, disciplined, quantifiable approach to the development, operation, and maintenance of software" [8]. Software engineering needs engineers able to play different roles during several tasks, coordinating efforts to achieve coherence in different phases of software engineering process.

Several aspects of team working in software engineering education have been studied. In particular, some authors such as [9], [10] focus on studying team performance. Several measurement instruments have been used; they all put more emphasis on the process results rather than on the behaviors that allow software engineers to obtain team objectives. Cohesion is considered as one of the most important factors that influence software teams. It has been found important for team effectiveness [11], [12], motivation [13], productivity [14], team collaboration [15] and for agile practices [16], [17]. However, cohesion has been scarcely studied in software engineering education and there is not empirical evidence on the relationship with team performance behaviors.

The remainder of this paper is structured as follows: Section 1 describes the framework proposed to guide the study. Section 2 refers to the context of the study, the method of intervention and the results of a pilot experiment. Section 3 concludes the paper.

1 IMOI FRAMEWORK ADAPTED TO THE STUDY

Factors that affect team work are very well known and largely studied in organizational settings. In a review of ten years of research on team effectiveness, [18] stated that all the affecting factors of team work can be studied using an IMOI model. This model describes how all the factors can be related with inputs, mediators or outcomes of the team work process. The authors state that cohesion acts as a mediator whereas team performance is related with the outcomes. Another meta-analysis done by [19] found that cohesion is strongly correlated with team performance when the latter is measured as behaviors. Identifying the input factors for team work in higher education, [20] identified team rules, task agreement, rules agreement and establishment as the most important ones. Taking into account that software engineering methodologies are clearer on task and roles, this study focuses on rules.

Following these statements the IMOI model was adapted to the pilot case in software engineering education at study, as shown in Figure 1.

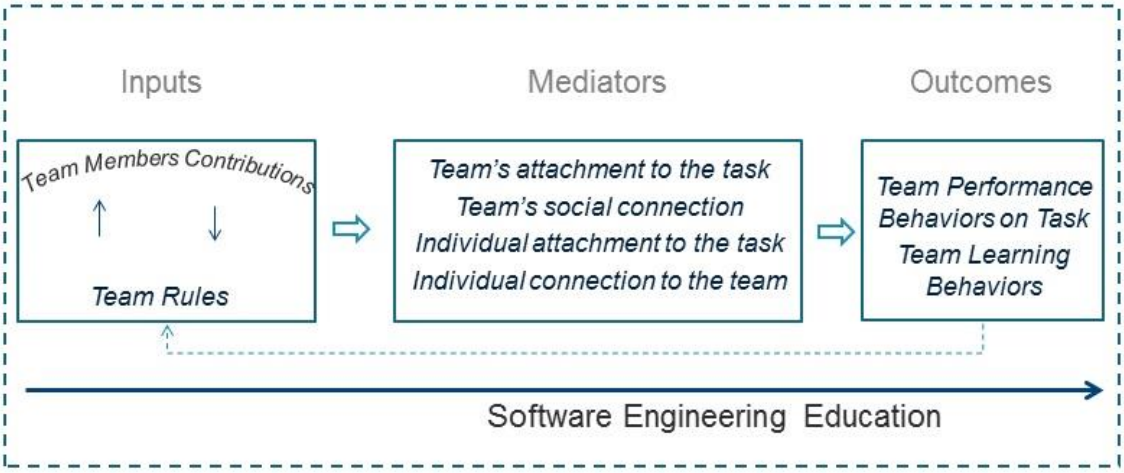

Fig. 1. Model IMOI used in the study

Team rules were established regarding communication and conflicts management. Communication has been postulated important to cohesion by authors such as [21]. [22] stated that communication difficulties decrease cohesion and increase conflicts. Team rules, as input factor, are updated based on team member evaluation of their individual contributions to the team work. Team members' contributions were indeed found highly correlated with cohesion by [23].

The factor team cohesion is considered as the mediator in the model. For the purpose of this study we go back to the conceptualization of [24], applied by [25] to software engineering students. In their vision cohesion can be thought of in two very different ways: the social attachment within the team and the team's connection to the project itself; and at two levels of granularity: at the individual level and for the team as a whole.

The output in the model is established by team performance seen as behaviors related to performance on task and team learning. Team performance is usually measured with indicators for effectiveness and efficiency. However, [18], [19] differentiated between performance behaviors and performance outcomes. According to [18] team performance behaviors are actions relevant to achieving goals, whereas outcomes are the consequences or results of performance behaviors. In this study are observed team learning behaviors as the 'activities carried out by team members through which a team obtains and processes data that allow it to adapt and improve' [26]. Performance on task is assessed according with the degree in which the team satisfies client needs and expectations.

2 STUDY REPORT

Software engineering is one of the most important discipline in the Informatics Engineering bachelor program at University of Holguin. The program taught includes team work applying methodologies while solving real life problems. The students in the study were in the third year of the program, and we observed them in two courses: Software Engineering I and Software Engineering Management. In these courses students learn how to apply the Iconix methodology and manage their software projects working in teams. During three months they had to perform the two first phases of Iconix methodology ‘a requirement analysis’ and develop a ‘preliminary analysis and design’. The rest of the Iconix phases will be studied in a next semester. They also have to organize their team work and plan and track their projects. A total of 34 students were studied. They were performing in 7 teams of 3-6 members.

As can be seen in Figure 2, the intervention by the teacher on the teams consisted of three phases over a period of three months. Teams were formed in the first week of the semester by a self-selection method. At that time an individual diagnosis on team working skills was done with a Team Knowledge Test (TKT) questionnaire, used by [27] to survey software engineering students. After three weeks performing, team cohesion and performance behaviors were measured. Questionnaires proposed by [24] and [26] were used, slightly adapted to educational settings.

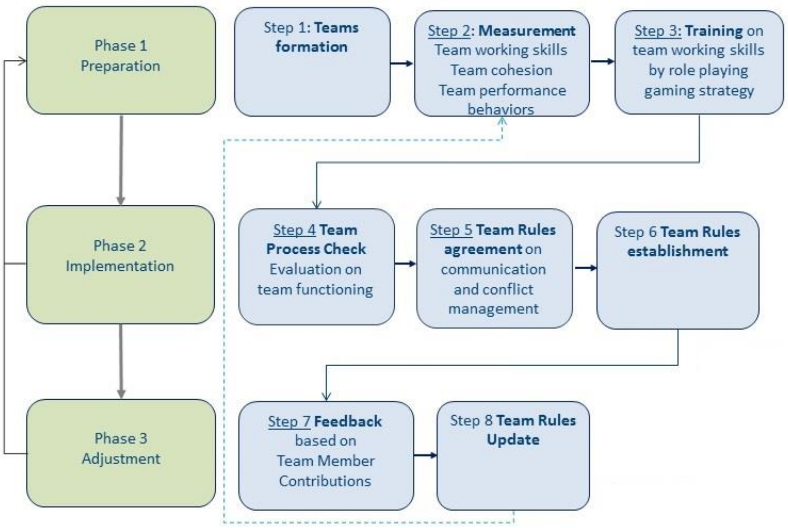

Fig. 2. Method of intervention

The training on team working skills was based on a role playing strategy and it was focussing on communication and conflict management. In order to play different roles, students were asked to fill in the Belbin questionnaire, which allows identifying team roles [28]. Belbin team roles are based on behaviors that individuals adopt when participating in a team. The awareness of those roles could help amongst others, to foster mutual trust and understanding and to build productive workplace relationships. Software engineering roles like analyst, programmer, tester and client were used. Conflict situations were simulated by providing software artefacts and project documents such as a project planning, a list of requirements and several check lists. Student had to solve those situations playing different roles as a software engineer.

After one month working together, students evaluated the functioning of their teams. Using that information and based on lessons learnt from the team working training and their individual diagnosis, they were asked to agree on team rules. The rules were about communication and conflicts management. Some examples of the rules they agreed were: *don’t discuss personal conflicts at work, appoint mediators to manage conflicts, discuss disagreements openly, put all information visible for all,* *listen to all opinions without interruptions, let everybody express their opinions, use blackboard to remember meetings, keep communication frequently with clients,...*

Students were then continuing their team work for one month under these team rules. After that they were asked to self- and peer-evaluate team member contributions. This information assisted as a feedback to update the rules. Team member contributions were evaluated on five areas, according to three levels of team performance behaviors, using the questionnaire proposed by [23]. The areas include contributing to the team's work, interacting with team mates, keeping the team on track, expecting quality and having relevant Knowledge, Skills, and Abilities (KSAs).

At the end of the third month the study was concluded and the same variables as in Step 2 of Phase 1 of the intervention were measured again. A 5-point scale, from "*strongly disagree*" to "*strong agree*", was used. Table 1 shows the overall values for each variable, averaged over the seven teams, before (i.e. three weeks in the study) and after the intervention (i.e. at the end of the study). In the third column we present the delta, and in the last column the p-value after perform a t-student test (using SPSS 20.0).

Table 1. Variables values before/ after the intervention

Variables	$\dot{x}_{Before}$	$\dot{x}_{After}$	$\dot{x}_{Difference}$	**p-value**
Cohesion	3,06	4,09	1,03	0.000
Team Performance Behaviors on Task	3,18	3,96	0,77	0.000
Team Learning	3,09	3,98	0,89	0.000
Team Performance Behaviors	3,14	3,99	0,86	0.000

As can be seen, the overall value all variables had a substantial increment after the intervention. However, during the study it was observed that changes in levels of the two team cohesion dimensions, social attachment within the team and the team's connection to the project itself, didn't show a similar change. It seems that the second aspect had more impact on the overall result for cohesion than the first one. For that reason, further analysis of these different dimensions of team cohesion is needed at the individual level of granularity and for the team as a whole.

3 CONCLUSIONS AND FUTURE WORK

The pilot study presented here shows that team rules on communication and conflict management improve team cohesion, which leads to more effective team performance behaviors. The individual diagnosis and subsequent training on team working skills using a role playing strategy, together with team functioning evaluation, provided the basis to the team rules agreement. The feedback obtained by team member's contribution assessment after working under this agreement enabled students' recognition of changes needed on the rules and allowed them to update their team rules agreement. Future work will explore in more detail how the intervention as described in this paper affects the different dimensions of team cohesion and how they impact the team performance behaviors.

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Designing an Integrated Approach to Realizing Communicative Self-Efficacy in Engineering Communication

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ABSTRACT

Abstract

Given the escalating demands for “work-ready” undergraduates plus the heavy workload of engineering faculty and students, adding effective communications instruction to the engineering curriculum is a significant challenge. In response to that challenge, the Sibley School of Mechanical and Aerospace Engineering (MAE) and the Engineering Communications Program (ECP) at Cornell University have begun to develop a new communications curriculum. The new curriculum has two components: 1) partnering a sophomore-level mechanical engineering course teaching mechanical design principles with an engineering communications course; and 2) integrating focused communication units in select junior and senior level MAE courses. Our aim is twofold. First, we hope that partnering these two courses will offer a more impactful and expertise appropriate way to deliver communications instruction. Second, we also hope that implementing a coordinated communication-across-the-curriculum (CxC) effort will better meet the needs of students, faculty, the college and industry.

This new (and still developing) curriculum, named the “MAE/ECP Engineering Communications Initiative,” is a collaborative and cooperative enterprise encouraging the development of students' communicative self-efficacy (CSE) across a range of engineering communicative genres. Four foundational concepts are our benchmarks: communication as social action, the importance of context, communicative design, and engineering identity. Both the partnering and coordinated communications modules are continually assessed through a multi-year, mixed-methods research program. The first years’ quantitative findings for the communications course show noteworthy increases in CSE, with the second year’s quantitative findings reportable by conference time.

Conference Key Areas: Engineering Skills, Curriculum Development, Engineering Communication

Keywords: Engineering Communication, Communicative Self-Efficacy, Curricular Integration and Assessment, Educational Research

Introduction

Engineering communication is ubiquitous in the lives of professional engineers and engineering students alike. Recent surveys indicate that engineers spend between 40 and 60 percent (and more) of their workday engaged in communicative activities [1-4], and anecdotal reports suggest an even higher percentage. And while many admit that effective communication is a core skill set of any adept engineer, too frequently curricula siphon off communication skills into a less-than category, too often called "soft skills," hinting (sometimes declaring) that other engineering skills are harder and more valued.

We challenge that thinking at its very core in our work teaching engineering communication inside a US college of engineering. Almost all job postings for entry-level engineers require "excellent communication skills, both written and verbal." Beyond entry-level jobs, employers assume good communication skills are in place, and people who rise quickly through the management ranks tell us that it is their communication skills that make them stand out. As well, experienced engineers or engineering managers often highlight not only the relevance of communication, but also the diverse range of communicative actions that they must perform in order to get work done. [5].

The challenge of infusing communication skills into technical-leaning courses in any engineering curriculum can be a difficult proposition. Most engineering curricula are already heavily burdened with core courses and specialized, field-specific content; so adding direct and recurring communications instruction to an engineering curriculum represents a significant challenge.

Responding to that challenge, some engineering programs are experimenting with creative and engaging ways to develop communication skills. One such experiment is the fostering and use of teaching "partnerships" that tap into the expertise appropriate skills of the technical specialist/engineering instructor and the technical communication instructor respectively. With these kinds of positive partnerships, course content can realign towards "socially situated [technical ***and*** professional] practice" [6], while also possibly reducing workload for that engineering instructor. The Sibley School of Mechanical and Aerospace Engineering (MAE) and the Engineering Communications Program (ECP) in the College of Engineering at Cornell University are actively facilitating the formation of such a partnership.

We discuss our theoretical and pedagogical underpinnings, teaching approach, and quantitatively report the outcomes of our first year teaching the partnered communications course. By conference time, we will have data to share from our second year.

1 Background: The MAE/ECP Engineering Communications Initiative

The Sibley School of Mechanical and Aerospace Engineering (MAE) currently requires its majors fulfill a college mandated technical communications requirement via its senior level (year 4) capstone lab course. The communication component relies primarily on lab reports and designing visuals. The engineering instructors do successfully empower students to produce good reports and well-designed visuals. However, departmental descriptive surveys, e.g., those involving students, alumni, industry representatives, suggested that MAE needed to do something more to prepare students for workplace and research communication needs. Indeed, MAE openly wondered if there might be a better way.

In search of this better way, the MAE department, in concert with the college's Engineering Communications Program (ECP), identified a number of important needs. Communication instruction should:

- begin sooner in the MAE curriculum; the aim is a coordinated and constant development of communication skills across the curriculum;
- cover multiple modes – written, oral, visual, electronic (WOVE); the intent is to encourage the transfer of communication skills across technical and professional endeavors;
- empower students to experience the integration of technical and professional practice and develop skills such as iterative revision, peer response; they should be ready to learn to learn how and to teach each other;
- build on single set of theoretically established and foundational concepts:
    - **Communicative Practice:** When we communicate, we perform specific social actions. All communication has one or more purposes.
    - **Communicative Context:** Communicative practice cannot be separated from context nor the context from practice.
    - **Communicative Design:** Communication is all about the particulars of design or structure and organization.
    - **Communicative Identity:** Communication creates identity, not only the identity of the one initiating communicative interaction, but also the identity or identities the one or ones being communicated with.

Rather quickly it became clear that to be able to realize these needs, MAE and ECP together needed to create a new MAE communications curriculum and devise a research program for assessment. The core design of the effort is this: one dedicated, engineering communications partnered with a (preferably design) MAE course at the sophomore level; integrated, focused communication units inside select junior and senior courses.

The sophomore communications course, ENGRC 2250, launched in spring 2016, had 20 self-selecting MAE undergraduates enrolled. Quantitative *and* qualitative research was done in parallel. We framed our research question thus:

> *How well can we facilitate the development of communicative self-efficacy (CSE)?*
> Or…more closely drawn:
> *How well can we facilitate in MAE undergraduate engineering students the development of communicative self-efficacy (CSE) through ENGRC 2250 and then foster its continuing development through select junior (level 3) and senior (level 4) courses in the MAE curriculum in a way that transfers to and enables proficient technical and professional communicative practice?*

We propose that the MAE/ECP Engineering Communications Initiative innovates in a number of ways:

1. It offers both a horizontal and vertical curriculum that is theoretically consistent for providing communication instruction. It potentially offers a model for other schools and colleges of engineering.
2. It anticipates and enables learning to learn how in post-graduate technical and professional communication by providing students experience applying those

foundational concepts within different contexts, using multiple modalities (WOVE) and across many genres.

3. It proposes a model program for near- and long-term assessment through locally-situated and emergent educational research.

2 Research mandate, self-efficacy, and methods

Briefly put, we designed our research protocols pragmatically. We needed to study the impact of communication instruction upon undergraduate students in an engineering curriculum. After much work, we formulated an explanatory, sequential mixed methods design, i.e., survey along with classroom participant observation, interviews, and portfolios. All data collection was institutionally IRB approved.

We built our survey around discovering reports of student communicative self-efficacy (CSE). In choosing to do so, we participate in a well-established practice in engineering education. Self-efficacy (SE) measurements capture how well subjects (in this case, undergraduate students) rate themselves as having positive behaviors; consequently, positive behaviors translate into higher-performing practices. In ASEE (American Society for Engineering Education) Proceedings alone, there are over 1400 references to self-efficacy in student engineering practice. The *European Journal of Engineering Education* boasts 70+ articles about self-efficacy in engineering students in the last decade alone. Self-efficacy is an established and useful construct based originally in Social Cognitive Theory [9]. It "refers to beliefs in one's capabilities to organize and execute those courses of action required to produce given attainments" [10], or a "person's awareness of their ability to accomplish a goal" [11]. As a research construct, SE has proven to be a powerful predictor of achievement in general areas– general learning, academic achievement, retention, mathematics – and more specific areas – computing [11], engineering design [12], engineering modeling [13], even tinkering [14] to list just a few. Implementing CSE requires development of a survey instrument, which, although not easy, allows us to generate quantifiable results and to avoid (quite frankly) those prohibitively time- and labor-intensive alternatives for assessing communicative performance. As a result, and along with other possible contributions, our research has the opportunity to offer a model for the development of other similarly focused assessment instruments.

MAE students enrolled in ENGRC 2250 took two identical surveys—at the start and end of term. Also, and for the purposes of comparison, the survey was distributed to other sophomore, junior and senior level students across the larger MAE curriculum at the start of the term. Details on method and data tables of results are at https://sites.coecis.cornell.edu/chec/ecp-research/.

3 WOVE: Actionable and socially constructed modes

WOVE is the acronym for the written, oral, visual and electronic modes of communication. It is an emerging research area for engineering education [5]. For our Initiative, specifically, we focused on the particular genres and those modes most important for undergraduate and sophomore level students enrolled in the MAE program.

WOVE elements do not exist in a vacuum [6]. Lab reports almost always include visuals: graphs, tables, charts, sketches. Engineers and scientists might use LaTex coding to convey equations inside of email. Visuals include strong captions, which involves a specialized style of writing that helps readers decode the graphical input.

Oral presentations bring speech, visuals, writing, and performance together. In truth, it is hard to find engineering or scientific work that exists in just one mode. Indeed, even student project teams thrive in the multimodal milieu: speech, of course, but that communication also involves email exchanges, texts/texting, drawing, and more.

By creating ENGRC 2250, we devised work cycles that encouraged the students to develop facility with each of the isolated modes, but they were also developing facility to combine different modes into a single communicative genre given the modality's relative affordances or potentialities and constraints or challenges.

4 Brief overview of the teaching partnership

Students in the mechanical engineering course are required to design a wind/water pump from basic, inexpensive materials that can move a specific volume of water powered by wind, with constraints for cost, etc. Those pump projects are a stand-alone project; students work in teams and do not have to configure a pump system beyond materials, design, and the ability to move a certain amount of water in a given time in a lab setting.

In order to make the experience in the partnered communications course *more authentic* and to encourage *real mastery experiences* (the most significant factor in improving SE generally and CSE specifically), the pump design project became the cornerstone of a larger vision of the place of engineering in solving localized problems. ENGRC 2250 asked that students explore ways in which good engineering design is always contextualized, answering the needs of a set of specific set of circumstances that are economically, environmentally, socially, and politically bound. Halfway into the semester, students began intense work that focused on team dynamics, functionality, and workflow, followed quickly with the teams' proposals for their projects. Teams chose a community that was water-poor and placed their designed pumps in that site (in theory). Written proposals plus a presentation required that each team to identify its target community for pump placement and define the wind/water pump solution that could best fit localized need. In addition those student teams produced final reports and gave presentations based on those reports.

Providing a context for the wind/water pump was an essential step in the journey for students, moving from the classroom + lab to the "real world." As well as communicating their technical work on the pump mechanism developed in their mechanical engineering course, the communication project charged teams with the investigative tasks of identifying a community in need, contextualizing water access problems, exploring the history of the community and its water needs, and delving into the aspects (as best they could) that reflect the social justice challenges of engineering. As teaching partners, our motive was to have students experience, even on a small scale, the complex process of moving a technological invention out of the lab and into a demanding situation that was impacted by those opportunities and challenges that every professional engineer encounters. Along the way, we asked them to examine, reflect upon, write about, present, and explore the communication strategies and channels needed for strong work and project deployment.

5 Results of the quantitative survey regarding student communicative self-efficacy (CSE), start of semester

Herein, we provide a quick overview of our research results from the 2016 findings. Our extensive data set (Tables 1-14) is provided fully at https://sites.coecis.cornell.edu/chec/ecp-research/.

Perhaps the most important result, at least as it pertains to the quantitative study of CSE, is that the survey instrument that we designed is valid. We know that "validity is not [merely] a property of an instrument" [16], or the answer to the statistical question – does the survey actually measure what it is supposed to measure? Rather, it is revealed by whether or not the resulting scores provide a reasonable and useful representation the subject/topic under investigation. We assert that our data do provide such a representation both for how MAE undergraduates understand their ability to communicate for engineering work and how they understand that that ability develops.

So, what is that representation? Our survey results from the general undergraduate MAE student population shows that CSE increases both for individual survey items items and across the various modalities or WOVE as experience increases. That is, the mean scores of seniors exhibit higher CSE than juniors and juniors higher than sophomores. This increase suggests that students understand that their ability to communicate is a ***learned experience*** that increases with ***deepening disciplinary involvement***, ***advancing academic level*** and is enhanced through ***opportunities to practice***. However, the increase in CSE between the sophomore and junior levels is relatively trivial. The average improvement of the mean scores for individual items is 1.3 points and 1.7 for modalities respectively on a 100 pt. scale. Indeed, there is even some regression. And, the increase between junior and senior levels is modest: 7.5 for individual items and 7.2 for modalities. Knowing that for these undergraduate engineering students CSE does increase, albeit incrementally and not without regression, is important for two reasons. First, understanding that students do improve with disciplinary involvement and advancing level and through practice reinforces the value of each of these factors. Second, understanding that that improvement is limited suggests that there may be (indeed should be) a better way to enhance that improvement.

In comparison with the general MAE undergraduate population, the ENGRC 2250 students report a threefold improvement in CSE. And, since the time points for the baseline and the follow-up surveys are the beginning and the end of the term, we attribute that increase to their experience in the course. Specifically, the survey revealed increases in the mean CSE scores both for individual items, approximately 26, and across the various modalities or WOVE, also approximately 26. On the individual survey items, nearly 46% of all MAE students rate themselves as high, between 80 and 100 on the survey scale; while 81% percent of the students who completed the communications course rate themselves as high. For modalities, the percentages are similar: 44% for all MAE students and 84% for ENGRC 2250 students. The average mean CSE scores for all students at the end of the communications course is 90 for both individual items and modalities. This score becomes even more impressive when we note that only 23% of students in the baseline survey rate themselves as high. Finally, the average change between the minimum score on each of the items in the baseline and the minimum score on each of the items in the follow-up survey is 42 points. To highlight just one item: we asked students to rate their CSE as to whether they could, "give effective talks/presentations." At the start of the semester, the mean score was 55.4. At the end of the term, the same question provided a mean score of 91.7 again on a 100pt scale.

The data we collected (available at [redacted URL]) clearly reveals that changes in CSE are significant for students in the communications course. The single most important takeaway is that there is indeed ***a better way***! The only caveat is that our research-to-date is based on a small sample, and it will be important to replicate these patterns and their associated intensities in future distributions of the survey.

7 Conclusion and Next Steps

We piloted the partnering of two courses in an attempt to create a more impactful and expertise appropriate way to deliver communications instruction. And, assuming that CSE is a legitimate means to assess that more impactful and expertise appropriate way, we found that the partnered communications course dramatically increases undergraduate students' CSE scores. Moving forward, we are keen to learn if their CSE continues to grow, stabilize, or decrease. Using our validated survey tool, we will be able to track such findings.

To review, there are three direct outcomes from the quantitative study: 1) We have a valid instrument to measure CSE, 2) The general population of MAE students show minor improvements in CSE advancing through their senior year, and 3) Students who did take the partnered communications course show a threefold increase in CSE when compared with students who did not. Consequently, we feel safe asserting that direct and recurring instruction and possibly the mastery experiences that result from that instruction leads to significantly greater improvement in CSE. We also feel safe asserting that the curricular model that we have developed for enhancing students' communicative abilities has potential.

While our research is still very preliminary, there is also an important and emerging question that will merit continuing study. Because those students who have taken ENGRC 2250 are familiar with the foundational concepts related to communication, because they are strategic users of the modalities, across a range of contexts while assuming new communicative/professional identities, and finally, because they have high CSE — are ready to learn to learn how to communicate? Are ready to engage in those behaviors that transfer well into professional practice and lead to communicative success? We will rely on our qualitative data and continuing research to answer this question.

Currently, our plan is to continue to foster and expand our teaching partnerships with MAE faculty across the curriculum by offering communication units in select junior and senior level courses. The impact will all the more be strengthened if we can reinforce the idea that good, thoughtful communication is, as we claim, ***ubiquitous***. Working with the assumption that our approach to near- and long-term assessment can enable not only MAE but also other engineering schools and departments to offer concrete learning outcomes and produce actual data to support those outcomes, we will be continuing partnerships in the College and potentially in other departments, as well.

We believe that we have made a promising start toward planning and implementing an alternative communications curriculum that empowers students to be stronger communicators and therefore better representatives of the university and assets to their future employers. Of course, we move forward carefully and intentionally, as we are so early in the research process and pull from such a small sample size. Nevertheless, it is safe to suggest that the partnered ENGRC 2250 course resulted in *positive and trackable impacts about students' reported communicative self-efficacy (CSE) in engineering contexts while providing for those students a way to experience communication as an integral component of engineering work.*

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Are you ready to innovate? Engineering students' perception of their skills to innovate

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ABSTRACT

This article aims to explore the self-perception of engineering students about their skills to innovate. We investigate what skills they need to innovate and to what extent they feel they are sufficiently well trained in their engineering school to work innovatively in their future career. Based on a recent literature revue, we point out the essential skills required to innovate. We applied a methodology of sequential exploratory approach including at the first phase a preliminary exploratory study and a quantitative online survey at the second phase. Our results indicate that open mindedness; objective outlook and creativity are perceived as the most important for innovation activities. Surprisingly, half of the surveyed engineering students declared that they feel not to be sufficiently well trained to innovate. We found for several soft skills such as creativity, objective outlook, critical thinking and open mindedness an important divergence between their training and their perceived importance. On the contrary, for hard skills like knowledge, technical expertise and experience our results show a particularly good convergence. Our results suggest that better integration of soft skills to innovate in the engineering curriculum would be beneficial.

Conference Key Areas: Engineering Skills

Keywords: Engineering skills, Innovation, Students' perception

INTRODUCTION

In our knowledge-based global society, the ability of industrial business organisations to innovate is an essential condition, if not the most important, of their survival on the globalised market. Consequently, they have to innovate continuously to retain their market shares and keep their place. In order to obtain sustainable competitive advantages and high performances, they have to be able not only to follow the market's global trend, but to be always one step ahead of their competitors. There is no doubt that their engineers' skills play a central role in innovation and value creation. Furthermore, they are considered as the main investment to develop a successful innovation strategy [1]. For this reason, industrial organisations have a strong interest to recruit young engineers adequately skilled to innovate.

For the younger generations of engineers, innovation skills have become more crucial for their employment and career prospects [2]. In a context of post-industrial society, there is a strong requirement for the engineering profession to innovate. In the case of innovation work, young graduate engineers need a solid technical background but also various non-technical skills. They have to be able to create not only technological innovation but products, services, processes, social or societal innovations. Given this larger scope of required innovation capacity, they need a new and larger set of skills.

Our research is based on engineering students' perception. Indeed, the study aims to answer the following questions:

1. What are the most important skills needed to innovate from an engineering student's point of view?
2. Do students feel they are sufficiently well-trained in their engineering school to innovate?
3. What skills do they feel they lack regarding their own curriculum?

In this article, we will explore the perception of engineering students if they feel adequately prepared or not to innovate in their future professional life. First, we will discuss about the needed skills to innovate based on a recent literature revue. Then, we will explain the applied methodologies for our research survey. In the next section, we will highlight significant results and their interpretations by outlining unexpected findings. To conclude, we are going to point out the limitations of our study and define future perspectives.

1 THEORICAL BACKGROUND

The increase in global market competition experienced by many employers forced higher education to adjust the academic training [3]. Consequently, engineering education had to adapt its curriculum by extending its composition to meet a more diverse range of skills than was formerly required. Thus, non-technical skills, also called soft skills, gradually entered the engineering training and became an essential component of engineering courses. Communication, relationship management, intercultural management and analytical capacities -among others- are included in these soft skills. As a whole, they are supposed to enhance the adaptability of future engineers in the ever-changing world that surrounds us. It impels graduate engineers to become pioneers of innovation and makes them more valuable on the labour market.

In his work, Passow [4] developed an ABET (Accreditation Board for Engineering and Technology) competencies ranking regarding their level of importance for professional practice from a perception of graduate engineering students. It shows that soft skills like the ability to work in a team, communication and ethics are perceived as being the most valuable competencies of the ABET program, before sciences. There are significant deviations between the technical and non-technical skills. This result is quite surprising regarding the fact that technical competencies are considered as the core competencies of engineering education. However, graduate engineering students evaluated these competencies as being less important in professional environments.

Innovation is a broad concept and there are many definitions for it in the literature. Between these definitions, the better-known is the definition by Oslo Manual [5] describing innovation as ‘the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations’. This definition includes not only technical innovation but also different adaptations such as social, marketing, processing innovation etc. that require mainly non-technical skills for innovators. Especially for engineers, technical skills are really important to innovate but they have to complete these skills with a strong background of non-technical skills.

In recent years, there has been considerable interest in skills needed to innovate. In 1985, Quinn [6] wrote one of the earliest papers about the most common skills that most innovators possess. She identifies several personal attributes that she observed in many innovative small companies: problem-solving abilities, multiple approach attitude, flexibility and the ability to adapt themselves to low resources. Following this idea, it was suggested that skills required to innovate are indeed a real issue and that the need for specific-skilled employees is not limited to the R&D function anymore [7]. Recently, it was observed by Toner [8] that only 2.2% of innovative firms recruited scientific personnel for innovation and that the skills recruited by the highest proportion of innovating firms were general business (22.6%), information technology (18.2%) and marketing (16.7%). He also studied the most common barrier for a business organisation to innovate, where lack of skilled staff is ranked as the third barrier to innovation (27.2%) behind cost and market related barriers. The phenomenon implies furthermore that specific skills identified as innovation skills are very valuable, especially for future innovators that graduate engineering students should be.

Boyd [9] introduces an innovation competency model in the industry where the core competencies are: creativity including generating ideas, critical thinking, synthetizing and problem solving; enterprising including identifying problem, seeking improvement, and gathering information; integrating perspectives such as openness to ideas and collaborating; and managing change regrouping sensitivity to situations, and intelligent risk-taking. A conceptual model was then developed by Harrison [10] for exploring skills for innovators. The model features indicators that influence innovation as a competence: cognition, technical knowledge, managing change and creativity. This means that these indicators of an individual’s personality and abilities impact on that person’s capacity to work innovatively. The two authors have a different approach of skills to innovate; indeed, Harrison [10] underlines the influence of the individual’s character on the ability to innovate while Boyd [9] highlights the importance of possessing advanced specific skills.

All of the previously mentioned research papers studied a range of skills needed to innovate, however the alignment of these skills with the ones that graduate engineering students actually possess is not well-explored.

2 APPLIED METHODOLOGY

To complete the literature review, we applied a mixed methodological approach known as the sequential exploratory strategy [11]. It involves a first phase of qualitative data collection and analysis followed by a second phase of quantitative data collection and analysis. First of all, an exploratory qualitative study was led by interviewing experimented engineers in order to define the most appropriate skills to innovate. Secondly, a quantitative study was carried out to target innovation skills and the way they are perceived by engineering students.

Our preliminary qualitative study was initially conducted to design the online survey. Twelve professional engineers operating in a highly innovative working environment were interviewed. We have chosen these professional engineers with different professional profiles working in diverse industrial sectors in order to have the most heterogenous sample possible. The interviewees were asked to speak about innovation in a general sense. The discussions then continued towards the actual skills they consider essential to innovate. Each interview was recorded and then transcribed in order to facilitate the analysis of the corpus. This allowed us to outline eighteen skills related to engineers' ability to innovate.

The development of our quantitative study final structure was based on findings from the literature revue and the results of the twelve qualitative interviews. The aim of this quantitative survey was to evaluate the impact of the engineering curriculum on the students' innovation skills and to highlight the domains where engineering students feel they are lacking. We designed an online survey that was sent to 678 engineering students at master level specialised in various fields (e.g.: electronics, mechanics, computer sciences etc…) to ensure the heterogeneity of the sample. First, the respondents were asked to evaluate the level of importance of innovation for the practice of engineering profession using a five-point Likert scale. The survey was then divided into two sets of questions. The first part questioned the perceived importance of the skillsets and competencies necessary to innovate. In the second part, we asked the respondents if they felt they were well-trained or not in their curriculum. We finally asked the students to indicate their missing skills.

We gathered answers from 181 students from a top engineering course in France that makes an answering rate of 26.7%. A method of ranking comparison of the eighteen skills evaluated by the students was used to analyse the data of the quantitative study.

3 RESULTS

Our findings clearly confirm the importance of innovation activities perceived by engineering students for practicing their future profession. They evaluated the importance of innovation activities for engineers at 4.24 on a five-point Likert scale in our online survey. This value correlates with the findings of our qualitative study where engineers' innovation capacities were outlined as a critical resource for industrial and business organisations. It was unanimously expressed by the interviewed professional engineers that innovation capacity is considered today as basic standard or transferable skills for modern engineers.

In order to understand what the most important skills to innovate are, we asked the participating engineering students to evaluate eighteen skills on a five-point scale (from "not important" to "vital"). Results indicate, as shown in *Fig. 1*, that soft skills such as open mindedness, objective outlook, creativity, critical thinking and problem-solving capacity are viewed by engineering students as the most valuable skills to innovate. Our findings are consistent with previous results of Passow [4], as knowledge and technical expertise that are generally viewed as basic skills of engineering profession were not considered as being the most important skills.

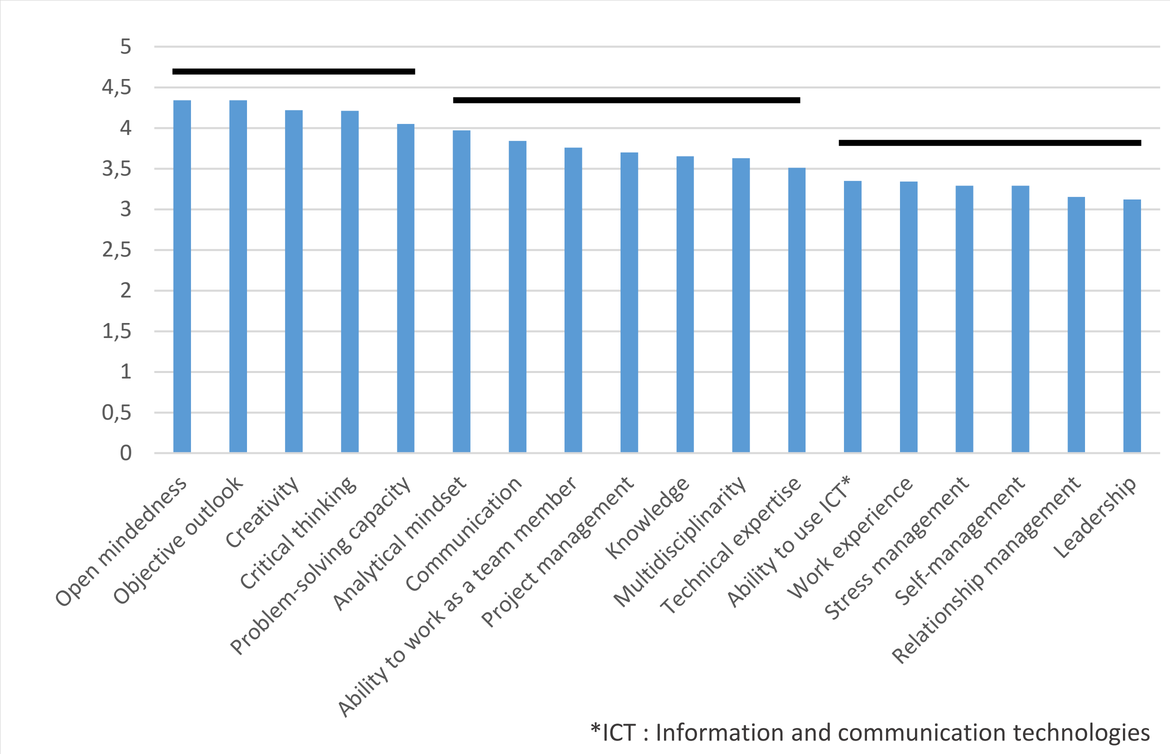

Fig. 1. Engineering students' perception of their skills to innovate

We investigated on how well engineering students perceive they are being prepared in their engineering school to innovate: do they consider they are being sufficiently well-trained or not? Surprisingly, 49.7% of the participants affirmed that they do not feel sufficiently well-trained to innovate. These participants were asked to evaluate the engineering training they are undergoing in their engineering school for each skill on a scale from 'good' to 'poor'. The results of this evaluation are shown in *Fig. 2*, where 1 corresponds to 'poor training' level and 5 corresponds to 'good training' level.

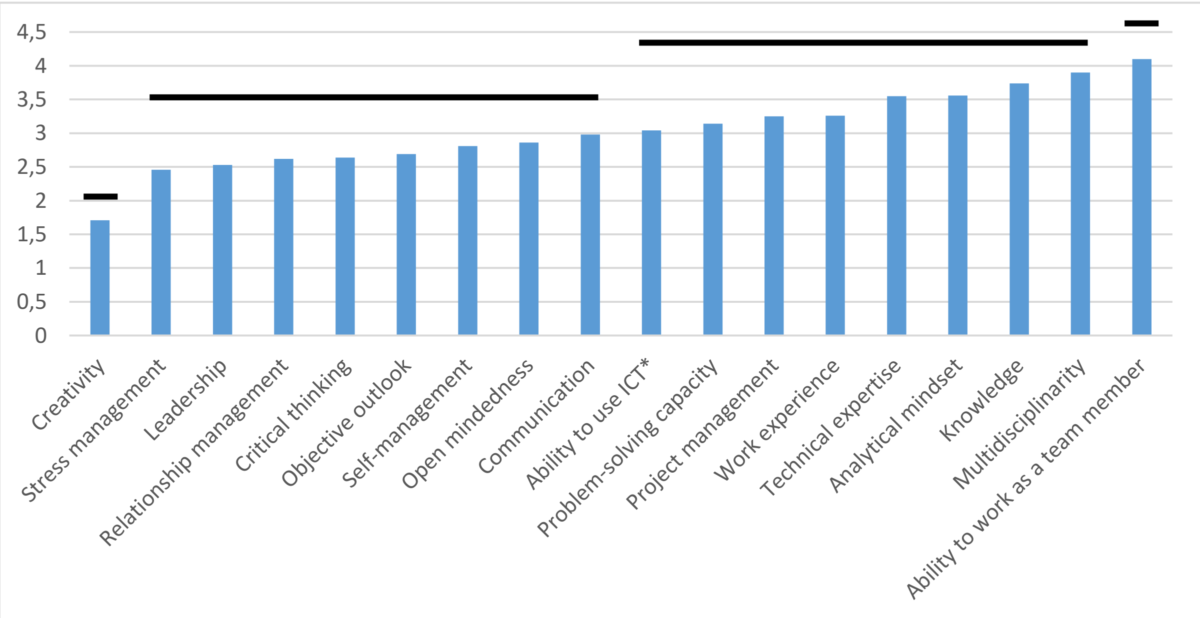

Fig. 2. Engineering students' perception of their training level to innovate

Our results indicate that nearly all the skills considered by the students as being the most important for innovation activities (creativity, critical thinking, objective outlook and open mindedness) are also the ones they feel are the most poorly studied in their curriculum. It is interesting to note that the majority of participants (66.7%) consider that they are not sufficiently trained to develop their creativity. In the conceptual model of Harrison [10], creativity is considered as a cornerstone of innovation activities and one of the most valuable workforce skills for industrial and business organisations. For this reason, the future development of creativity, considered as a valuable intellectual ability, would be beneficial for engineering students and their future employees.

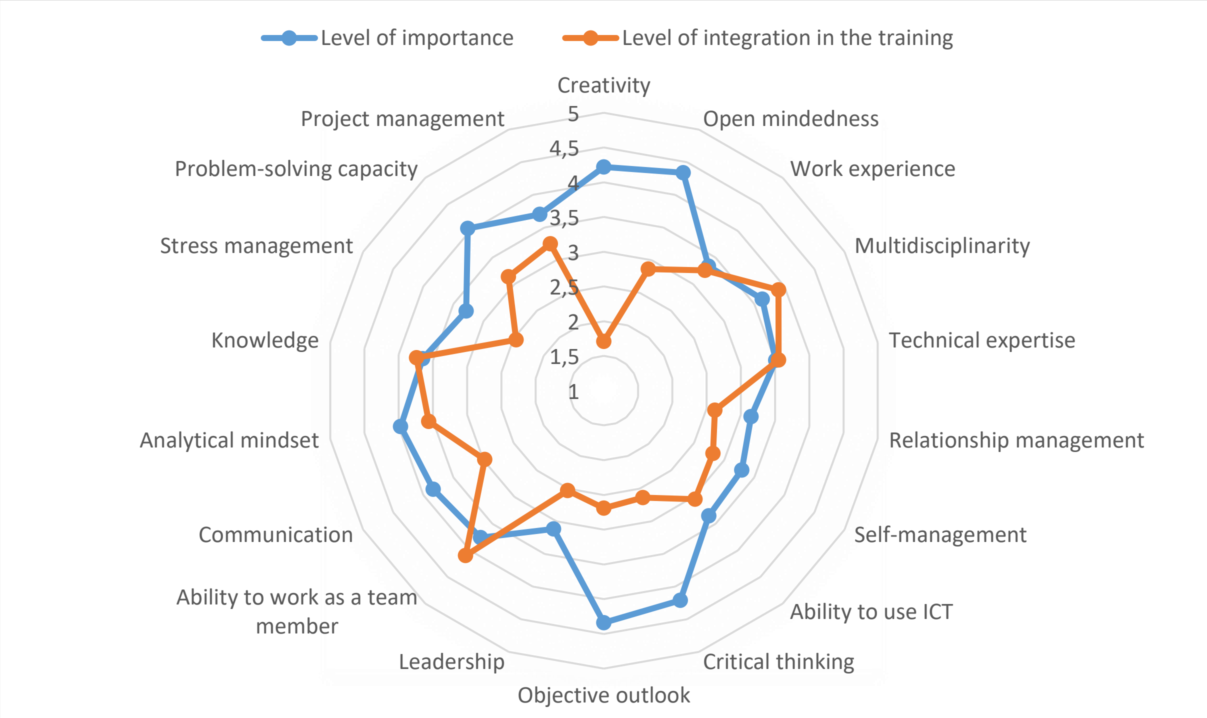

Fig. 3. Comparison between the level of importance and perceive training

We have made a comparison between the two evaluations of skills to innovate in order to observe the deviation between the level of importance and the level of their training perceived by engineering students'. The deviations are shown in *Fig. 3*. On one hand, there is a particularly good match between the perceived level of hard skills like knowledge, technical expertise and experience. On the other hand, we can observe a huge gap between the most important skills for working innovatively like creativity, objective outlook, critical thinking and open mindedness. This outcome is in a sharp contrast with the fact that these skills were considered as the most important skills for innovation activities. However, we can observe a positive deviance only in the case of team working and multidisciplinarity where the perceived training level is slightly beyond of the perceived importance.

4 CONCLUSION AND DISCUSSION

To conclude, our study confirms the importance of integrating innovation skills in the engineering curriculum in order to train modern professional engineers. According to our results, engineering students have a satisfactory evaluation of their training of hard skills needed to innovate. It is not surprising given that these hard skills traditionally benefit from a higher consideration and a stronger emphasis in the curriculum development. Controversially it was not the case for soft skills training. It was evaluated by the majority of students as having an insufficient level. However, these soft skills are considered as more important than hard skills by engineering students, contrary to the traditional perception. We would like to highlight the existing discrepancy between the hard and soft skills development to innovate.

Our research suggests that soft skills to innovate should be better integrated in engineering curriculum to ensure a higher level of innovation capacity for graduate engineers. We are conscious that this integration is a huge challenge and would be difficult to accomplish suddenly, but the results of this study might be taken as a suggestion for a progressive change. For the future generation of modern engineers 'the mastery of innovation skills will become paramount for a successful career [12:60]. Consequently, young engineers' capacity to innovate would be one of the most important elements of their professional skills, having a direct influence on their future employability.

To further our research, we intend to compare engineering students' self-perception of their skills to innovate and the industrial business organisation perception of young graduate engineers' who are freshly employed in their organisations. This study aims to give us a better understanding and clearer vision of how to develop engineering curriculums to reduce the gap between the reality and requirements.

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Categorizing student's learning strategy as a basis to improve their educational results.

Author 1
Author 2
Author 3

ABSTRACT

Companies desire for well-educated engineers because they want to optimize the company's processes and invest in technical developments. It is therefore seen as an assignment for Universities to achieve a high efficiency in educating many engineers for these companies. This means that Universities need to attract students and to make sure that the number of dropouts in the first year is minimal. In practice we see the opposite happening. Already in the first semester, students' motivation seems to decrease dramatically and even quite an amount of students leaf the University. This amount needs to be decreased as much as possible. Motivation is related to the learning strategies students use in practice. A tool is developed which enables study Counsellors to measure, to a certain extent, what the learning strategy is of a student and how, if it would be disadvantageous, an unfortunate situation can be changed. Using the tool in practice shows that it would help to lower the dropout rate. The first results seem to be positive. In the coming academic year this tool will be used to a full extent.

Conference Key Areas: Engineering Skills, Curriculum Development, and Attractiveness of Engineering Education.

Keywords: Motivation, first year students, learning strategies, improving methodology

INTRODUCTION

Now, leaving behind the financial crisis, markets again are flourishing. Companies regain markets and are increasingly selling their goods. These companies are investing in innovation of their products, and engineers taking a significant part in the researches to find and realize innovative products, which necessarily need to be sold on those markets. It's seen that on one hand companies desperately are seeking more young engineers to start their career in their companies but on the other hand Universities of engineering need to provide these companies with well-educated starting engineers. Therefore, it is important that Universities of engineering attract many starting students. But often it is the perception of these youngsters that the engineering education is too difficult, using 'complex' mathematics and physics. That could be the cause of many youngsters not to choose for an engineering education. Students, who are starting at the University, encounter most likely a different approach of learning compared to the learning approaches they were accustomed with in their former high schools. In Universities, students themselves need to be responsible for their learning behaviour. It also often occurs that the real educational situations in University do not meet their expectations and perceptions. It is additionally seen that students, nowadays, use their mobile phone in class very often and in some cases students even have a form of game addiction, which makes them having less time for school businesses or even see they need to work during school hours for living. On the other hand, there is a tough scheme of learning activities and they have to come up with positive exam results and tasks relatively fast. As a consequence of some or all of these occurring situations, students develop lack of motivation and, in worst case; they drop out of the University. In [1], [2] and [3], clues for this lack of motivation has already been seen. They also pose some clues for a starting development a lack of motivation in the definition of the four stages of learning strategies of Maslow, especially in the first stage. Students probably enter the University with having an ‘unconsciously incompetent’ attitude in their approach mastering the engineering content of the lectures and other educational programmes. It can be observed these students are frequently making wrong choices in operating their learning styles and controlling their educational programme satisfactorily. To help students in their struggle for mastering the engineering curriculum and becoming good professional engineers, it is important that Universities try to understand what effects their motivation and correspondingly to this, what effects their learning strategies, after which University can help students to regain motivation and have a progressive result in their continuing engineering education.

In 2015, a first paper was presented at the SEFI Conference in Orleans about a research carried out by [Name University], Mechanical Engineering, on what causes to block student’s motivation to continue their engineering education. In the research, it became clear that great numbers of students show their lack of motivation already after the first few weeks of their education. However, the research was not based on finding elements of intrinsic or extrinsic taxonomy of student’s motivation. The purpose of that research was to gain insight into students’ learning strategies in a relatively simple way. From this information it is aimed for to find ways and methods to improve motivation, to ensure that students stay in University and to increase the effectiveness of their work. In [4] an overview study of learning strategies, as it was researched in engineering education, can be found.

The [Name University] approach can be found in the SEFI 2015 paper [5]. A questionnaire was used to ask students about the level they want to reach in terms of a grade, next to the question on how much effort they want to put into their education, in order to reach that grade. From that information 6 categories of learning strategies were distinguished. Where [5] is showing a measurement set up of motivation as it was used in 2015, in this paper the next step is presented. At [Name University] Engineering, Study Counsellor check and help students with their study results. These Study Counsellor are very essential in contact with the students. In their discussions with their students, they are provided with information on motivation of these students. These Study Counsellor than can have discussions with the separate groups of students having the same kind of lack of motivation. They can discuss what is the reason for their lack of motivation and what can be done to regain student’s motivation. These counsellors can discuss improvement of students’ learning strategies. The [Name University] University wants to get more insights into using this tool and to understand better what is happening during the first semester to a student’s motivation. The goal is to take action and to ensure student’s motivation does not eventually result into such dramatically dropout rates. In the paper a conclusion of this research will be drawn, and especially what were the experiences of the Study Counsellor?

1 FINDING STUDENT'S LEARNING STRATEGIES

In our research we see possibilities to measure students' motivation and connect this to their learning strategies in a relatively easy way. In this paper it is the focus how the information coming from the questionnaires can be transformed to advices towards students on how to improve their learning strategies. From the information from the questionnaires, it is supposed students' motivation can be perceived. The students answered the questionnaires in November 2016 and in March 2017. Some questions are included, where students can indicate to what level their motivation is. Also two indirect questions on motivation were asked. 1: What is your commitment to reach for a grade, and 2: How long would you do homework in order to get this grade? In the Netherlands, grades are given in a score from 1 to 10. 5.5 is just a positive grade and lower than that is a negative grade. For the grades 4 levels is used.

1 Just sufficient: students don't have intention to reach more than (5,5-6).
2 Normal grade: this is normally what students will reach (6-7).
3 Higher grade: students really want to achieve higher grade (7-8).
4 Excellent grade: students want to be excellent (8-9).

For the amount of work on doing homework, six stages are defined. The stages are divided from hardly any commitment to do homework (a few minutes of doing homework per day), till having a challenging commitment (more than one and halve hours of doing homework per day). In the next enumeration the six stages of doing homework is listed up.

1 $0 < h < 0.2$ hours/day: No work commitment (<1 hours/week)
2 $0.2 < h < 0.4$ h/d: too little work commitment (1-2 h/w)
3 $0.4 < h < 0.8$ h/d: work commitment for possible positive results (2-4 h/w)
4 $0.8 < h < 1.2$ h/d: more than normal commitment (4-6 h/w)
5 $1.2 < h < 1.6$ h/d: hard working commitment (6-8 h/w)
6 $h > 1.6$ h/d: Extensive work commitment (>8 h/w)

With these two data combined in a two-dimensional graph, an estimation of categories on learning strategies of the students can be acquired. In the two-dimensional graph below, Figure 1, zones of certain learning strategies are shown. When students showing their commitment to what level of grade they want to reach in combination to the amount of hours of homework they want to spend to get this grade is seen as combined information to which a classification of learning strategies can be identified. This learning strategy of the student is the basis where personal study coaches can have discussion on in order to help this student making decisions accepting a more effective learning strategy and gather a better result for the upcoming education.

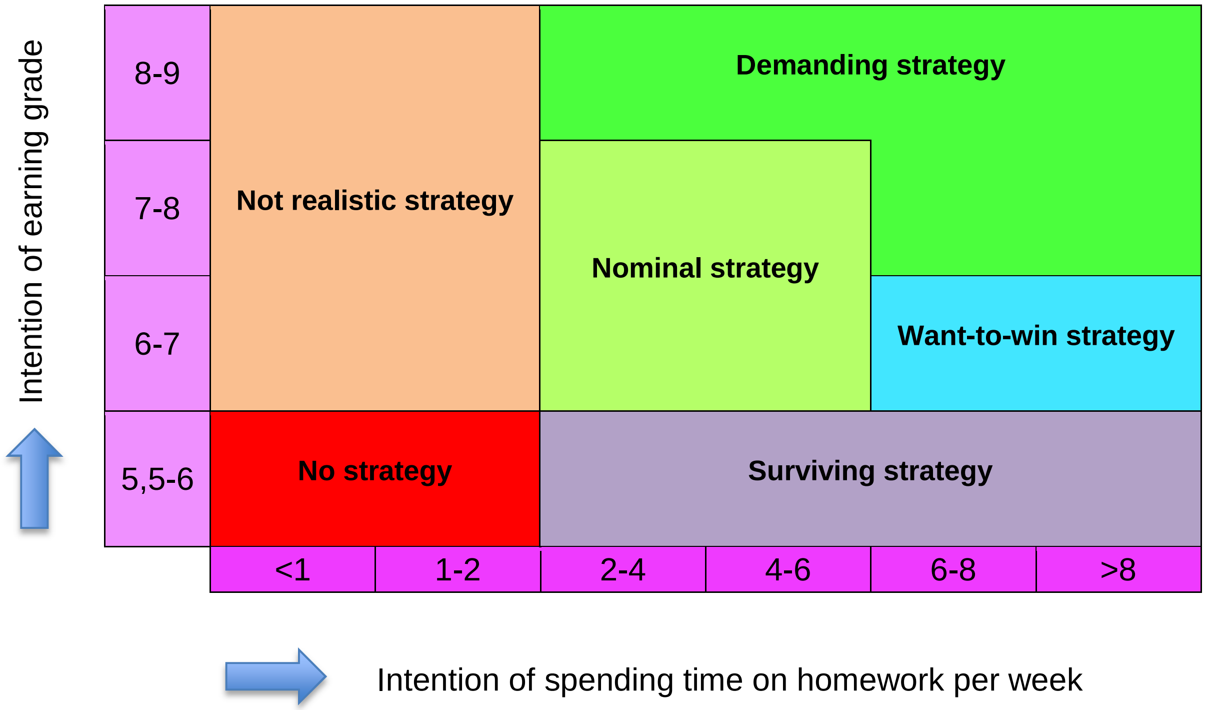

Fig. 1. Attempt to classify levels of learning strategies

In Figure 1 six different students' learning strategies were distinct:

1. **Demanding strategy:** students want to work very hard in order to achieve the highest grades possible. Often these students can easily have good results in their education and want to do special work, e.g. doing an honours programme.
2. **Want-to-win strategy:** students estimate that spending the maximum amount of time on homework will enable them to have average/sufficient marks. These students see they need to work hard to get higher grades and they are very motivated to do extra work to get normal grades.
3. **Survival strategy:** students think they need to work hard for getting an engineering degree. They believe or feel they have not the right cognitive capabilities to get normal grades, so they are willing to work very hard to achieve this goal.
4. **Nominal strategy:** students' intent to achieve good marks by working a nominal amount of time on homework. These students are seen as students achieving nominal educational results by working a nominal time on their homework.
5. **Not realistic strategy:** students' work under the assumption that they are able to invest a minimum amount of time to no time for their homework and nonetheless getting maximum high marks. But it can also be that these students are brilliant and need to go to the academic University or they have arrogant thinking that the education is too easy for them.
6. **No strategy:** students without specific strategy. It can be the case that these students are struggling for finding out if mechanical engineering is really something for them.

Helping students to change their learning strategies is concerning students selected for the learning strategies: 'Not realistic strategy', 'No strategy' and 'Surviving' Strategy. The approach is to convince students to change their way of learning to the other learning strategies. In Figure 2 the arrows are showing what the intention is of the Study Counsellor. They want to discuss with students on how to change their unfortunate learning strategy into a more successful strategy.

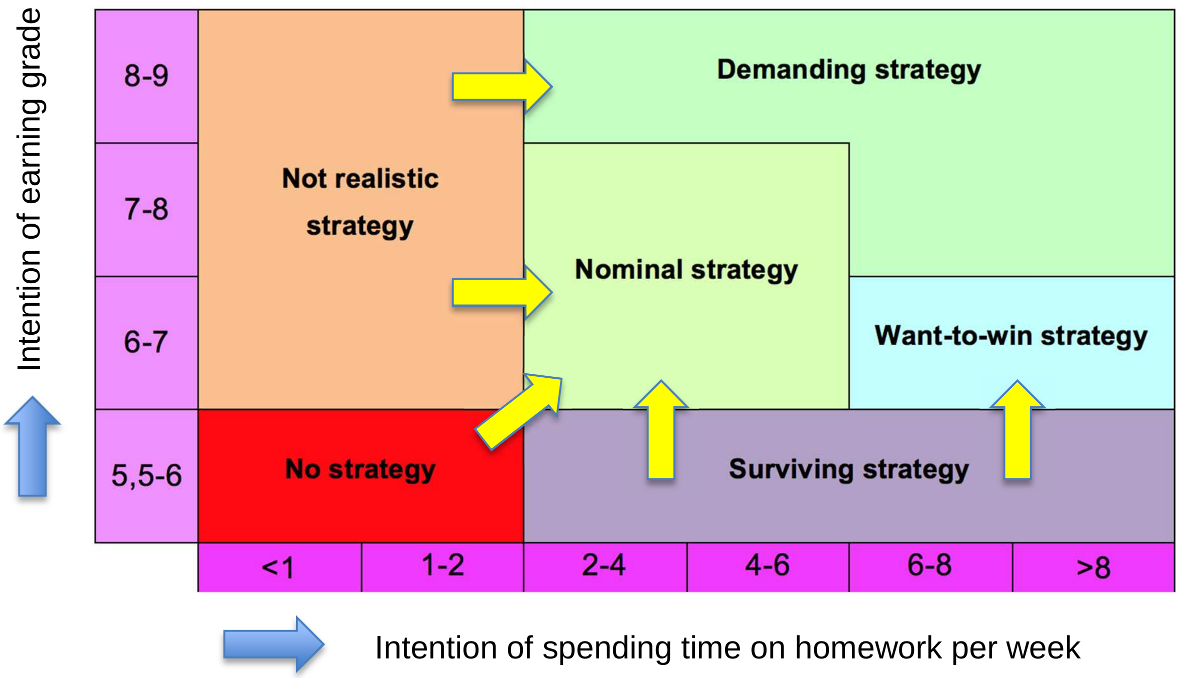

Fig. 2. Change direction of non-effective learning strategies to the more effective

In the methodology composed Study Counsellor are an important element really being able to discuss with students changing their unfortunate learning strategies into more fruitful learning strategies. But how this discussing should take place? Especially for this intervention a questioning and answering table was assembled. In Table 1 in total 13 questions were formulated. Students can answer in a 5-point Likert scale. But it is always the question what are the perceptions of the students answering to the questions. What is their perception to fill in a 3 and is this the same perception for another student? It is likely each student has his own perception about the five levels of answering. In order to harmonize the answering each level of the Likert scale is given a written answer. Students have to choose which of those five answers are the most likely to their situation.

Students can choose the right answer to their situation. Study Counsellor can use, for each student, the outcome of filling in this table as discussion items. To the far right (5) students, to their opinion really function perfectly, while to the far left students really expressing themselves that there is something not okay. Counsellors can use the outcome as a discussion document on which they can consider together with the student what is the best thing to do, and how a student can change from the left side more to the direction of the right side? So the table can be used to give students possibilities to express their motivation and an advice to change their motivation in order to obtain better results in the engineering education. In the next paragraph the outcome of the inquiry will be presented.

Table 1. Answering table formulating student's learning strategy

	QUESTION	ANSWER				
		1	2	3	4	5
1	**What do you expect from your education?**	I don't see education is helping me realize my career wishes.	I'm struggling if this is what I want, but I want do technical education.	I have difficulties to focus what to become in my career.	I know that engineering is what I want. But I need specialisation focus.	I really can grow. I see what to become. I want to do more.
1[a]	**How does your environment effect your education?**	Somehow it was not my decision to come to engineering.	I'm doubtful about right education. My environment isn't supportive.	It was my decision, but I cannot discuss this with my environment.	I see in my environment what is the work of an engineer. I like that.	My parents really are proud about me and my friends too.
2	**Do you accept your educational situation?**	I can't accept the today's situation. I want to change it.	I want information about going somewhere else.	I doubting if this situation is what I want.	I accept today's situation, but I want to make some changes.	I fully accept my today's situation.
2[a]	**Do you accept the demand of doing homework?**	Homework is not what I want. I make no homework.	I can't get the motivation to do homework.	I'm doing just what I think is needed to pass exams.	I see that if I don't make homework I won't pass exams	I'm focussing on higher grades, so I do homework to be able to get those.
2[aa]	**Are you aware of the success factors getting positive grads?**	I don't know and don't want to know what success criteria are.	I don't know why success criteria will help me.	I want to know what success criteria are.	For some courses I do know but for other I don't know.	I know for every course what the success criteria are.
2[ab]	**Are you resilient when things are going wrong?**	I see my results are bad but I don't want to do more work.	I thought I couldn't engineering and it seems I was right.	I'm not demotivated, but when things are going wrong it demotivates me.	I see it is important to do work extra hard, but I have several other things to do.	I can find extra motivation to do things better after they went wrong.
2[b]	**Do you see the demands of doing engineering work?**	I don't know what the demands of engineering are. It's about Physics.	I will see what the demands are. Now I'm focussing on my education results.	I'm eager what the demands of engineering are.	I know, in some cases, what the demands of engineering are.	I see what an engineer needs to do. I work already in an engineering company.
2[ba]	**Are appealed to the Engineering work?**	I think I'm not on the right education.	I doubt if engineering is my education.	I know that the engineering profession is giving me a good career.	Engineering is really what I want, but not in which kind of engineering direction.	Engineering is really what I want. I know what I want to become in this profession.
2[bb]	**Do you have perceptions of your future profession?**	I don't know if engineering is part of my feel good in the future.	I want to talk to someone who can tell me more about an engineer career.	I need to have more information what a possible engineering task contains.	Engineering is really my career but I don't know in what kind of company.	I already know what I want to reach in the future in an engineering job.
3	**What were your grades in preparatory school?**	I just passed. For mathematics I had a negative grade	I just passed. For mathematics was just positive.	I passed quite easily. For mathematics I had a high grade.	I had all grades positive, but not very high	I had high grades for every part.
3[a]	**What is your intellectual capability?**	I feel I can't understand the engineering knowledge. Especially mathematics.	I think I can get my propaedeutic certificate in two years if I work hard.	I must work hard to get my propaedeutic certificate in 1 year.	My results are good. I'm going to pass in 1 year.	I'm really doing well. My mean grade is > 7.
4	**What is your financial situation?**	I have to do everything alone. I must work for living.	Sometimes I think what to do about my financial situation.	My financial situation is not hindering me doing the engineering education.	My financial situation is not a problem.	I have no financial problems. My parents helping me.
5	**Do you have the will to change your learning strategies when needed?**	No, it is taking me too much time.	I want to change only if it is not effecting my daily live.	I don't know. Can I get some help of someone?	If it makes me getting better, I'm certainly willing to change.	My strategy is ok and my results too.

2 DATA

The method proposed in the previous section is used to map the learning strategies and study motivation of Mechanical Engineering students that started their education in the academic year 2016-2017. We asked the students to fill out the questionnaire twice and see whether their learning strategies and study motivation change in time during the year. The first time we questioned them was in November 2016 and the second time in March 2017.

2.1 Results of the questionnaire

The distribution of the students per learning strategy is found in *Table 2*. Between 2016, November and 2017, March already 20 students decided to quit the education (16%). There were only 17 students that participated in both the survey in November 2016 and the one in March 2017. From this subgroup of students, 12 students didn't change the learning strategy during that period. Three of them moved from want-to-win strategy to surviving strategy, one student from demanding strategy to want-to-win strategy and one student from nominal strategy to not-realistic strategy.

Table 2 Information and results of the motivation questionnaire

	2016, November	**2017, March**
# students	122	102
# respondents	37	66
# no strategy	0	2
# not realistic strategy	0	0
# surviving strategy	7	11
# nominal strategy	9	18
# want-to-win strategy	13	26
# demanding strategy	8	9

After the first semester Study Counsellors give each student a Study Progress Indication (SPI). This indication is practically based on the number of credit point obtained at the moment the SPI is awarded by the study coach. The Study Progress Indication is to be explained as:

A – On schedule (student progress is up to standard)
B – Initial signs of study delay
C – Considerable study delay
D – Serious study delay

An SPI – D at the end of the first year means that the student has obtained less than 45 credit points out of 60 and therefore, as it is the policy out education, has to quit the educational program. We will use this indicator to validate the information from the Tables 2 and 3.

Table 3 SPI at the moment the third questionnaire is filled out.

	STUDY PROGRESS INDICATION			
	A	**B**	**C**	**D**
# no strategy	0	1	1	0
# not realistic strategy	0	0	0	0
# surviving strategy	1	1	5	4
# nominal strategy	0	6	8	4
# want-to-win strategy	2	8	9	7
# demanding strategy	2	4	2	1

Students with a D indication in March are considerable candidates to leave the education at the end of the year. The majority of these students have a want-to-win strategy, surviving strategy or nominal strategy. This indicates that these students say we want to do our best to achieve positive grades but the reality is otherwise. Study Counsellors can discuss with these students what the reason was for these severe delays in learning results. For these students it is the last call to change. Otherwise they are really not capable to stand the demands of the education.

Another good indicator for the possibility in succeeding the engineering education is the final grade for mathematics in the secondary school, since we see this as a relevant indicator that shows, to some extent, the learning capacity of a student, entering the University education. The students entering our University are coming from the VWO (Secondary school level for academic education), as well from HAVO (Secondary school level for bachelor education) and from a middle technical occupational school. From this last group we don't have information on their final grades on mathematics. In Table 4 those grades are given for the respondents to the survey in March 2017. None of the students got an 8 as a final grade for mathematics in their secondary school.

Table 4 Final grades for mathematics in secondary school per learning strategy.

	FINAL GRADE MATHEMATICS			
	5	**6**	**7**	**9**
# no strategy	0	0	2	0
# not realistic strategy	0	0	0	0
# surviving strategy	3	3	5	0
# nominal strategy	1	5	11	1
# want-to-win strategy	1	13	12	0
# demanding strategy	0	3	6	0

Except for the categorisation in learning strategy, the students also respond on the questionnaire of 13 questions from Table 1. The answers from the respondents in March are graphically represented in Fig. 3.

From Fig. 3 Is becomes clear that only incidentally students answer with option one. Option two is more often present as an answer, especially for questions 2, 3[a] and 4.

Fig. 3 The distribution of answers options given by the students per question.

The results seen in the Figure 3 show that coaches really can have topics to discuss with students in order to understand the background of their not so successful study results. Especially level of answers 1 and 2 give reasons for Counsellors to have discussion with students. As an example, on question 4 students really see the financial situation as an obstacle to spent their attention to education. Counsellors can than discuss the reason and try to discuss, as an example, to lend more money from government, as in the Netherlands students are given the possibility to loan money from Government under relatively advantageous terms. (Low rate and advantageous pay back condition.)

2.2 Results of a single class

As a test case we take a closer look at a single class of 11 Dutch students Mechanical Engineering. The students have filled out the questionnaire. The classification in learning strategies is graphically represented in Fig. 4. Their answers to the questions are given in Table 5.

The first observation is that incidentally all of these students respond with answer 4 to question 5: each one of them is willing to change the learning strategy if it makes him/her getting better. This definitely could be seen as a positive sign to discuss with these students what the best way is to change their learning strategy.

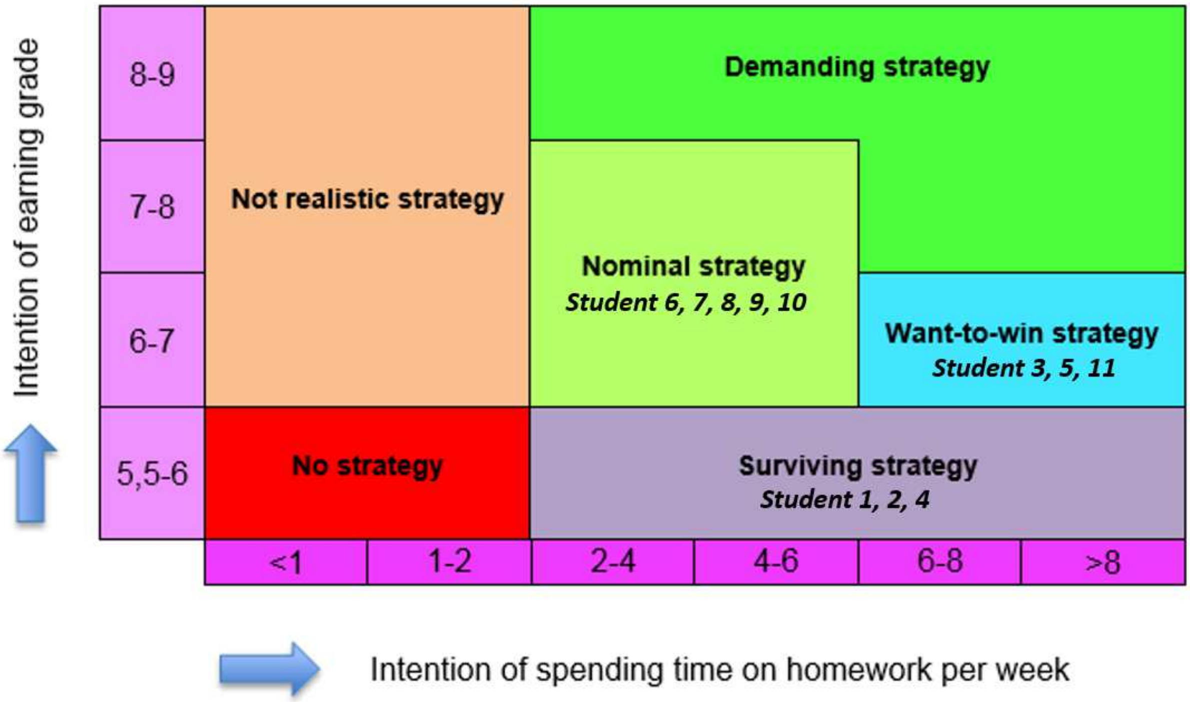

Fig. 4 Classification of students from the test group in the six possible learning strategy categories, according to Fig 1.

Table 5 Answers to the questions (see Table 1) from the students in the test group.

STUDENT	**QUESTION**												
	1	**1^a**	**2**	**2^a**	**2^{aa}**	**2^{ab}**	**2^b**	**2^{ba}**	**2^{bb}**	**3**	**3^a**	**4**	**5**
Student 1	4	5	4	3	4	4	4	4	3	3	3	4	4
Student 2	2	4	3	4	4	2	4	5	2	4	2	3	4
Student 3	4	4	5	4	5	4	3	4	3	4	4	4	4
Student 4	4	5	1	4	4	3	4	5	4	5	2	1	4
Student 5	4	4	4	2	4	3	4	4	4	4	2	2	4
Student 6	4	4	4	4	4	4	4	4	4	2	2	3	4
Student 7	3	4	4	5	5	5	3	4	4	4	3	4	4
Student 8	5	5	4	4	4	4	4	5	4	5	2	3	4
Student 9	4	2	4	4	3	4	5	2	2	4	2	5	4
Student 10	4	5	4	3	4	4	5	4	4	2	3	4	4
Student 11	4	5	3	4	5	5	2	4	2	4	2	4	4

2.3 Feedback from the Study Counsellors and students

Based on the student's study progress and his/her answers to the questionnaire, study development coaches reflect on the results with the individual student in a one-to-one conversation in order to find a way to improve the learning strategy. Study Counsellors put the method into practise. Summarizing the experiences of both the students and the study coaches:

1. The questionnaire provides good input for a conversation and gives clues and directions on how to improve students study results. Best would be to use the method in the first week of the academic year. Halfway the academic year students find it hard to change their direction.
2. Students mention that the survey increases their level of awareness with respect to study motivation. Two aspects have influence on the motivation:
   a. Although students like the education in Mechanical Engineering, they don’t know exactly what it will lead to for their future professional careers. More orientation on career possibilities during the first year would be most welcome. Seeing the purpose of their education would increase the motivation.
   b. Most courses examine in two or more separate parts. Credit points (ECTS, European Credit Transfer System) will only be awarded when a student passes all separate exams. When a student misses one part or more, then no ECTS will be awarded, although in fact the student might have gained “virtual” credit points for the parts he/she did pass. This also influences the motivation.
3. The classification of students in the six categories of learning strategies, as specified in section 1, agrees with the perception of both the Study Counsellors and the students on how the student performs at the moment. Student said: “I agree to be put in the certain learning strategy”.
4. The method also works for discussing and raising awareness with a group of students placed in a same learning strategy at the same time. They inspire each other by explaining how to study.

3 SUMMARY AND ACKNOWLEDGMENTS

This paper is giving information about the procedure at [Name University] University of applied Sciences in [place] on how they approach the effect of the occurring situation of lack of motivation of students during the first year. The information gathered can be seen as positive to the use of the new method on the improvement of learning strategies. The result encourages the staff to continue using this method right from the start when students enter the University. The relatively positive feedback from students as well as from accompanying teacher coaches gives us the power to continue with this learning strategy tool. From the next educational year this tool will be used to all students right from the start when they are entering our education. We feel that this method gives us the opportunity to really improve student’s learning strategy and therefore increase students’ educational results and therefore also their motivation.

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Sustainable Desalinator – An EPS@ISEP 2016 Project

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ABSTRACT

The European Project Semester (EPS) is a one semester capstone project/internship framework offered by the EPS providers to engineering, product design and business undergraduates. While a student-centred project-based learning offer, EPS proposes a unique multidisciplinary and multicultural teamwork set up to promote soft, technical and scientific competencies. In the spring of 2016, the EPS at the Instituto Superior de Engenharia do Porto (ISEP) welcomed a team of engineering students who chose to develop a sustainable water desalinator, the working principle relying on solar energy and natural temperature differences to convert saline water into fresh water. This paper describes the team's journey, including the motivation, the solution design process, considering the technical & scientific state of the art as well as the potential impact in terms of ethics, sustainability and marketing, and the development and testing of the prototype. The results obtained validate the purpose of the developed system since a significant reduction of the salt water conductivity, to values of the same order of magnitude of tap water, were observed. Although improvements can be made, the desalinator prototype produced 70 ml/d of distilled water in late spring and 7 ml/d in midwinter atmospheric conditions.

Conference Key Areas: Sustainability and Engineering Education, Engineering Skills.

Keywords: EPS, Project-based Learning, Multicultural and Multidisciplinary Teamwork, Water Desalination.

INTRODUCTION

The European Project Semester is a one-semester engineering capstone project/internship programme offered by a group of 18 engineering schools from 12

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countries – the EPS providers. The EPS defines a common structure composed of a multidisciplinary project module together with a set of project supportive modules devoted to soft skills, aiming to prepare students for international collaboration. The EPS providers implement the programme in accordance to a set of core rules, the "10 Golden Rules of EPS[2]". These rules specify, among other features, that English is the working language, teams must be formed by students from different countries, and it is worth 30 ECTS credit units (ECTU). Despite this common structure, each institution enjoys some freedom in the implementation of EPS. The programme is addressed mainly to incoming exchange students so that the class becomes a truly international setting. The goal of the EPS is to expose participants to diversity, both cultural and scientific, teamwork and multidisciplinary problem-solving [1].

ISEP offers EPS to 3rd and 4th year engineering, business and product design students every spring semester since 2011. The EPS@ISEP assigns 20 ECTU to the project module and 10 ECTU to complementary project supportive modules: Project Management and Team Work; Marketing and Communication; Foreign Language; Energy and Sustainable Development; and Ethics and Deontology. EPS@ISEP has been challenging students from multiple educational backgrounds and nationalities to join their competences to solve multidisciplinary real life problems in close collaboration with industrial partners and research institutes. This approach stimulates students to contribute with and apply their specific knowledge and develop transversal skills, namely social and communicative skills, during the different stages of the team collaboration process [2].

In the spring of 2016, a team of civil, packaging, mechanical, electrical and logistics engineering students chose to develop a sustainable water desalination module. The team embraced this challenge motivated by the idea of providing a sustainable source of drinkable water to populations located in coastal areas where water is scarce and/or contaminated. The team, driven by this opportunity, decided to design, build and test a sustainable desalination system using solar energy. Solar distillation involves direct absorption of solar energy in the saline water and its evaporation (at a temperature substantially below the normal boiling point) in an enclosed space. In contrast to the fossil fuel powered desalination, solar desalination is a sustainable process. This process removes impurities, such as salts and heavy metals, as well as eliminates microbiological organisms. The purified water can be used for human and animal consumption, farming, gardening, etc. The team decided that their system was intended for human and defined as their main marketing target governmental institutions, non-governmental organisations (NGO) and environmentally aware individuals. The team first conducted a state of the art review together with sustainability, ethical and marketing studies in order to define the use cases and requirements of their system. Based on these requirements, the team designed the structure and control system, chose and procured the materials and components and, finally, built, tested and determined the average daily volume of distilled water obtained with their solar powered desalination prototype.

This paper is organised in six sections. Section 1 presents existing desalination methodologies and describes the team own approach. Section 2 presents the complementary analysis performed by the team in terms of sustainability, marketing and ethics. Section 3 describes the proposed solution, whereas Section 4 reports the functional tests as well as its results and Section 5 draws the main conclusions.

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[2] http://www.europeanprojectsemester.eu

1 WATER DESALINATION

The most common chemical-free water desalination processes are Vapour Compression, Reverse Osmosis, Direct Contact Membrane Distillation and Water Desalination Powered by Renewable Energy Sources [3].

Vapour Compression process evaporates the salt water by using heat delivered by compressed vapour, as shown in *Fig. 1*. This type of desalination requires a mechanical driven compressor or a blower connected to the mains. The team rejected this technique for its expensiveness and high consumption of energy.

Reverse osmosis, relies on high pressure to overcome the osmotic pressure of a membrane, forcing the water through the membrane while retaining salt and other minerals (*Fig. 2*) [4]. Although an efficient technology, the team rejected it for being complex, difficult to downscale, expensive and susceptible to membrane fouling [5].

The direct contact membrane distillation process relies on a membrane dividing a container in two parts, at distinct temperatures (*Fig. 3*). The vapour flows from the heated tank, through the membrane, into the lower temperature tank, where the vapour condenses into drinkable water [6]. Although compatible with downscaling, this approach suffers from high energy consumption [5] and a cost incompatible with the available budget.

Sustainable water desalination systems are powered by renewable energy sources. As an example, solar power desalination relies on the Sun to convert saline water into fresh water [7]. The Sun heats the salt water, which evaporates and, then, condensates on the transparent cover. Finally, drinkable water can be collected (*Fig. 4*).

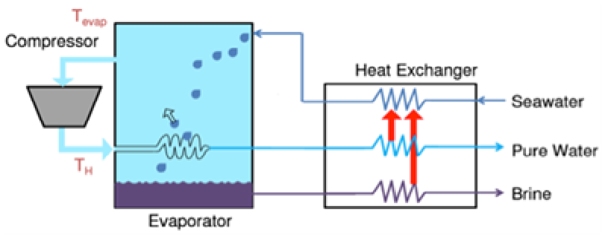

Fig. 1. Vapour Compression [4]

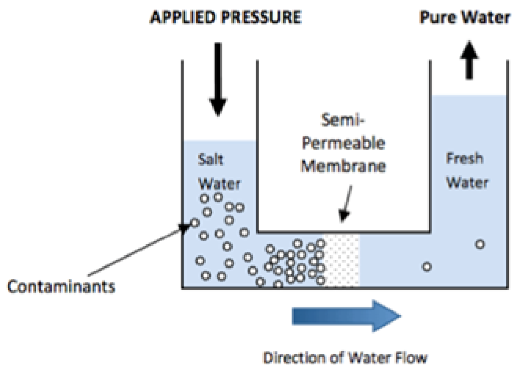

Fig. 2. Reverse Osmosis [8]

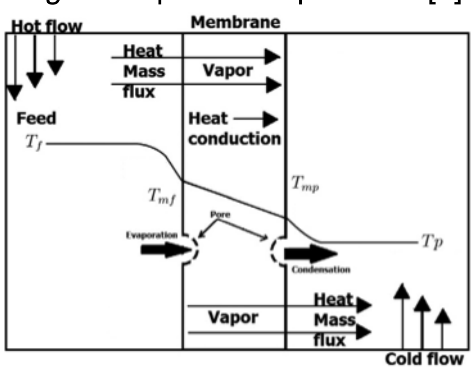

Fig. 3. Direct Contact Membrane Distillation [6]

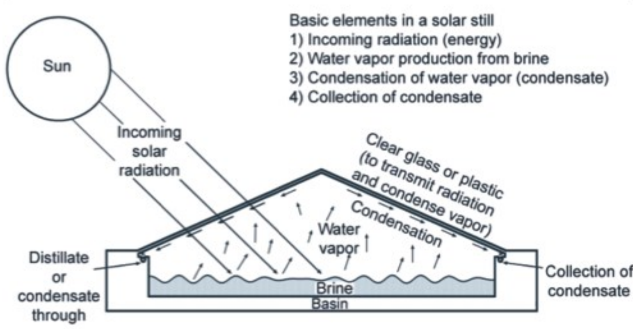

Fig. 4. Solar powered water desalination [7]

The team, under the motto “You don't need to be a fish to drink seawater”, chose to develop a modular solar powered desalination system named “Water Pyramid”.

Furthermore, the Water Pyramid should be modular, scalable and low cost.

2 COMPLEMENTARY STUDIES

The goal of this project was not just to build a working prototype, but to adopt a comprehensive approach considering the distinct relevant perspectives when developing a product like the Water Pyramid, namely, Marketing, Sustainability and Ethics. The idea is to make the team consider the development of a product, rather than just a technical proof of concept prototype, including the eventual creation of a company.

2.1 Marketing

The team defined as their target governmental institutions, NGO and environmentally aware individuals. Governments and NGO could provide the desalination module at reduced or no cost to dislocated or low-income people living close to the coast. Eco-friendly individuals, *e.g.*, nature lovers or outdoor sports practitioners, could also buy and use the product while exploring remote coastal areas. In addition, the module could also be marketed as an educational tool to: (*i*) promote environmental education by raising the awareness for the need to preserve, save and share existing water resources; and (*ii*) enrich the learning experience in the field of thermodynamics, *e.g.*, by performing experiences involving unpredictable factors such as the meteorological conditions, as well as in the field of data acquisition and automation, by providing a stimulating set up covering different areas such as sensor selection, Internet of Things and cloud based computing (sharing the data available).

2.2 Sustainability

Sustainability is a holistic concept involving economic, social and environmental perspectives. In this project, the resulting product – an affordable solar powered desalination module for households – is expected to have a good market acceptance and pay itself, considering there will be no further need to buy bottled water.

The team envisioned the creation of a company to develop and market an eco-friendly domestic water desalination product. The company is not just focussed on selling and making profits, but above all in meeting the users' needs and expectations. Based on these ideas, the team decided to use raw materials and sustainable energy sources (sunlight rather than fossil fuels) to minimise the generation of environmental pollution. On the one hand, a domestic scale system places the burden of the operation know how on the customer side. On the other hand, it can also mean a strong personal customer service where a company instructor will demonstrate how to operate and explain the relevance of the desalinator from a sustainable development perspective.

2.3 Ethics

In terms of code of ethics, the team chose the American Academy of Water Resources Engineers (AAWRE) code for the Water Pyramid. This code specifies a set of good practices standards regarding water resources for engineers [9], *i.e.*, helps engineers to adopt a professional practice and individual behaviour conducive to the preservation and respect towards existing water resources. The objectives of the AAWRE are the: (*i*) identification and certification of engineers with specialized knowledge in water resources for the benefit of the public; (*ii*) recognition of the ethical practice of water resources engineering at the expert level; (*iii*) enhancement of the practice of water resources engineering; (*iv*) support and promotion of positions on water resources issues important to the public health, safety and welfare; and (*v*) encouragement of life-long learning and continued professional development. In particular, the team decided to focus on objectives *ii* and *iii*.

3 WATER PYRAMID

Standard strategies to provide fresh water to human populations imply typically high energy costs. The challenge of this project was to design, build and test a sustainable water desalinator module for a multifunctional dome with minimum energy consumption. The Water Pyramid was designed to be placed on top of a modular wooden dome described in [10], *i.e.*, to become the top module of the dome.

3.1 Structure

The Water Pyramid (*Fig. 5*) includes fresh and salt water containers for desalination, a transparent cover to allow the passage of the sunlight in and to condensate the evaporated water as well as external fresh, salt water and leftovers storage tanks. Three pipes connect the pyramid with the different storage tanks. The fresh water container is the white pentagonal base, with a 3º slope to ensure the drinkable water flows into the fresh water storage tank. The black salt water container, with a 1000 ml capacity, is centred in respect to the white base and placed horizontally to optimize evaporation. The transparent cover is made of five triangles with an inclination of approximately 30º. The resulting pyramidal cover is easier and more economical to build than the intended bowl shape. *Fig. 6* shows a general view of the structure and a cross section. For the cover, the team chose transparent polymethylmethacrylate (PMMA) instead of glass because: (*i*) typical PMMA grades allow the passage of 92 % of the sunlight, including ultraviolet (UV), which speeds up the process; (*ii*) the thickness does not affect the transparency; (*iii*) the lightness and hardness of the material; and (*iv*) the manufacturing process does not involve toxic materials or heavy metals. The salt container is made of black plastic – a flowerpot coaster – to absorb heat and increase the distillation process efficiency.

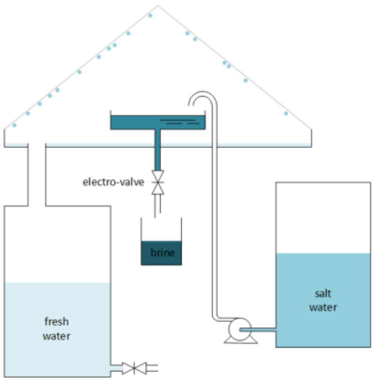

Fig. 5. Water Pyramid system

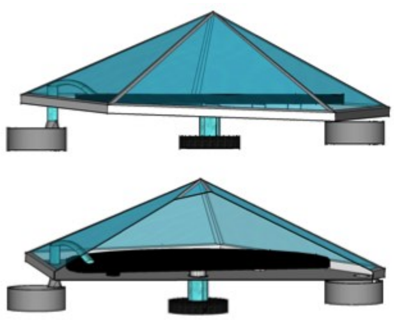

Fig. 6. General view of the structure and cross section

3.2 Working Principle

The desalination starts with the pumping of salt water from the external storage tank into the black container. As the sunlight passes through the transparent cover, it heats the inside of the pyramid, raising the inside temperature – greenhouse effect – and, consequently, decreasing the relative humidity and increasing the ability to evaporate the salt water. Due to the temperature difference between the inner and outer sides of the PMMA cover, the water vapour condensates on the inner side and runs down into the white base container. Finally, the drinkable water flows through the sloping surface of the white container into the external fresh water tank.

The black container needs to be periodically emptied of the process leftovers. In order to remove the highly concentrated brine remaining in the black container, the system opens the electro-valve, which connects the black container with the leftovers tank, and turns on the salt water pump to help draining the brine from the black container into the leftovers tank, and, finally, closes the electro-valve.

3.3 Control System

The team designed an electronic control system to make the Water Pyramid autonomous. The system comprises a micro-controller, a pump (output), an electro-valve (output) and four ultrasonic sensors (inputs). To prevent overflows, two ultrasonic sensors measure the maximum level of the water in the internal salt water container and in the external fresh water storage tank. The remaining two ultrasonic sensors measure the minimum level of water in the internal salt water container and in the external fresh water storage tank. These sensors are responsible for the removal of the leftovers from the black container and for the restart of the process when the fresh water tank is below its capacity. To prevent salt deposition in the black container, the system refills the black salt water container whenever the low level sensor detects a level corresponding to approximately 100 ml of salt water by opening the electro-valve (*Fig. 5*). The micro-controller, based on the measurements of the level sensors, operates the pump – to fill the black container with salt water – and the electro-valve – to remove the leftovers from the black container.

4 EXPERIMENTS AND RESULTS

To evaluate the performance of the prototype, two experiments were carried out. The first was focussed on proving the concept and detecting problems in the prototype (late spring) and the second on establishing the performance of the system in a worst case situation (midwinter). While the late spring experiment lasted one day, the midwinter one took 27 days. All experiments were performed using a 1 to 5 scaled prototype of the real structure to reduce costs and improve transportability, while achieving the same functionality.

The initial experiment took place on June 2016 (late spring) in an obstacle free area (the terrace of building F). Specifically, the prototype was placed at N 41º10'45.26'', W 08º36'29.21'' and data was collected from 8th June 2016 till 9th June 2016. In this 24-hour period, the prototype collected 70 ml of fresh water. In terms of average temperature values, the brine and the inside of the pyramid were 15 % and 13 % warmer than the outside, respectively. Concerning the average relative humidity, the value inside of the pyramid was 35 % higher than outside. *Fig. 7* illustrates the evaporated water conduction under the cover. The condensed fresh water flows down the cover inner walls into the white container as shown in *Fig. 8*.

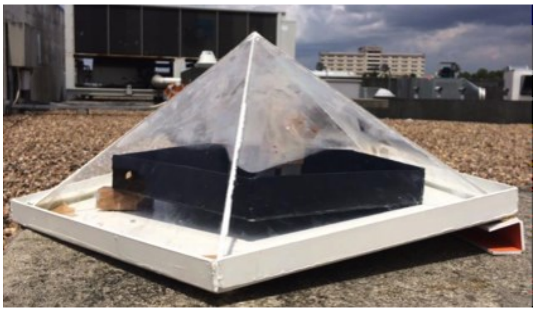

Fig. 7. Conduction on the cover

Fig. 8. Condensation process

The second experiment was conducted during the winter from 8th December 2016 to 4th January 2017. The prototype was positioned on an obstacle free horizontal surface located at N 41º13'39.67'', W 8º36'53.96''. *Fig. 9* displays the daily temperature and relative humidity conditions, including the outside air temperature (navy blue), inside air temperature (light blue) and brine temperature (red), outside air relative humidity (orange) and inside air relative humidity (green). Considering the average values, the brine solution was 7 % warmer than the outside air, whereas the average inside air temperature was 6 % higher than the average outside air temperature. In terms of the average relative humidity, the relative humidity inside the device was 14 % higher than outside.

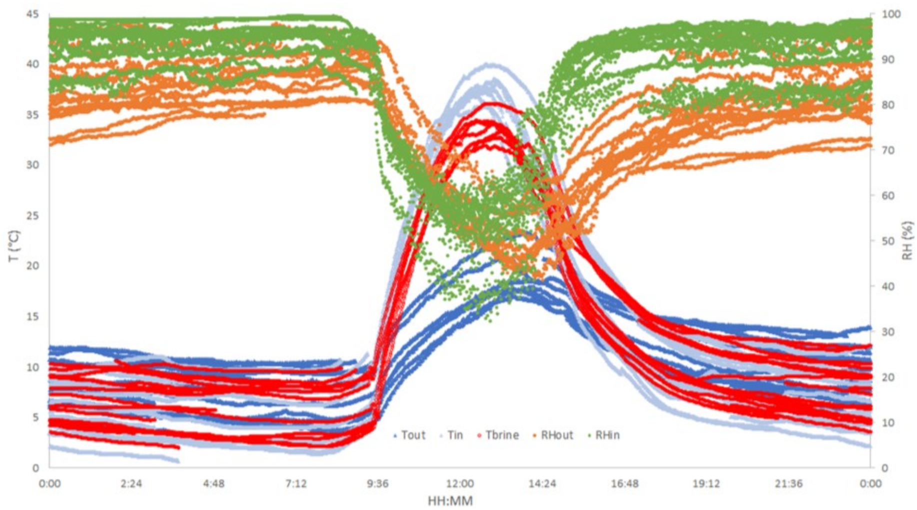

Fig. 9. Daily temperature (outside, inside and brine) and relative humidity (outside and inside) during the midwinter test

Table 1 summarises the results of both experiments concerning the average, minimum and maximum values of the temperature (T) in ºC of the (B)rine, (I)nside and (O)utside the pyramid, the minimum and maximum relative humidity (RH) in % (I)nside and (O)utside the pyramid and the daily volume of distilled water (DW) in ml. As expected, the late spring temperature and relative humidity were, respectively, higher and lower than the corresponding midwinter values. The average daily volume of distilled water in late spring was 70 ml and in midwinter 7 ml.

Table 1 Spring and winter results

		T (ºC)			RH (%)		DW/d (ml)
		B	I	O	I	O	
Spring	Avg	25.5	24.7	22.1	83.7	62.0	70
	Min	17.9	16.6	15.9	31.4	15.0	
	Max	49.9	61.2	43.6	95,7	83.7	
Winter	Avg	11.0	10.9	10.2	88.9	78.3	7
	Min	02.0	00.6	03.3	32.5	41.5	
	Max	36.1	40.0	23.3	99.7	98.5	

The electrical conductivity (EC) of the salt water and of the fresh water obtained after desalination was evaluated using a WTW LF 538 Conductivity Meter. EC decreased from 5.05 S/m to 0.154 S/m, indicating that a significant reduction in the salt water concentration occurred as a consequence of the desalination process.

5 CONCLUSIONS AND ACKNOWLEDGEMENTS

The EPS@ISEP framework provided a holistic, multicultural and multidisciplinary learning environment. First, the team specified and justified the requirements of their design solution – the Solar Pyramid – based on multiple team studies, brainstorming and coaching. These studies involved marketing, sustainability, ethics and deontology, as well as water desalination principles. After, the students selected, procured and acquired the materials and components from local suppliers. Next, they developed and tested a scaled model. The tests allowed the team to: (*i*) identify and correct assembling problems; and (*ii*) verify experimentally that the yield of the process depends on the atmospheric conditions, enabling the team to confirm the Solar Pyramid potential for regions with high atmospheric temperature range even in low relative humidity conditions. In terms of the learning experience, the team considered that the "*European Project Semester enriched all team members with culture, teamwork and team bonding*".

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Professional Roles and Employability of Future Engineers

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ABSTRACT

Although there is high degree of agreement on the importance of transversal skills for engineers, employers observe a significant gap between expectations and reality. This paper discusses the need for the development of a framework of professional roles for future engineers and the implementation of dedicated skills education in engineering curricula to train students for this role. Based on an extensive literature study, an

overview is given of previous research on this topic. The paper also outlines the next steps that will be taken by the authors as part of a European project PREFER to develop and implement these roles in engineering education.

Conference Key Areas: Continuing Engineering Education and Lifelong Learning; Skills and Engineering Education; Curriculum Development

Keywords: Labour market entry; Transversal skills; Professional roles; Skills mismatch

INTRODUCTION

A large survey among 467 Flemish engineers who graduated between 2014-2016, indicated that 22% of the respondents were no longer working with their first employer. Almost half of these graduates left because the job did not meet their expectations [1]. The European project PREFER (Professional Roles and Employability of Future Engineers) aims to reduce the skills mismatch in the field of engineering. Managers of human resources departments report that fresh engineering graduates frequently display (1) a lack of transversal skills required by the labour market and (2) a lack of self-awareness of their own strengths and weaknesses and of who they are as an engineer.

The objectives of the PREFER project are threefold. First, we aim to construct a Professional Roles Framework. This framework will describe the different roles engineers can take on at the beginning of their career, independently of the engineering discipline (e.g. electrical, mechanical, chemical). Each role will be characterized by an associated set of transversal skills. Thereafter, a Test System will be developed in order to (1) increase engineering students' awareness of the multitude of professional roles in engineering and (2) to make them reflect on their own engineering identity and their interests, strengths, and weaknesses. Thirdly, we will explore how to implement these innovative tools in the engineering curriculum by running a number of pilots in the participating universities.

In order to realize the PREFER objectives, a well-balanced consortium was built with both universities (University of Leuven [Belgium], Delft University of Technology [The Netherlands] and Dublin Institute of Technology [Ireland]) and companies (Engie, Siemens and ESB) involved. In order to develop reliable and valid test material, an experienced test development partner (BDO) is a member of the project team. To establish a stable connection with the engineering labour market, the three national engineering federations in Belgium, The Netherlands and Ireland were brought on board (IE-net, KIvI, Engineers Ireland). These federations play an essential role in connecting higher education institutions (HEIs) with a large number of employers that hire engineers. Validation in a wider European network of universities and companies will be tackled by respectively SEFI and FEANI.

1 PROFESSIONAL ROLES IN THE FIELD OF ENGINEERING

1.1 Problem statement

The McKinsey '*Education to Employment*' survey [2], organised with more than 5,300 young people, 2,600 employers, and 700 education providers, shows that only 35% of the employers agree that new graduates are adequately prepared. Interestingly, for education providers, these percentages increase to 74%. Apparently, on the supply side, education institutions believe that they are equipping their students with the necessary skills and competences whereas employers, on the demand side, feel

otherwise. This skills mismatch has become an important topic on the agenda of many policy makers. A focus on transversal skills (e.g. self-management, interpersonal skills, adaptability, communication skills, interpersonal skills) is often put forward as an important way to overcome this skills mismatch.
In the field of engineering education, interpersonal skills, teamwork, communication, and problem solving skills are most frequently identified as highly important by engineers [3-4]. As stipulated by Chan et al. [3], although there is high degree of agreement on the importance of these skills, employers observe a significant gap between expectations and reality.

Apart from the skills mismatch, a number of employers indicated that fresh engineering graduates are unable to identify their strengths and weaknesses during a job interview. It appears that fresh engineering graduates lack the introspective qualities to look at themselves and reflect about the question "*Who am I as a, for example, electrical engineer?*". Answering this question does not only entail a critical self-reflection on one's own thoughts and prior achievements, but also an articulation of one's future aspirations in the engineering profession. The latter aspect presumes a more detailed knowledge of the different professional roles that engineers fulfill in the labour market and which sets of competences are required. For example, in the field of chemical engineering, an R&D engineer may require a completely different set of transversal skills compared to an engineer in a more commercial role.

1.2 Employability: Increasing self-awareness

Employability is often used as a container term without exact definition. In line with Yorke and Knight [5], we endorse three components of employability: (1) increased understanding of academic knowledge, (2) a set of generic skills appropriate to the workplace, and (3) personal attributes (e.g. enthusiasm, flexibility, self-reliance, aspiration, seizing opportunities). As pointed out by Creasy [6] improving employability skills "*requires students to record their achievements and to reflect on these*" (p. 18). The author showed that students find it difficult to articulate their employability skills and that they have problems with writing reflective reviews about themselves and their own assessment of their competencies.

Increasing self-awareness among engineering students requires a high level of metacognitive thinking and the ability to reflect at a higher order level about oneself as a future engineer. Improving metacognition includes helping learners to (1) be more aware of their own implicit beliefs and (2) build a broader sense of purpose behind their learning [7].

1.3 Labour market entry for recently graduated engineers

As stated by Hofland et al. [8], there is a wide variety in career paths for graduated engineers. Going beyond the typical specialist versus management-dichotomy, this diversity is reflected both in terms of disciplinary wealth (e.g. electrical engineering, chemical engineering, civil engineering) and the professional roles that engineers fulfil in a particular organisation (e.g. service engineer, technical sales engineer, production engineer, process engineer…).

An important challenge of the PREFER project is to come up with an integrative framework wherein this multitude of engineering positions is summarized in a manageable and sensible way. Rather than mutually exclusive categories, we argue in favour of a framework wherein engineering positions can be described in overlapping sections if they fit several professional roles.

A similar framework has already been designed for the field of medicine. The CanMEDS framework that identifies and describes the abilities physicians require to effectively meet the health care needs of the people they serve. These abilities are grouped thematically under seven roles [9].

2 PROFESSIONAL ROLES FRAMEWORK

In contrast to the plethora of studies focusing on the essential transversal skills in the field of engineering, research on the classification of the multitude of professional roles that fresh engineering graduates can take on in the labour market is scarce. It is often presumed that all engineering careers are homogenous and require the same balance of technical and transversal skills [10]. Other engineering careers than the stereotypical 'engineering practitioner', for example, researcher, consultant, technical-commercial representative, often receive less attention. In their study, Brunhaver and colleagues [10] discriminate between three engineering roles of a large sample of recently graduated engineers (N=543): manager (15%), engineering consultant (21%) and engineering practitioner (64%). Problem solving and analytical skills were deemed equally important in all three engineering roles. Communication was rated as less important by engineering practitioners than by managers or consultants. Managing uncertainty, business knowledge and leadership were rated significantly higher in importance by engineering managers.

2.1 Business strategy model of Treacy and Wiersema

The business strategy model of Treacy and Wiersema [11] describes three strategic positions that companies can take in the value chain: (1) Operational Excellence (i.e. focus on maximizing efficiency by reducing costs while optimizing quality); (2) Product Leadership (i.e. focus on cutting-edge research & innovation), and (3) Customer Intimacy (i.e. focus on service of client systems and customer satisfaction).

Interestingly, the business strategy model of Treacy and Wiersema can easily be translated into the engineering field. A large-scale analysis of more than 7,500 job vacancies in the field of engineering in the year 2014 [12], showed that each job vacancy could be classified in one of the three categories outlined above: Operational Excellence (46%), Customer Intimacy (30%), and Product Leadership (24%).

2.2 First-year student survey

In the Rolling project [8], the Treacy and Wiersema model was operationalized by means of three fictional engineering job vacancies. A sample of 172 first-year engineering students was asked to indicate which job vacancy they would apply for. In contrast with the outcomes of the large-scale job vacancy analysis, 58% of the first-year students expressed a preference for the Product Leadership role. Thus, there is a very clear discrepancy between the preferred type of jobs of first-year engineering students and the jobs that are available in this category (24%).

In a second stage of the survey, the first-year students were asked to rate their self-perceived mastery levels of the 13 faculty learning outcomes (e.g. problem solving, communication, critical reflection, entrepreneurship, for a comprehensive overview, see [8]). Interestingly, students with a preference for the Operational Excellence vacancy, expressed significantly higher levels of problem solving/analysis and operationalisation compared to the other students. Analogously, students with preference for the Customer Intimacy vacancy rated themselves significantly higher in communication and entrepreneurship. In sum, there seems to be evidence that students tend to be more interested in job vacancies for which they deem themselves to have the required competencies and consider themselves to be good at.

2.3 Company survey

The Treacy and Wiersema model was also presented to a large sample of companies employing engineers (N=121). 91% of the respondents indicated that they recognised the model in their own company. A small proportion (6%) indicated that they needed some adjustments to the model (for example, management was considered missing). In a next stage, respondents were asked to indicate to relative importance of each of the aforementioned learning outcomes for each role. For example, for the Product Leadership role, design and development and specialized technical knowledge were considered to be the most important (for a more detailed overview, see [8]). In general, the company response pattern closely reflects the outcomes of the students' survey.

2.4 Conclusion

The Treacy and Wiersema model seems to be a promising framework to look at the variety of engineering positions. An important objective of the PREFER project is to fine-tune the model and to further tailor it to the engineering domain. Special focus will need to be spent on the specialist versus management dichotomy, a prevailing theme among many young engineers.

3 INTEGRATION INTO THE ENGINEERING CURRICULUM

In the following paragraphs of the paper, we will address how students' employability can be addressed in the engineering curriculum. An extensive search in engineering education literature as well as in literature on the initial path of recent engineering graduates was carried out. Despite higher education institutions' claim to prepare their students for their future career as an engineer, little evidence was found of institutions making a distinction between the different roles a graduate will function in when working as an engineer, and the skills pertinent to such a role. Many of these preparations include the earlier defined transversal skills, next to internships and other activities such as company visits, guest lectures, etc.

In order to limit the scope of this project, it was therefore decided to focus on a number of transversal skills: Entrepreneurial Skills, Innovation Skills, Communication and Networking Skills, Teamwork and Ways of Thinking, and Lifelong Learning. The selection was made based on the 4TU Centre of engineering education's vision on the future of engineering education [13].

3.1 Entrepreneurial Skills

Entrepreneurial skills are defined by Adeyemo as the ability to manage and create an enterprise by having vision and taking initiative and risk [14].

The idea of learning technical and entrepreneurial concepts while solving problems was the goal of a case study and lab experiences introduced in a core mechanical course of a Western private university. The case study comprised a realistic case scenario where engineering and entrepreneurial concepts were taught. Pre and post tests were carried out of students in order to understand if entrepreneurial skills could be implemented in core engineering courses without interfering with the technical skills and if a student's entrepreneurial self-efficacy (based on business confidence) changes with one case study. Results showed that students are able to increase their entrepreneurial skills without decreasing the learning of core engineering competencies and students reported self-efficacy improvement pre-to-post in just one case study [15].

Moreover, business and engineering are bridged by sales education in engineering programs. A department of industrial engineering supported by the university business school and industry partners provided a technical sales course introducing investment economic methods and theory. A pre-post survey of students assessed their interest and learning ability of sales skills. Results as published by Bumbluskaus et al. showed that the course enhanced students' sales skills and increased their desire to pursue a sales career [16].

3.2 Innovation Skills

Benjamin et al. defined innovation as the creation of new and technically feasible ideas or the adaptation of others' ideas [17]. Innovation requires thinking out of the box and an open mind, using creativity and imagination but also the use of logic, analytics and planning. According to Kamp [13] students should be stimulated in innovation by going to new environments with new challenges, and new ways of thinking (e.g. going abroad for studies).

The Engineering School of Los Andes University integrated a 2 semester prototyping course in the third year of the curriculum of System and Computing Engineering in order to improve teamwork and innovation skills. The students present it in periodic written reports and oral presentation, and in a final presentation carried out in an engineering projects fair. Hernandez and Ramírez [18] indicated that students' perception of this course showed that they are aware of the importance of teamwork and innovation for their projects.

The Department of Computer Science and Information Engineering in the National Chung Cheng University of Taiwan created a capstone course which integrates training creativity. This training involves workshops of management techniques provided by managers, of work experiences delivered by alumni and of sustainability and globalisation shared by industry experts. According to Hsiung et al., the results of a project-based learning in combination with creativity training showed enhancement in students' creativity skills [19].

3.3 Communication and Networking Skills

Communication for engineering universities is commonly conceived as oral and written technical skills. However, communication is no longer restricted to oral presentation and written technical reports, but involves interpersonal communication such as listening, compromising, understanding others point-of-view and discussion with others [20]. A study in the field of pharmacy in Finland showed improvement in communication competences by using practical training in real work situations, and feedback and communication between mentors and students [21].

As Kokkonen and Almonkari, we view networking as an interpersonal communication skill because networking is the ability to interconnect with individuals through initiated and maintained communication [20]. As shown by a study of Aerospace Engineering alumni at Delft University of Technology, it is essential to make students aware of the importance of networking and to enhance their networking competences which may open them to future professional opportunities [22].

Donell et al. [23] showed that there appears to be a disparity between the communication situations in the classroom and in the industry. Students are simply not able to switch when they enter a professional environment. In addition, the content of the communication courses may be too limited. Generally, communication courses in engineering curricula consist of a writing and a presenting course but typically do not involve listening exercises, intercultural communication, or observing, interviewing and meeting skills. This does not mean students are not exposed to these skills in project-based education but they are not formally taught. Whether feedback is offered, depends on the individual tutor, rather than this happening in a structured fashion.

3.4 Teamwork and Ways of Thinking

Working in teams is a vital skill in engineering. This was the primary reason it was added to the ABET criteria in 2001 [24]. We define teamwork as being based on collaboratively working in groups to achieve a goal. In teams, engineers are asked not just to think critically (i.e. to ask the right questions to formulate new directions to operate) but also to think interdisciplinarily (i.e. to collaborate and involve other engineering disciplines, humanities and social sciences) [13].

Master students of Aerospace Engineering at TU Delft have the option to attend a Forensic Engineering course which uses real-life based learning. This course consists of lectures and practical exercises, ending with a practical exam where students conduct an investigation and apply the forensic concepts learned during the course to find the cause of the accident. The results of this course show that students developed forensic knowledge, critical thinking skills, standard investigation methodology, hypothesis forming and interviewing [25].

At the University of South Australia, architecture and civil engineering undergraduates in a two-week course tackle a hands-on construction problem. The collaborative work and knowledge interaction between groups of 2 to 4 students of different disciplines, architecture and civil engineering students showed that students increase their multidisciplinary teamwork skills [26].

3.5 Lifelong Learning

Lifelong learning encompasses continuous personal and professional development. In a world full of changes and uncertainty in career paths, “learning how to learn” should be the goal of engineering studies in order to prepare students for constant and continuous learning [13]. To engage lifelong learning skills, the Center for Engineering Learning and Teaching at the University of Washington, provide a course where students are taught to plan their studies, to assess and monitor their learning, and recognise their strengths and weaknesses [27].

Lifelong Learning is becoming a key focus for many industries and governments alike. In order for a person to stay employed in their position they must be able to keep up with technological developments and changes in the way their industry carries out its business. An example is the retraining of the workforce at the Boeing Company for the production of the Boeing 787, Dreamliner. 2D Paper technical drawings were no longer used, only 3D computer models. The aircraft was to be manufactured primarily out of composites rather than aluminium. An intensive retraining schedule was created and successfully implemented [28].

3.6 General observation

Although many institutions eagerly implement transversal skills in their curricula with the aim to better prepare students for the labour market, a simple self-assessment of participants is often the only form of evaluation carried out. No longitudinal studies were found where students were followed in their years after graduation, or other forms of measuring the effectiveness of the skills education. This is an area that deserves serious attention in the opinion of the authors.

4 DISCUSSION

When examining the professional roles in the labour market of engineering graduates, a number of issues should be taken into account.

Firstly, in the 21st century labour market, the calls for interdisciplinarity grow louder and louder. In most cases, engineering graduates are no longer predestined to become part of an exclusive team of highly technical skilled peers but they are more likely to cooperate with colleagues from diverse professional backgrounds. This observation has important consequences for a research project focussing on professional roles of engineering graduates. In some roles, being part of an interdisciplinary team constitutes a fundamental aspect of the content of the role (e.g. project engineer) whereas for other professional roles the interdisciplinary scope is rather limited (e.g. service engineer).

Secondly, we should look at skills training. Previous research has shown that transversal skills are often not that role-specific [27]. They are needed for each role but with different emphasis. Also the effectiveness of skills training is hardly ever investigated beyond the point of self-assessment by the learners. It remains to be proven that exposure to skills training is effective but proving the gaining of skills is an area that has yet to be investigated.

Finally, of a more philosophical nature, we could debate the prime responsibility for a student's employability. Where does the responsibility of engineering education institutions stop and where does the student's responsibility takes over? Personal growth and career development are often considered a 'joint venture' between employer (e.g. through providing training opportunities) and employee (e.g. actively reaching out to new opportunities). For example, Colman and Wilmott [29] showed that 67% of the respondents (N=108) indicate that the development of soft skills for engineering graduates is a joint responsibility for both engineering institutions and students. Only 13% of respondents considered this only to be a responsibility for students. All partners of the PREFER consortium agree that engineering institutions should (1) give a first impetus to students' emerging self-awareness, and (2) contribute to students' empowerment potential for personal and professional growth.

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Decision Making Skills in Engineering Education

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ABSTRACT

There is a growing concern about responsibility of decision makers. Professional and personal life environments are more than ever Volatile, Uncertain, Complex, and Ambiguous. This system paper discusses decision making skills in engineering education along three complementary perspectives: Maths-based, Social-based, and Career-based. This review sketches the premise of a transversal decision skills learning outcomes framework for the continuous enhancement of engineering education programmes around decision making skills, and in line with the evolution of graduate engineering profiles.

Conference Key Areas: Engineering Skills

Keywords: Transversal skills, decision making, engineering and STEM education, learning outcomes.

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INTRODUCTION

Nowadays, the organizational reliability depends on the ability of the actors to organize and reorganize in order to anticipate and cope with unexpected situations, including skills of improvisation, creative bricolage, and attitude of wisdom [1]. The context of this system paper is the growing concern about responsibility of decision makers. The world is more complex, with multiplex of forces and no cause-and-effect chain. Whether they are to act as experts in STEM or other fields, future engineers should be specifically prepared to making decisions in VUCA environments (i.e. Volatile, Uncertain, Complex, and Ambiguous).

How to prepare future engineers to make more reliable decisions in VUCA environments and equip them with decision making skills in formal curricula? This paper first recalls accreditation requirements around decision making in engineering. Along three perspectives of decision-making (DM), it proposes specific learning outcomes applicable for educational programme design or realignments, and presents for each some active or experiential courses to meet relevant skills. The three perspectives considered are (i) Maths-based DM, (ii) Social-based DM, and (iii) Career-based DM. Unified for the three perspectives, the paper then discusses the opportunities of a transversal decision skills learning outcomes framework.

1 PROGRAMME OUTCOMES AND TRANSVERSAL SKILLS

1.1 Accreditation requirements

Decision is not only about knowledge, it is also about skills. Skills relate to the "ability to apply *knowledge* to complete tasks and solve problems. Skills can be described as cognitive (use of logical, intuitive and creative thinking) and practical (involving manual dexterity and the use of methods, materials, tools and instruments)" [2]. The ENAEE, which sets Programme Outcomes for Engineering Education accreditation in EU [3], introduced in 2015 priority in Decision Making and Judgment abilities. From now on, in Europe, the learning process should enable Master Degree graduates to demonstrate:

- ability to manage complex technical or professional activities or projects that can require *new strategic approaches*, taking responsibility for DM;
- ability to *integrate* knowledge and handle complexity, to *formulate* judgements with incomplete or limited information, that include reflecting on social and ethical responsibilities *linked* to the application of their knowledge and judgement.

In the CDIO Syllabus [4], decision analysis with uncertainty (ref. 2.1.4) and initiative and willingness to make decisions in the face of uncertainty (ref. 2.4.1) are requirements for personal and professional skills. Making complex technical decisions with uncertain and incomplete information is also a requirement for exercising judgment and critical reasoning (ref. 4.7.7). The European Qualification Framework, recalls at level 5 "competence to exercise management and supervision in contexts of work or study activities where there is unpredictable change"; and at level 6 "to manage complex technical or professional activities or projects, taking responsibility for DM in unpredictable work or study contexts".

1.2 Multidimensional and transversal Decision Making skills for Education & Training

Judgment skills correlates to DM skills. Psychological explanations describe inaccuracy in forecasting. The central theme is that most people use mental strategies called heuristics to cope with the complexities of making estimates. These heuristics can also lead to systemically biased judgments (e.g. over-optimism). Heuristics could thus lead to erroneous decisions. A new heuristic requires a learning time, if the environment is too volatile, actors will not have resources to mobilize adequate heuristics, leading possibly to dramatic consequences. Complexity can lead to information overload with effects on the DM process. Moreover, uncertainty and ambiguity have consequences on the level of performance. The conditions of VUCA environments strongly affect constraints the decision capacity. Ones has to understand VUCA characteristics and sources, and their effects on DM processes.

The concept of decision has multiple dimensions. For engineers, DM echoes in scientific methods (e.g. Math-based), human environment (e.g. Social-based), or even in professional pathways (e.g. Career-based). DM skills, been learned in one context or to master a special situation, are also transversal (i.e. “skills acquired in one context that, with adaptation, may be applied in another context” [2]). Students are to capture the multiplicity of contextual factors influencing individual and / or collective DM processes.

2 BACKGROUND ON MATHS AND SOCIAL BASED DECISION MAKING SKILLS

2.1 Foundational background: rationality and uncertainty

The giant leap in mathematical approach to DM is arguably in 1202 with the publication of *Liber Abaci* by Fibonacci [5]. The next year hundreds saw great improvements to standardize Decision Methods aimed at calculate future events as an attempt to minimize risk. DM skills from mathematical viewpoint are originated in gambling: the player constantly estimates his/her chances of winning or losing. The field of decision analysis, originally mostly a mathematical discipline, has evolved into a useful method for industry and government. The core of the method is to help decision makers gain a greater understanding of the problems they face, both quantitatively and behaviourally. The expected utility theory, game theory and decision theory are important to understand how politicians and other stakeholders behave under condition of uncertainty and how decision models are constructed. But the limitation of the classical approach to probability in the context of decision theory is that the prediction of the outcome of a single event is based upon events that have already occurred, based on empirical evidence. However most decisions are disposed to the uncertainty of events that have not yet materialized. Expected value (or, where appropriate, utility) is the metric value of decision theory. The highest (or lowest if the assessment is cost related) expected value of a decision process is the best option in a portfolio of options, when all possible outcomes have been accounted for, with weights (probabilities) indicating the chance of occurrence (uncertainty).

People are not always rational and they do not always think about maximizing their own interests. Taleb [6] claims that the fundamentals of using probability distributions for estimating the impact of events on outcomes are idiosyncratic. This leads to what Taleb calls ludic fallacy for explaining the drawbacks of using the basic axioms of probability to estimate future uncertainty. Students are to understand the scope and limitations of mathematical decision-making methods and of computing tools.

2.2 Irrationality and VUCA contexts: reliability

There is no simple explanation for decision which seem sometimes irrational. There are limits to the cognitive and information-processing capacity we can devote to any judgement. Technical explanations cover inaccuracy in terms of project uncertainty, unreliable or out-dated data and the use of inappropriate forecasting models [7]. If sociological factors play a role, it is only a limited role. Both perspectives (economic and psychology) also focus on individual behaviour rather than social processes. However, sociological forces interact with psychological forces and will affect individual behaviour if groups act without any clear coordinating mechanism. In reality, on the interactions between individuals and groups in a social learning context, group forces and group motives are important, reflecting not only conformism, social imitation or conscious identification with group but also group-centred goals and behaviour.

The most fundamental capability of human beings is arguably conscious decision-making. Such decisions are made in non-emergency situations but often under a high degree of uncertainty (where uncertainty can be defined as the subject's conscious lack of knowledge about an object which is not yet clearly defined, in a context requiring action for decision). But in VUCA contexts, dynamicity and emergency are in the place. Mechanisms to detect early signs of crisis and react early enough are required. This point is a key element of High Reliable Organizations (HRO) [8] which seeks to understand the normal functioning of human-based decision systems by identifying the characteristics of HRO and explaining their exceptional performance. To reach a higher level of reliability, Roberts recommends flexibility in the decision-making process. Weick [1] identifies three characteristics of HRO in contexts where the error is unforgivable: information overload, constant turbulence, and increasing complexity. Unlike other theoretical frameworks on reliability (e.g. Theory of Normal Accidents), the HRO and Actionnist currents have even the specificity to consider human behaviours as a source of reliability rather than failure. These organizations are able to create and maintain a state of collective watchfulness thanks to the quality of the interactions between their members [9]. Weick mentioned that respectful interactions, a system of roles, improvisation, and watchfulness are the four sources of reliability. A work on VUCA conditions from this theoretical works is supposed to answer the limits faced by maths-based decision making methods. The authors suggest to use this approaches which take into account VUCA parameters, as active learning courses.

3 LEARNING ACTIVITIES

3.1 Active learning activities

As course examples, In France, ESSEC Business School created the MOOC "*L'avenir de la decision : connaître et agir en complexité*" (Edgar Morin chair, https://fr.coursera.org/learn/lavenir-de-la-decision), composed of videos and lectures, including knowledge oriented courses. Aside, student may learn from real experiences, to develop and reinforce their decision competencies. In another context, in Spain, there are on-line university courses in decision engineering such as that given by the Rey Juan Carlos University of Madrid [10], to learn to make the best decisions with less time and to analyse them in a globalized world. With these courses, students are expected to improve the quality of decisions taken and, consequently, improve the results of decisions.

Various pedagogical models exist to foster collaborative dimensions and practical skills in formal STEM curricula (e.g. Problem-based learning, project-based learning).

In formal curriculum, the Disaster Week, initiated at Reykjavik University [11], exposes students to real-life engineering, as a multidisciplinary introductory course. With one week of team work, students are to develop an action plan for dealing with an unforeseen event of some complexity, demanding DM, fast based on incomplete information. Topic includes a natural disaster, e.g. a potentially devastating epidemic in Iceland or a volcanic eruption with the lava flow towards the city. This style of learning enforces the importance of teamwork, the need to gather information quickly, and one has to make decisions fast based on incomplete information. It permits to meet intended learning outcomes for freshmen around Maths-based DM.

At IMT Atlantique, French graduate engineering school, the Springfield serious game exposes students to real cases in order to show the complexity of actions and decisions in risky situation. The context is an accident which occurred in a nuclear plant. Each player has a specific role, with specific objectives and information (a plant manager, a safety engineer, and operators). Players have to work together in order to save the plants. In debriefings, students explain their behaviour and decisions.

3.2 Towards experiential learning activities

Future graduates are to be able to turn knowledge into skills, especially in DM. The complete development of a competence is better covered by various integrated learning activities, including real experiences or work-based learning models. For DM skills, in all its dimensions, experiential and cooperative learning is the key for Teaching & Learning innovation. Some courses permit to show by experience that DM is a complex process, particularly when the decision leads to irreversible consequences.

Still at IMT Atlantique, an inter-semester course (2 ECTS) trains students to take decisions and react in unexpected and unpredictable situations [12]. Using an experiential learning model as proposed in the French Naval Academy, the one week course has some outdoor elements in the sea environment for novices. The real experiential situations so selected reflect nautical risk scenarios with levels of complexity and time pressure (including Man Over Board exercises, cf. Figure 1), where specific decision skills are to be acquired or reinforced, such as risk and priority management, watchfulness, team management with respectful interactions, judgement and responsibility, etc. Participants also have to prepare a navigation (weather, equipment, refuelling, practical information), plan the stages, estimate the navigation times, the possible risks and dangers, prepare the most delicate passages, prepare fall-back solutions and identify success factors. Just like a project, the success of a sailing cruise requires a certain number of technical and human skills. In these real situations, flexibility constitutes the sources of reliability and performance. These in-context experiences are to be useful in an engineer career where responsibilities increase (e.g. decision-makers to face complexity, uncertainty and urgency). A first experience, as a non-expert from the environment, may create a learning-loop for future work-based situations including improvisation [1].

The experiential scenarios proposed rely on theoretical frameworks dealing with reliability. They use the four sources of reliability as assessment criteria and include situations with a high level of complexity, uncertainty, and time pressure that future decision makers are supposed to face in their future professional activities. As learning outcomes, the learning process should enable graduates:

- to tackle moral, ethical, and social issues of a situation;
- to identify sources of uncertainty, face complexity and continuously recognize and qualify the criticality of a situation, inc. its events and factors;

- to accept uncertainty, fix priorities and formulate judgment on situational events individually and collectively;
- to react flexibly to events and regularly assess the weight of an error in the DM process;
- to take initiative and responsibility on choices and actions during the situation, and reflect from experiences in order to increase resilience.

In [12], empirical evidence on motivational factors have been first analysed qualitatively. Based on direct observations and experiences, quantitative analysis is under investigation to determine how to better prepare future engineers to make more reliable decisions in VUCA environments. One's and team's DM skills are thus formalized in program components, as transversal, with aforementioned learning outcomes and VUCA-based progressive proficiency levels. Design-based research methodology is also under consideration in order to conceptualize experiential learning activities and iteratively analyse learner achievement and program coherency and framing.

Fig. 1. Collective urgent rescue.

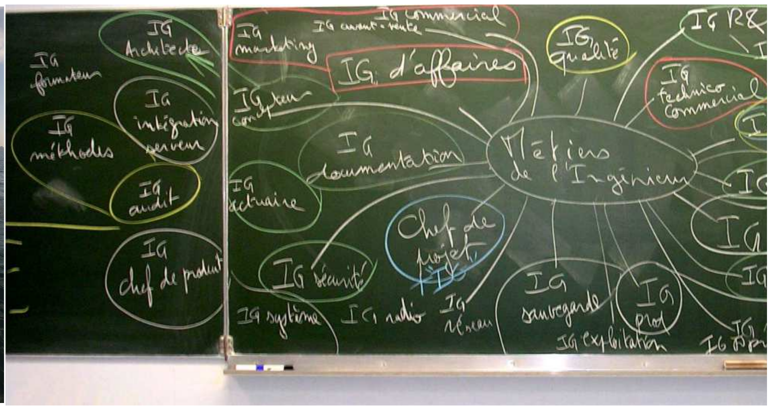

Fig. 2. Job map, from [14].

4 CAREER BASED DECISION MAKING SKILLS

Investigations on courses including progressive VUCA circumstances should also facilitate the integration and career paths of young engineers in their professional life and workplace. Engineer diplomas greatly facilitate first job offers and open up on broad career possibilities in many economic fields where engineers may often exercise their potential as leaders and future decision makers. However, uncertainty and indecision often result from student appraisal of the career kaleidoscope. Some struggle to identify career directions and therefore need some time before feeling committed and being operational within their curriculum and first jobs. The European Lifelong Guidance Policy Network (http://www.elgpn.eu/) regards career management skills as competencies which help individuals to identify their existing skills, develop career learning goals and take action to enhance their careers.

It is thus critical to reinforce students' self-confidence, especially when considering that the recruitment market is becoming more and more demanding and competitive for newly graduated engineers. Students' perception of a profession can strongly influence their career choices. In addition, yet many students who have had only limited exposure to a profession may base their decisions on limited or distorted perspectives, for example a single internship or co-op experience, both positive and negative [13].

It is essential to provide students with means which will enable them to participate actively in their own learning and develop a long-term aspiration for future career paths. As learning outcomes, the learning process should enable graduates:

- to know oneself and analyse his/her set of skills;
- to gather information, identify options, and explore career options;
- to recognize and define one's choices;
- to define career paths, to plan and evaluate them, to select options;
- to gain flexibility and propose a coherent professional project inc. career orientation, and to combine personal development therewith.

Traditionally, educational institutions design career preparation programs which focus on making their students more attractive to potential employers. As example, in a University context, the Department of Guidance and Professional Insertion of the Foundation University-Enterprise of the Balearic Islands has realized the Occupational Guidance and Occupational Assistance Program. This non-compulsory program aims to guide and improve the possibilities of self-employment of the university graduates and students who are seeking employment. Concretely, it permits to improve employment opportunities by designing a personalized itinerary for job placement. This personalized itinerary consists in the realization of individualized sessions of professional orientation: how to properly take decisions to get a job, how to apply for a job interview to get an employment. Students learn the ability to make the right decisions from the individualized orientation sessions. At IMT Atlantique, a compulsory 63h career preparation course is in place since 2007, to disclose to students, via active workshops over three years, their career perspectives, enable them to participate actively in their own learning path, to build their future professional identity, and to plan proactively their future career [14], in VUCA workplace contexts.

5 SUMMARY AND ACKNOWLEDGMENTS

In a rapidly changing world, the VUCA context requires now to rethink the vision for engineering education [15]. As seen today in the European society, the nature and dynamics of change creates unpredictability and future engineers are to manage complex situations with critical reasoning. Professional life environments are more than ever VUCA. This context makes decisions even more strategically critical. To prepare future engineers to make more reliable decisions in VUCA environments best benefit from experiential learning models, progressively all along a curricula, with a transversal skills approach. As Le Boterf defends it [16], a skill is only effective once it has been tested and validated thanks to its confrontation to reality. This system paper tends to thus support the coherent inclusion of active and engaging pedagogical models, with DM as a transversal skill, in association with three complementary and unified perspectives including learning outcomes:

- Maths-based DM, with rationality;
- Social-based DM, including people's interdependencies and social identities;
- Career-based DM, according to own career path.

A dedicated decision framework is to provide support for faculty staff to improve student competence in decision skills, interwoven with the learning of disciplinary knowledge and its application in professional environments. Mastering of these skills is to be assessed by various stages of complexity, e.g. partial application, realisation, adaptation to various VUCA situations, and anticipation. Societal responsibilities are elements of DM and included in the three aforementioned perspectives. In fact, good decisions rely on many factors, context-dependant. The DM learning outcomes are to be indicated to provide a pragmatic guide to deal with the pressing ethical and social considerations. The aim is to ensure that students are educated, trained, and empowered to prioritize ethical and social considerations in their decisions, diminishing negative consequences in their future work, professional itinerary, and personal life.

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Innovation engineering project in collaboration of three international universities

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ABSTRACT

Innovations are a prerequisite for enterprises in order to be successful and competitive in fastly developing markets demanding interdisciplinary development of complex products. The education of engineers in universities has to enable them to deal with these challenges and growing international cooperation in most business areas.

A consortium of three universities of applied sciences (UAS) from Finland, the Netherlands and Germany has agreed to advance their curricula by these demands and to set up an international collaboration of a group of universities and companies to educate students in projects that teach them how to develop innovation in collaboration with companies.

This paper describes theoretical background, the setup and the planning process of this project.

Conference Key Areas: Engineering Education Research, Curriculum Development, Continuing Engineering Education and Lifelong Learning

Keywords: *Project Learning, Design Education, Interpersonal skills, International Collaboration,*

1 INTRODUCTION

Actual and future markets in a globalized world challenging companies in all fields of technology are developing their portfolio fastly. Therefore innovations (= new and economically successful products [1]) are a prerequisite for enterprises in order to be successful and competitive in these markets. Furthermore most products require the interdisciplinary combination of e.g. mechanical, electronical and software components. Companies not only have to know their area of expertise but also to be able to adopt quickly to a changing environment, open up new markets as intrapreneurs (= persons working within the company having entrepreneurial capabilities) and possibly developing lead innovations worldwide.

These tasks challenge the Innovative, Interdisciplinary, International, Intrapreneurial and Interpersonal (= $\mathbf{i^5}$) skills of engineers and universities of applied sciences have to be able to educate especially engineers to fulfil these requirements. Engineers have to be able to command the entire chain from the first idea up to the product in the market. This chain includes product development, production and marketing.

When observing the curricula of engineering education within Europe, it can be seen that this kind of skills hardly, or not in coherence to each other, is implemented. A consortium of universities of applied sciences (UAS) from Finland, the Netherlands and Germany has been setup to get more experiences implementing these aptitudes in their curricula. Starting graduates are being positioned in key roles in SMEs and there they can help Companies to develop meaningful innovations. UAS (universities of applied sciences) therefore need to decide to adopt in their curricula i^5-competencies to these needs and to set up an international collaboration of a group of universities and companies to educate students in projects that teach them how to develop innovation in collaboration with companies.

The basic idea is to set up a mixed group of students from all three UAS, give them an innovative development task from a company. This is important especially in the case when the graduated engineer is employed in a small and medium sized enterprise and in the case when the young engineer creates his/her own company. In bigger companies there is always need to find new managerial potential to be trained for higher management. The first implementation of the setup is planned in spring 2018.

This paper describes theoretical background, the setup and the planning process of international design projects in cooperation with companies, their allocation in the bachelor programs of mechanical engineering at the Universities of Applied Sciences in Oulu, Eindhoven and Ulm. Experiences in planning process and consequences will be drawn up for future education of engineers.

2 THEORETICAL FOUNDATION

Outstanding Mechanical Engineers are essential for enterprises in order to develop new and successful products for actual and future markets. Thus universities all over the world are challenged by industry´s demand for ideally ready-for-practice engineers coming out of study programmes and to orient their study programmes on the actual needs of industry in the area. Curricula have to be extended beyond deep knowledge of “the fundamentals” of professional engineering and the ability to apply it in practice that is taken for granted by most employers.

These requirements have also influenced accreditation criteria, thus study programs in mechanical engineering should ensure, that students “apply principles of engineering, basic science, and mathematics …; to model, analyze, design, and realize physical systems, components or processes; and prepare students to work professionally in either thermal or mechanical systems while requiring topics in each area” [2].

After finishing mechanical engineering programs, students must be able to work professionally in an engineering environment and to “identify, formulate and solve engineering problems” under typical boundary conditions and to apply and extend their knowledge independently [2].

To fulfil these criteria, professional engineers ideally should have an “entrepreneurial” spirit and some skills beyond pure technical knowledge, here described as the i^5 skills based on Geraedts [3], Fig. 1. The authors therefore aim at integrating these skills into their study programs.

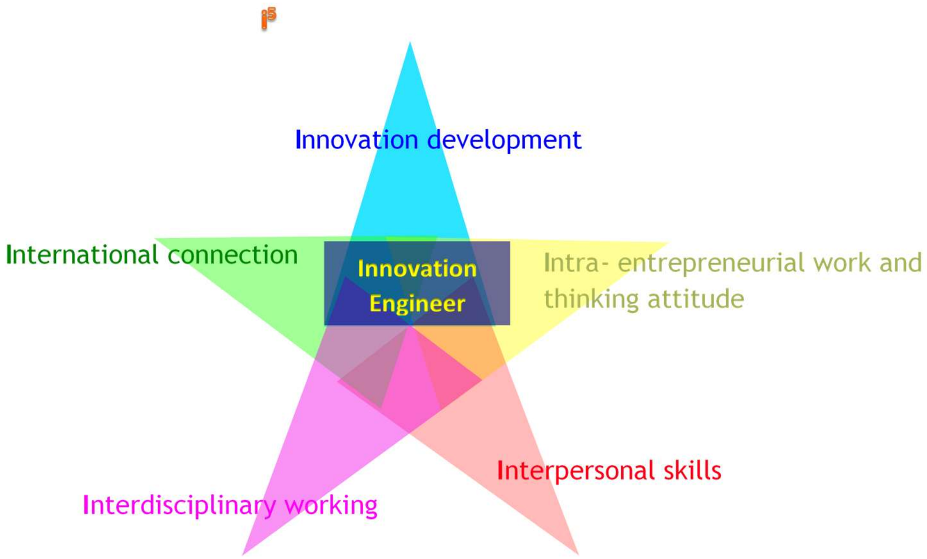

Fig. 1. i^5 – Approach [3]

- The development of **innovative** products deserves that mechanical engineers must acquire basic knowledge about patents as well as methodological approaches in developing innovative products. The importance of these abilities is stressed intensively in literature [4], [5], [6]. This ability is strengthened by project tasks that are based on largely untackled problems taken out of the “real world”.
- Entrepreneurship is important both for the development of national economies and for career of young engineers. Entrepreneurial thinking is not only important for founding new companies but also for the long-term development of existing companies, here called "**Intrapreneurship**". Nevertheless, entrepreneurship as “process of transmitting entrepreneurial knowledge and skills to students to help them exploit a business opportunity” [7] it is rather rarely taught in engineering programs. There are approaches to add this knowledge by extra-curricular activities [8] Expanding lectures by teaching basic questions of company foundation, project tasks requesting parts of it like setting up a business plan, visiting fairs, presenting ideas to potential sponsors or even providing a business

incubator as a university are possible targets of projects in engineering programs.

- **Interpersonal** skills include advanced knowledge about communication within teams, companies or towards customers and public, team leadership and other skills needed for successful implementation of complex projects [9]. Engineers have to be able to arrange duties and to ensure their performance, to create an open minded atmosphere within the teams, to recognise and improve their strengths and weaknesses and to cope with conflicts. Methodical competences particularly include the ability to recognise and analyse technical problems, to plan a way to solve problems, find an adequate solution and to reflect the chosen approach critically. They can be encouraged by setting up a realistic and challenging environment for student projects e.g. in cooperation with companies.
- Modern technologies are typically **interdisciplinary** and involve the combination of knowledge and technologies from diverse disciplines. Engineers must be able to determine the interfaces between their area of expertise and other disciplines and to define these interfaces, their interdependencies and their mutual requirements. Therefor they must have a basic knowledge of neighbouring disciplines, to be able to understand project partners from other disciplines and to communicate successfully with each other. Project tasks for mechanical engineering students should include aspects of other disciplines like economy, software engineering, electronics or even ethical or social disciplines.
- In an increasingly globalized economic world engineers need **international** experiences to be able to communicate with customers and project partners all over the world. This requires not only to improve language skills but also to support students in gathering intercultural knowledge and the ability to cooperate in international teams or internationally distributed projects. The most effective way of obtain this experience is working in foreign countries, which is difficult to generally integrate into study programmes. Alternatively an increasing number of universities launch “internationalization at home” as a substitute by lecturing in foreign languages (preferably English), inviting guest teachers from foreign countries or involving international students in their study programs. The approach of the project described in this article is to or organize international projects in cooperation with partner universities or companies from other countries.

Based on these foundation, the partner universities decided to set up a collaborative student project that is targeting at teaching students the i^5- skills.

3 OBJECTIVES OF THE PROJECT

The collaborating universities started cooperating in exchange programs a couple of years ago and are regularly comparing their educational approaches and their study programs. They realised, that several objectives support the needs of all partner universities and partner countries. From the point of view of universities, goals are:

Educational objectives:

- Enhanced curricula with a focus on i^5
- Implement innovation and entrepreneurship oriented education
- Evaluate new ways of teaching in universities
- Strengthened education oriented on the actual needs of industry in the area
- “Internationalisation at home” as an enabler for international experience for students

Collaborative objectives

- Increase the number of students and staff involved in international activities and mobilities
- Anvance existing cooperations between universities, companies and institutions
- Improve the qualitiy of interantional collaboration between universities and companies
- Demonstrate new ways of collaboration between companies and increase and internationalise cooperation with companies of different sectors and sizes
- Include company staff in international activities

Entrepreneurial objectives

- Encourage and enable students to innovate and achieve patentable ideas
- Encourage students to start entrepreneurial activities
- Strengthen intrapreneurial abilities of students and within universities

Industrial and organisation partners target at **collaborational objectives**

- Lower the barrier of SMEs to start collaboration with universities
- Start sustainable collaboration between universities and companies
- Aim at high quality of collaboration between companies and universities
- Build up international contacts and collaboration to universities and companies
- Support sustainable innovation activities in SMEs
- Support entrepreneurial companies in expanding their portfolio
- Strengthen intrapreneurial abilities within companies
- Recruitement of talented students
- Learn from quality-assured systematic innovation projects how to improve the development process within the company
- Facilitate innovative ideas for the development of the company
- Build up connection to universities and to expert knowledge
- Achieve patentable ideas and competitive advantages

Prior to this project, OUAS (Oulu University of Applied Sciences) and FUAS (Fontys University of Applied Sciences) have executed, just the two of them, several project where students have searched for an idea, created a concept, realized the design and built the prototypes. The student groups have been a combination of students from both universities. In that project, the students have not made proper business scrutiny. In the project of this research, the idea is to widen the work to cover preparing to the production and marketing, as well. Also, the financing of the entire product process will be taken into account. The project group will not only be students from different universities, but from different disciplines as well. The guidance of the project will be performed by university teachers together with the professionals from businesses. In this way, students will reach a feeling of real business and entrepreneurship. Along the project, the students can experience the holistic chain from the search of an idea up to the market. They learn also how to work internationally. In this connection the communication in the working group and in meetings is one big subject and use of digital communication technology as well. It is not only technology they learn but also how to work professionally with people who have been educated in different countries in different sectors like in business and technology as well as in different methods.
Because the length of the project will be three years, it is possible to follow the whole chain. After this kind of experience, students are more ready to take a responsible position in a company having own products. The position of product manager is especially suitable for an engineer possessing this kind of special education.

4 SETUP OF THE PROJECT

Based upon the objectives of the project, the project partners decided to set up a project-based learning environment to allow the successful integration of **i⁵** key competencies in undergraduate courses for engineering design students. The setup of the project is shown in Fig. 2.

The general aim of the project is to create a model to realize engineering and business education into the direction of innovations and entrepreneurship in technology sector together with enterprises. Thus each partner university cooperates with 2 companies to ensure close contact to industrial practice and a real entrepreneurial environment where students work in real development projects together with employees from businesses.

The main task of these participating industrial partners is to offer project ideas and to accompany the students during the solution phase to bring in a realistic environment. The project setup is completed by institutional partners like the chamber of commerce and a patent office to add information about the handling of innovations and chances of entrepreneurs.

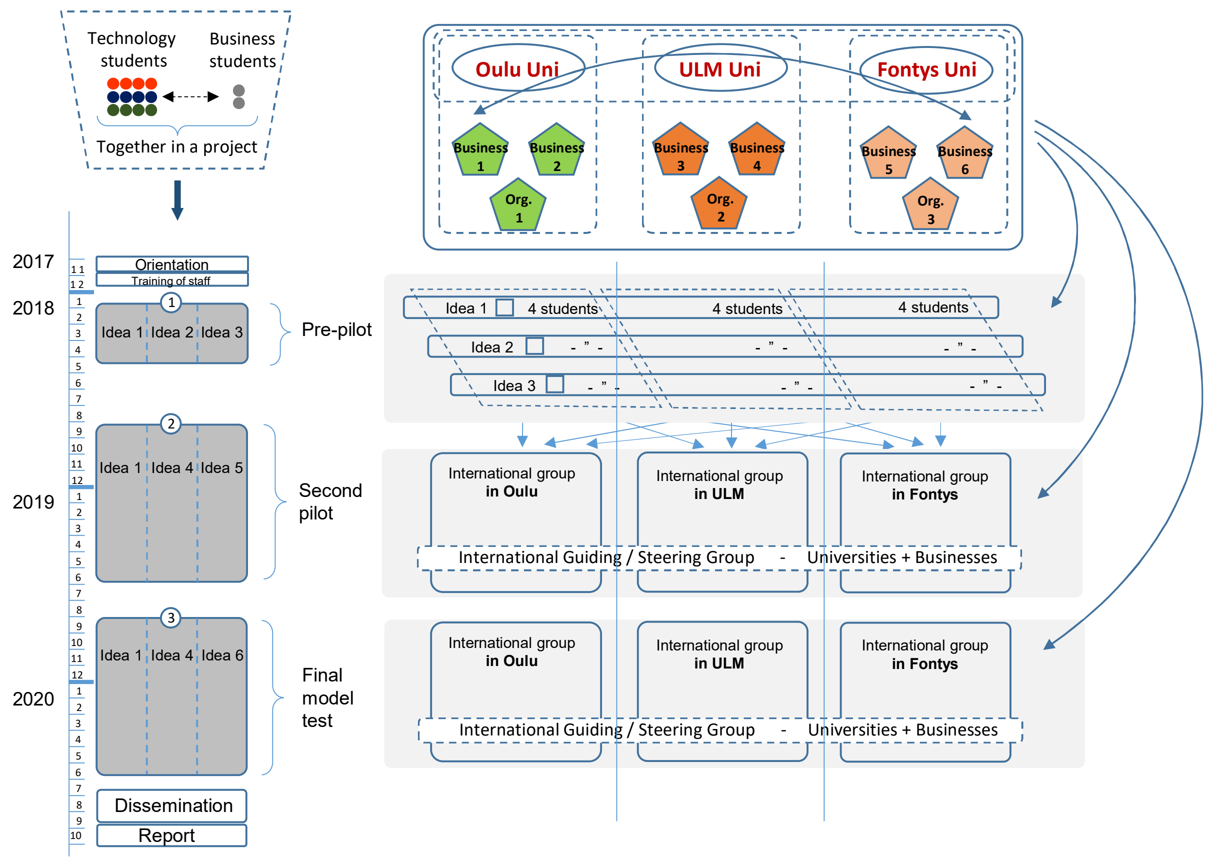

Fig. 2. Project setup

The project is carried out in technically oriented study programs, but will involve business students in all universities as well. The students will be organised in groups of 12 students from all 3 countries (4 from each country) and therefore have to cooperate in an international environment and to handle distributed product development. Their task is to solve a problem from a basic idea of a solution to prototypes and if it comes up along the development process that the idea is on the way to real market the development work will be continued as far as it is possible in the time limits of a student project. The idea is to start shorter projects that can be solved within one round of the project and more complex tasks that need to be handed over to other group(s) in following project rounds to complete it. An idea can be also students' own, so that they will be supported by an industrial partner and institutions to develop their idea towards a real market. It is one goal of the setup of three project rounds to find out what kind of framework is most valuable for the students.

The development projects start with kick-off-meeting of all students and representatives of companies and institutions in one of the partner countries. Students can choose an idea that will be formed to a concept that is worth to develop further. They can form their teams, clarify open questions, make up a time plan and share the tasks and then continue the design work in their home universities and continue a virtual collaboration using digital media.

It is planned to involve not only technical students, but also business students to develop a business model around the coming product, conduct a survey about the market situation, clarify economical demands or the profitability of the product. All the actions on the way from the idea to the market will be identified and evaluated from economical point of view. This examination supports the technical product development decisions as well. Additionally, the business students analyse different financing possibilities that are available to realize the total innovation process up to market. This total view teaches technical students to understand the economic framework of innovation and business students to understand the technical problems on the way form an idea to a product.

During the project students also gain experience in working in international multicultural groups by guidance of business professionals. The result of the development work will be presented and professionals make an evaluation on it. Performance of students will be assessed and grades will be given regarding these evaluation. Students will be asked to write learning diaries to collect their experiences and evaluations of learning during the project.

Teachers of universities and representatives of companies will make evaluation about the project from an educational point of view. This will help to improve the project setup after the first pilot phase. Based on that an improved model to realize the next student project PILOT 2 will be done. At the moment it is planned to carry out 3 pilot phases and then transfer the experiences into a final model to be used in continuous practice in the partner universities.

5 CONCLUSION

This contribution describes the idea, the theoretical background and the planning of an international and interdisciplinary educational development project carried out by 3 European universities. The main idea is to integrate students of universities from different countries and to give them an innovative development task provided by industrial partners to create a realistic environment. In the next step, the idea will be implemented and results will be presented in future conferences.

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Teaching the management of innovation to engineers

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ABSTRACT

The literature on the management of innovation has strongly emphasised the need for a complex and wide set of competences to successfully manage technological innovation within companies. This paper provides eight years of experience teaching industrial engineers how to integrate technical and non-technical skills in the management of technological innovation. The paper presents the experience of a design based learning course for industrial engineers concerning the New Product Development (NPD) process. The course has been offered to around 400 master students. As an initial result, the paper proposes a model for designing courses on innovation and new product development, useful for engineering schools. In addition, our study suggests that design based learning (DBL) seems to be effective for developing the ability to integrate technical engineering and non-engineering skills, and for developing professional "soft" skills, as well. The DBL approach seems to be less effective for supporting the specialisation of technical competences.

Conference Key Areas: Engineering Skills, Attractiveness of Engineering Education University-Business cooperation

Keywords: Innovation management, Engineering skills, Managerial skills, Organizational skills

INTRODUCTION

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The literature on the management of innovation has strongly emphasised the need for a complex and wide set of competences for successfully managing technological innovation within companies [1] [2]. In fact, along the innovation funnel, several competences, other than engineering ones, become critical: managerial, organisational, and relational competences are especially relevant. This is also confirmed by the many empirical studies that bring into evidence that the high failure rate of technology-based start-ups is mainly due to a lack of managerial competencies, rather than to a lack of financial resources or technical competences [3].

A way to face the problem is to provide engineers with the necessary skills to effectively communicate with other people. At times, this has been interpreted as the need to introduce “soft” skills, and/or “professional” skills [4; 5; 6]. We argue that some of the complementary skills necessary to engineers to successfully manage technological innovation are not only the “soft” or “professional” ones. Engineers also need the “hard” skills related to economic, financial, organisational and marketing matters. This paper provides eight years of teaching experience aimed at providing industrial engineers with the tools needed to integrate technical and non-technical skills in the management of technological innovation.

Starting from an analysis of the innovation process within companies –called the “innovation funnel”- the set of competences necessary in each phase of the funnel was identified. Then, in coherence with the results of this study, a program was defined for teaching the management of innovation to engineers, not only in terms of topics to be introduced, but also in terms of teaching methodology. Active learning was considered the best way to ensure the actual integration of technical and non-technical competences. It is not simply a matter of juxtaposition of competences, but of integration [7]. Students were asked to generate an idea for re-designing an existing product and to actually design the development, manufacturing and commercialisation phases of the innovation process. They were also asked to present and discuss their work with a committee of external experts who were able to evaluate the industrial feasibility and quality of their projects.

The paper explores the results achieved by around 400 students involved in the program whose work was evaluated by external experts in terms of real ability to integrate technical and non-technical skills.

The paper is structured as follows: section 1 gives the theoretical background; section 2 clarifies the research question and the context of the study; section 3 describes and discusses the study results; section 4 gives some final conclusions.

1. THEORETICAL BACKGROUND

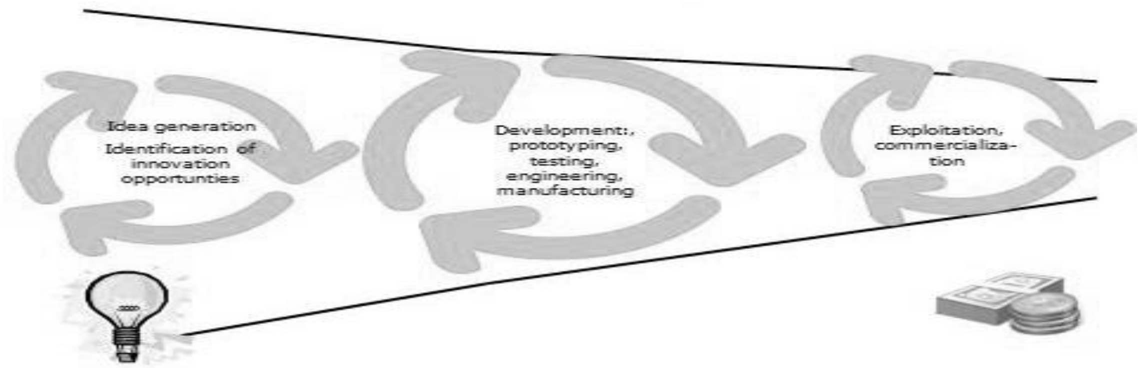
The theoretical background of this paper relies on two fields of study. Research on the management of innovation was investigated in order to define the set of competences needed by engineers in order to successfully contribute to innovation processes. Research on active learning is the reference for defining the methodology of the teaching program.

1.1. Innovation as a managerial process

Technology innovation as a managerial process can be dated back to the ‘80s and ‘90s, when innovation started to be considered an endogenous variable for companies. Before that, in neoclassical economics and traditional industrial economics, technological innovation was mainly conceived of as an exogenous variable. As a result, managerial problems were related mainly to internal R&D

efficiency and information gathering. During the '80s, within the evolutionary economics approach [8], and especially in the ‘90s, within the resource-based [9] and the competence-based approaches [10], technology innovation became a managerial process that needed to be properly managed in order to support a company’s long-term success. This literature also brings into evidence the relevance, for both the individual and the organization, of how learning, competences and skills are fundamental determinants of innovation.
In its Oslo Manual [11], the OECD defines innovation as “the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational, method in business practices, workplace organisation or external relations.” It describes innovation activities as “all scientific, technological, organisational, financial and commercial steps which actually, or are intended to, lead to the implementation of innovations.” It is thus evident that the management of innovation requires a wide set of competences.
Moving from a general definition, technology innovation within companies can be represented by the innovation funnel [12] shown in figure 1.

Figure 1. The innovation funnel [12]



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The innovation funnel includes a phase of investigation of new ideas and technological opportunities, after which the development of an innovative product and/or process and/or service is developed. All along the funnel there is a selection process, according to which ideas and opportunities are gradually screened and selected according to strategic, technical and economic criteria. For many reasons, the innovation funnel takes specific characteristics. So, its slope, total duration and the specific activities conducted in each phase can change significantly.
It is important for companies to be able to properly manage the whole funnel, as the return of all the investments are actually achieved at the end of the funnel, when something new is commercialised. Certainly, technical competences that focus on the specific object of innovation are necessary to successfully manage the innovation process, but they are not sufficient. In order to draw economic benefits from innovation, creativity, problem-solving, economic and managerial skills, marketing know-how and tools are fundamental as well [1].

1.2. Active learning for the management of innovation

Teaching innovation is not only a matter of contents, but also of methods. The literature proposes even the concept of Innovation Pedagogy, a learning approach based upon constructivism that “utilizes academic staff innovation competences and ensures students’ active involvement in innovation processes” [23]. According to innovation pedagogy, active involvement of students is necessary to link academic skills to practice. Reflections on the methods for teaching innovation also come from the field on entrepreneurship learning [24; 25]. This stream of literature confirms the need for active learning in order to "train individuals to act entrepreneurially" [24]. In particular, teaching innovation and entrepreneurship to engineers poses the problem of providing them with the necessary business and cross-disciplinary skills, especially in a global competitive context [25]. And that requires a balanced learning approach including classes as well as exercises, fieldworks, involvement in actual projects. Active learning refers to all teaching approaches in which students are directly engaged in learning activities [13], including problem- and project-based learning [14]. Active learning is recognised to be particularly relevant for supporting the acquisition of skills such as team working, conflict management, problem-solving, communication, and coordination [15] [16]. Within the several approaches to active learning, Problem-Based Learning (PBL) stimulates the acquisition of inquiry skills and the integration of theoretical knowledge by engaging students in solving ill-defined, open-ended, interdisciplinary problems [14] [17]. Among PBL approaches, in DBL students are involved in a project-planning process, in which they are assigned the task to develop an end product, an object. Such an involvement is thus characterised by the six features described by Wijnen [18]: professionalization, activation, co-operation, creativity, integration, and multi-disciplinarity. DBL is an active learning method in which "students gather and apply knowledge while designing creative and innovative practical solutions" ([17]. All the characteristics described above make DBL especially suitable for teaching the management of innovation to engineers. Indeed, DBL allows for achieving and integrating interdisciplinary competences, of both the technical and non-technical sorts.

2. RESEARCH QUESTION AND CONTEXT OF THE STUDY

2.1. Research question

Starting from the premises drawn from the literature with regards to the multidisciplinarity of innovation management and the suitability of design based learning for such a topic, the research question becomes: how can a course on the management of innovation for engineers be designed? Two sub-questions arise: How to identify the appropriate set of competences? and How to design a learning method able to foster the integration of the required technical and non-technical skills?

2.2. Context of the study: the course on Industrial Design

The questions were studied in the context of a course for graduate students in industrial engineering, which was designed and launched in 2007 at University Cattaneo in Italy and monitored over an eight year period. The course is dedicated to a specific type of innovation: NPD [19] and it is labelled "Industrial Design". It is held within a master program on Industrial Engineering and it is offered to interested graduates in industrial engineering, or any technical engineering field (bio-medical, mechanical, electronic, etc.). NPD is the process that leads to the commercial launch of a new or improved product onto the market. The course is thus aimed at teaching students how to successfully identify an idea for a new (or improved) product and how to manage it until its launch onto the market. It is given at the end of the master program and thus provides students with the opportunity to exploit all the competencies acquired in their previous courses and to integrate them with those specifically concerned with innovation management, having a strong practical focus.

2.3. Course design: competencies

To identify the set of competencies needed by engineers to manage the innovation process, we started from the innovation funnel and the related activities, with specific reference to the NPD process. In coherence with Eppinger and Ulrich [19], the funnel of the NPD process can be conceived as composed of four main phases: concept development, product design, process design, and commercialisation.

The early phases of the NPD process are concerned with idea and concept generation. In this part of the funnel the market and the competitive environment are investigated in order to identify potential unsatisfied needs. The technological environment is also investigated, in order to identify technological innovations and trends potentially useful for market needs. In coherence with the market and technology investigation, a first tentative design of the new product is put forward, which is then tested and experimented by means of models or prototypes. The commercialisation of the new product should also be conceived in terms of target pricing and distribution channels, as these strongly influence the product and process design phases. After the concept design phase, the phase of development includes the engineering and the manufacturing phases, i.e, product design and process design. In the product design phase, the product's architecture, components and subsystems are defined, together with the final assembly scheme. Simultaneously, suppliers are identified and cost analysis is conducted. In the process design phase, the tools and machineries to be used in the production process are defined, together with the procedures for quality assurance and process control. As the NPD process should generate value for the company, a Business Plan of the whole initiative must be provided to decision makers, who must synthesise not only the main features of the products, but also its impact on the company’s revenues and costs. This certainly influences the definition of price, and of all the costs of the manufacturing and commercialisation processes. The various phases of the NPD process are not strictly sequential: the concurrent engineering approach suggests, whenever possible, to conduct them partially in parallel, in order to exploit feedback throughout the different stages and anticipate problems.

The set of competencies necessary for the NPD process are synthesised in table 1. As can be seen, the course of Industrial Design was organised in four sets of contents: concept development, product design, process design, business plan.

Table 1. The NPD process phases and the related competences

Phases of the NPD process competencies	**Concept development**	**Product design**	**Process design**	**Business plan**
Technical engineering competencies	Technical know-how about the specific product; product modelling; prototyping;	Technical know-how about the specific product (materials and functionality); manufacturing technologies, assembly issues;	Technical know-how about the specific product; manufacturing technologies, assembly issues; quality issue; control issues;	Technical know-how about the specific product;

Technical non engineering competencies	Competitive environment strategic analysis; technology intelligence; marketing	Cost analysis; management accounting; supplier evaluation; purchasing	Cost analysis; management accounting; manufacturing organisational issues;	Financial accounting; marketing; management accounting;
Professional and soft skills	Creativity; awareness of the external environment	Awareness of the external environment; coordination	Coordination;	Communication; coordination; awareness of the external environment

2.4. Course design: learning methodology

An active learning approach is adopted in order to favour the actual integration of all the competencies necessary in NPD. In particular, a design based learning approach is adopted, in which students are actually engaged in solving an ill-defined problem by designing something new. In the Industrial Design course, students are asked to generate some ideas for improving an existing product and to develop the new product concept, define the product and process designs and build a business plan of the overall initiative. Just to give a few examples of the products studied, students' projects have concerned the redesign of a vacuum cleaner, an electronic transformer, etc. The work is conducted in groups of 4 or 5 people, which are formed by the students themselves. The course is organised according to the four parts of the NPD process: concept development, product design, process design, business plan. For each part, some sessions are dedicated to theory, after which a set of tutorial sessions are offered, during which each group works on its own project. In total, the course provides 12 ECTS credits in around 100 hours, 50% of which are based on theory, and the other 50% dedicated to tutoring for the projects. Each teacher is specialised in the specific phase of the NPD process, not only in terms of theoretical knowledge, but also in terms of professional practice. Hence, the improved, re-designed product studied by students develops from the idea to the final industrial version, while respecting the business plan, all throughout the period of the course. All the technical and non-technical hard skills are thus used on a real product. Real problems need to be solved and students themselves have to choose the specific theoretical tools to be implemented. Hence, students can appreciate the skills they are using to successfully manage their project. The involvement of students in all the phases of the NPD process allows them to conduct the phases in parallel whenever possible, in coherence with the concurrent engineering approach. Furthermore, working in a group should favour the development of professional and soft skills, in particular those regarding conflict management, coordination and communication.

2.5. Course design: evaluation process

The evaluation process is divided in two parts: an individual written theory test and the group project evaluation. The individual test includes open theoretical questions concerning all the topics and issues presented during the course. The evaluation of group projects is based upon five elements: four written reports, and a final presentation. The four written reports describe how students have conducted the four phases of their project. An evaluation for each report is provided by the pertinent instructor. The final presentation is discussed with a committee of professionals, who are qualified to evaluate the industrial feasibility and quality of the projects. Involving professionals, who directly participated in innovation processes, is fundamental for ensuring the multidisciplinary skills to successfully participate to the innovation process [23]. Students should convince the committee that the project is actually worthy, feasible, in line with market needs and economically sustainable. Soft and professional skills concerning team working, effective communication, interdisciplinary abilities, and awareness of the external environment [5] are also evaluated during the presentations.

3. RESULTS AND DISCUSSION

3.1. Students' results

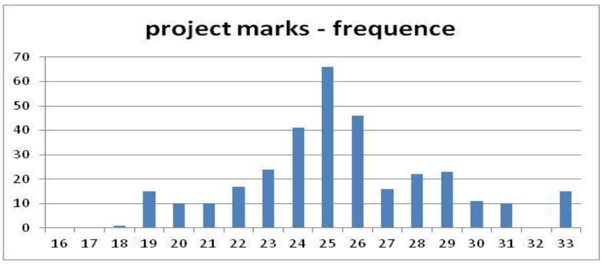
In this section a quantitative synthesis of the results is given. Given the exploratory (and theory building) nature of this study, this is given to provide a comprehensive picture of the students' performance, and it is not aimed at validating the proposed teaching approach. Table 2 gives some descriptive statistics of the results, distinguishing the two parts of the evaluation: the project and the written theory test. The total number of students evaluated is 327. This means that our analysis is based upon 327 individual written tests and 81 group projects, which involved the same 327 students. Comparing grades obtained in groups to the ones obtained individually is interesting for verifying the effect of group working on the final performance of students. As shown, there is not any relevant difference between the two parts of the evaluations, in terms of mean, modal and median values. Standard deviation is limited. As concerns the difference between the two parts of the evaluation, the mean and median values are close to zero, even if the modal value is -2. So the project marks are somehow lower than the written test, and there is a higher standard deviation.

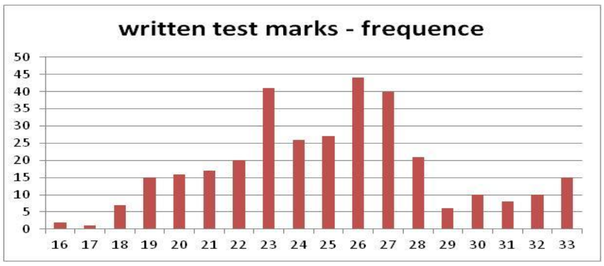
Table 2. Students results (the Italian marks range is 18-30. The maximum evaluation, "30 with merit", is usually translated in numbers as 33)

	Project	**Written test**	**Difference (project – written test)**
n. of students	327	327	
mean value	25,44	25,02	0,42
std. dev	3,28	3,81	4,61
modal value	25	26	-2
median value	25	25	0

Going more in depth in the two parts of the evaluation, figure 2 gives an overview of the distribution of the marks. This brings into evidence that there is some difference: even if the mean values are very similar and the median values are identical, the evaluation of the projects are more close to a very tight, normal distribution, while the evaluation of the written test is more uniformly distributed. In other words, the projects bring the majority of the evaluations towards the mean value.

Figure 2. Distribution of the students marks





The analysis of the correlation between the evaluation of the two parts, (not reported here for sake of brevity) suggests that there is no correlation.

Moving to an in depth analysis of the evaluation of projects, table 3 distinguishes the marks achieved by students in the five parts evaluated. The descriptive statistics reported here is referred to the 81 projects evaluated, each project referring to groups composed typically (with some exceptions) of 4 students.

Table 3. Evaluation of projects

	Concept development	Product design	Process design	Business plan	Project presentation
n. projects evaluated	81	81	81	81	81
Mean value	27,12	25,10	24,48	25,56	26,13
Std dev.	3,83	4,57	3,85	4,05	2,63
modal value	30	26	25	25	28
median value	27	26	25	26	26,75

Mean and especially modal values for those parts of the project that require mainly technical specialised skills (product and process design, business plan) are lower than those requiring the integration of different typologies of technical, non-technical and soft skills. We have also checked for correlations among the various parts of the project evaluations (Pearson), though it is not reported here for the sake of brevity. No statistically significant correlations have been found.

3.2. Discussion of results

The results illustrated above suggest some interesting issues concerning the effectiveness of design based learning when applied to the teaching of innovation to engineers. As described in section 2, innovation is intrinsically a discipline requiring the integration of technical engineering and non-engineering skills, as well as soft skills, such as team working, creativity, and leadership. How the Industrial Design course described in section 2 favours the integration of different typologies of skills is partially indicated by the evaluation of the presentation and concept design parts of the project. Indeed, these two parts are those that require the maximum level of integration of different typologies of skills, both soft/professional and technical. As the evaluation of these two parts presents the highest mean, and especially modal values, we can argue that the integration required has actually been achieved. Evaluation mean and modal values for the other parts of the project, which require more specialisation of technical engineering competences, are lower. This suggests that DBL, conducted by means of team work, is particularly effective precisely when there is the need to make students be able to use their competencies in an integrated manner, applying both technical and professional/soft skills. As concerns the development and application of technical specialised skills, DBL does not seem to be so effective. This is also confirmed by the fact that the results of the individual written test are similar, or even lower, than those of the projects, especially when looking at the results of the three more technical parts. So, DBL with working groups does not seem to add great value when the teaching objective is the specialisation of technical competencies, while it is effective for supporting their integration.

Concerning the development of professional skills, the course on Industrial Design allows for the evaluation of some of them, such as the ability to function on multi-disciplinary teams, the ability to communicate effectively, and the capacity to understand the impact of engineering solutions in a global, economic, environmental, and societal context [5]. This set of skills can be evaluated by the marks achieved by students in their presentations given to the committees, which include external business experts. From this point of view, the results achieved by students are very positive, as the mean and modal values are both very high, especially in comparison with the three more technical parts of the project. Hence, it can be argued that the development of professional (or soft) skills can benefit from DBL with team working.

Some negative effects also emerge from our experience of DBL.

The marks achieved by students in the two parts of their evaluation are not correlated between them. Comparing the marks of the same student in two types of examination, individual and in group, is interesting especially in terms of effectiveness of two types of learning approaches, “passive” or “active”. Obviously, a deeper understanding of this lack of correlation requires investigating the topics of performance of individuals within groups and of teams’ dynamic [20; 21], which are out of the scope of this paper.

Furthermore, the project marks smooth over the evaluation, reducing the differences between good and bad students. This is an effect that can be related to the several difficulties that characterise project-led learning, such as differences in motivation and pace of work among team members, time management, interpersonal problems, and free-riding [20; 16; 21]. Such a smooth over effect, which could be perceived by students [16] may be negative in terms of motivation, and can reduce the willingness of students to actively participate in team working.

4. CONCLUSIONS

This paper deals with the issue of teaching innovation management to engineering, which is recognized as a crucial topics in most important engineering schools [26]. The paper presents the experience of a DBL course on the management of innovation for industrial engineers concerning the NPD process. In particular, two main results of this study are relevant. First, the paper proposes a model for designing courses on innovation and new product development, which could be used in engineering schools. Such a model, presented in figure 2, allows for tailoring the contents of the course in coherence with the specific technological fields of innovation, by changing technical engineering contents while maintaining the technical non-engineering ones. Second, the eight-year experience allows for drawing some tentative conclusions concerning the effectiveness of DBL in the field of the management of innovation. Our results suggest that such a learning approach seems to be effective for developing the ability to integrate technical engineering and non engineering skills and to develop professional “soft” skills. The DBL approach seems to be less effective for supporting the specialisation of technical competences, which are necessary in the field of innovation.

The study presents several limitations, especially concerning team formation. Indeed, we have adopted only self selected teams and thus we are not able to evaluate effects related, for example, to gender, type of background (Bachelor's), and age, which are relevant in team working. Future experiments could be conducted with instructor selected teams, in order to investigate whether and how such factors can influence the effectiveness of the approach. Future research could also be devoted to compare the results achieved in this study with those obtained through other teaching approaches, in order to verify the effectiveness of DBL. Another relevant limitation concerns the theoretical background, which is currently rather focused on problem-based learning, with limited attention to other teaching approaches and, more generally, to educational research. Hence, future effort could be devoted to enrich the theoretical background.

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How to apprehend leadership related skills in a project management experiment?

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ABSTRACT

The ambition of our engineering school is to train competitive engineers who are able to manage complex projects in fast-changing environments. To this end, we have developed a project based course, controlled by teachers (Steering Committee), where students are confronted with a practical long term assignment which includes unexpected events.

Over the six years of experience gained in running the course, the important question of leadership has emerged, even though it was not an a priori explicit objective of the course. In a large group, if responsibilities can be relatively easily identified and assigned, the group dynamic often relies on the presence of one or several leaders. The Steering Committee puts pressure on the student groups to highlight the capacities of the leader(s) and those around him/her/them. The bounds of the exercise are established by the natural peer-to-peer relationships between fellow students in each year group.

Even if the project does not run well, even if the project leader makes mistakes, leadership skills are understood by the whole group and students still acquire skills. We debrief with the students in order to relativize the success of their production in relation to the organization of the group. Different leadership situations are analysed and discussed in this paper.

Conference Key Areas: Engineering Skills, Ethics in Engineering Education

Keywords: Leadership, project management, return of experience

1 INTRODUCTION

A practical knowledge of project management tools and methods is certainly of great help to properly manage a project. However, being able to motivate teams, to take decisions at critical moments, to resolve disputes, to negotiate with customers and other third parties are some of the numerous skills that will eventually make the difference between managers. These so called “soft skills” are facets of what is called leadership. They are difficult to apprehend in the traditional academic education with respect to the technical “hard skills” that an engineer must display as an accomplished professional. Although these key skills are best addressed in a project context, they still remain difficult to teach as they rely on a complex alchemy between students’ characters and aspirations, working group dynamics and circumstances. In this paper, we propose an analysis of group leadership scenarios that we have experienced over six school years in large project groups where the students have to organize themselves. The diversity of scenarios, the extreme sensitivity of team organization to group composition and dynamics, the influence of a teacher’s behaviour and policy once again testify that managing and leading are not the same thing and that complexity remains undoubtedly the main descriptor of human organizations.

2 LEADERSHIP

Literature on leadership is abundant. Politicians, the military, CEOs are obviously interested in leadership. On a smaller scale, leadership is employed within communities, teams or projects. It is in this context of project management that our training meets this leadership skill.
Historically, our project management-oriented curriculum emphasizes task management, i.e. forecasting, planning, organization, quality, risk, documentation, reporting, etc. without explicitly addressing leadership. We are reluctant to use the term "project leader", and prefer the words "responsible" or "facilitator". It is difficult for students - and for teachers - to break the egalitarian relationship between peer students. However, the role of a leader is important as will be shown by the student feedback from section 4.
Leadership includes several functions. (1) Give direction, vision, meaning to work. (2) Decide, arbitrate, select in accordance with the vision. (3) Motivate, inspire, animate, create and maintain momentum. (4) Ensure group cohesion, avoid or resolve conflicts. Ann Senn summarizes this in [1] as "leadership is about inspiring and enabling others to do something that they otherwise could not or would not do”. To do this, "the greatest measure of leadership is the ability to gain the trust and loyalty of others." C. Richard Panico adds [1].

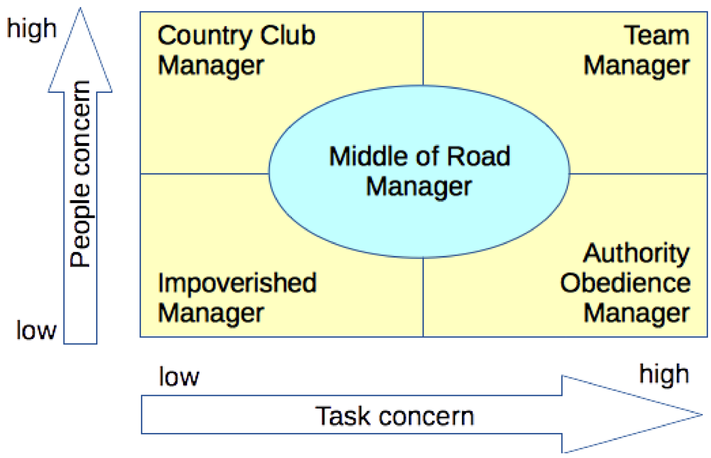


Fig. 1. Blake and Mouton’s managerial grid

In the management model of Blake and Mouton [2], our teaching is therefore mainly focussed on "task" and little focus is placed on "person", thus covering the Authority-Obedience Manager and Team Manager styles (see Figure 1). In practice, the human aspects are obviously very present with a pedagogical backing for the management of confits in particular. The following questions arise: How does the performance of the leaders and especially of the project manager impact the quality of group's execution and the final level of production? Is there a clear correlation between good managers and good results? Can the leadership skills be acquired in educational experimentation? The next section describes our current pedagogical choices.

3 PEDAGOGICAL ORGANIZATION AND EXERCISE LIMITATIONS

3.1 Educational situation for students in the co-op engineering program

In our undergraduate school, we train engineering students, most of whom will be future managers, in a three-year Information and Communications Technology (ICT) program. They have a particularly strong profile in the technical area, which they wish to practice further on at a high level or even at an expertise level. Our training is carried out in a school-company co-operative program with periods of several months at both sites. In the first and second years of school the students, who then work in small groups, discover the traditional tools of project management such as the analysis of the client's needs, planning, risk and delay management. At the end of the second year, the students are thus armed to manage simple, well-targeted projects in small groups. In the third and final year, we bring an extra dimension by putting the students in a position to undertake a complex project in a large group where random situations arise irregularly. Our goal is to bring the students, who are generally much more centred on technical skills, towards strong skills in project management methods [3]. This exercise has been carried out six times and has evolved to a course unit that now lasts 63 hours spread over 12 weeks, consisting of a few lectures and three-hour long tutored sessions.

3.2 The type of technical projects

What could be better than having the students carry out a project [4] in order to make them discover the notions of complexity? The director of the school, together with his executive committee, is the client of the specific projects that we propose to the students. When we initially designed this course unit we proposed a project whose technical core was centred in the ICT area where the students already had acquired some expertise. However, the students' taste for these technologies is such that, contrary to our expectations, the energy spent during the activity was focused on the technical aspects at the expense of the organization and the management of the team. Since this first inconclusive experience, we have chosen a project whose technical framework lies completely outside the skills already acquired by our students. These projects are chosen outside the students' normal comfort zone of technical skills, which ensures that they are equally unprepared for the technical tasks to be accomplished. After the initial moments of destabilization, the groups have to organize themselves to acquire the needed technical skills and to distribute the work to be performed in order to try to reach the client's objectives at the project end. It is at this stage that we see natural leaders emerge and contribute strongly to the structuring of the group. Much of the work at the beginning of the project is then people centred and on the organizing of the group. Conversely, in the absence of a leader, we have observed that this "forming" phase is slow and unproductive [5, 6].

3.3 Course organization

To introduce complexity into this course we have addressed several parameters which, once aggregated, make the project management complicated. First, we divide the students into two groups of about fifteen. This high number of members forces the group to structure itself effectively. We let the groups organize themselves autonomously. It is up to them to choose the project manager. We claim that the choice of leaders by and for the group is a fundamental element in the structuring of the group. They must also define the management rules that seem to be the most appropriate to them. To organize their project, the students must go beyond their regular friendly classmate structure that they have experienced for two years and create a work hierarchy that will apply during the project. The project manager and work package leaders will have to take decisions that hold and handle conflicts with their peers, a task that is far from simple. To help, a communication coach regularly intervenes to help the students deal with human relations, to address conflict management and to advise them on management methods. Students, who wish to do so, can consult this coach freely for counselling.

A Steering Committee (SC), made up of eight professors of different cultures and skills, organizes the course. This SC only intervenes in project management aspects and organization of groups. The SC organizes weekly methodological discussions where representatives of the two groups explain how the group functions, what works well and what doesn’t. The SC questions, suggests and formulates proposals that students are free to implement. In general, the SC is not directive; we leave the initiative to the student managers to lead their groups. In special cases of blocked projects, the SC puts pressure on the group to bring out the capacities of the manager and of his team. It is then observed that managers use different strategies according to their personality and according to their experience. Some project managers voluntarily delegate decision making power to the work package leaders while others decide for the group.

After one third of the duration of the course, we organize an audit to evaluate the processes defined by the group. The audit examines elements such as: the hierarchical organization chart of the group, decision-making processes, document management, risk management, time management, and management of internal and external communication. At the end of this audit, the SC makes a report containing recommendations which highlight the strengths and gives suggestions to improve the weak points of the group’s organization.

The SC organizes a debriefing at the end of the course during which the students express themselves on the functioning of the course. Often, they comment/criticize the grade they have been awarded. The SC emphasizes the acquisition of relational and project management skills by relativizing the importance of the technical production. This is an essential moment to make students aware of the skills they have actually acquired during the project [7]. It then becomes clear to the students that the lack of decision-making or bad decisions made at the wrong time during the project illustrate the need for good leadership. The success of the course in these terms is sometimes difficult for our students to accept or understand.

4 FEEDBACK

We present six stories that have particularly struck us by looking at the role of the nominal leader and then we analyse the results. The natural leader is the one that was identified by the steering committee, because of his/her previous actions in courses or projects. A project is deemed a success when the project satisfies the client's request. Over the 6 years there were no project failures, all missions were completed, but they were carried out with varying degrees of effort where the difficulties related mainly to the methodological and human aspects of project management.

4.1 Six stories

Case 1: The first story concerns a project where the natural leader was chosen. He carried out all the expected functions. He proposed a vision by applying an original management style, based on fair management[1]; he delegated and guided; he ensured the cohesion of the team by generating confidence. The project was a success and the work of the team and its leader was unanimously appreciated.

Case 2: In the second group, several natural leaders could have been chosen, but it was another student who wished to try this role. Uncomfortable at first, she was kindly assisted by others and gained confidence and fulfilled the role effectively throughout the project. She knew how to get support when she needed it and the help she got was fine. The project went well and was a success. At the end of the project, she acknowledged that she had met the challenge and was now able to fulfil this role alone. This is one of the biggest individual progressions we have seen throughout the six years of teaching this course. However, she remained more manager than leader. She has benefited from very favourable conditions. So far, she is the only female team leader.

Case 3: In this third story, two candidates wanted to be the project manager. A close vote chose one, leaving the second frustrated. The second student supported the first throughout the project but without conviction. The leader was not confident about his managing abilities. He was made aware of the difficulties of this project by the older students which disturbed him. The team was poorly organized and the progression difficult. The Steering Committee organized an audit and reported on organizational shortcomings. This audit was badly received but served as a trigger. The group eventually reacted to this by banding together. They became aware of their deficiencies and organized themselves better. This was the first time that a “group operating charter” was established and signed by all members. This event then led to a new start and consolidated the leader. Confidence was restored, team spirit strengthened. Finally, even if the technical project had mitigated results, it was a great success for people relationship and management. It is this group that made the most progress.

Case 4: In the following group the project manager stepped forward essentially because no other candidate volunteered. He did the work but did not facilitate the tasks for the team members. He was quickly seconded by a more experienced student. The transition was smooth and accepted with great relief by the whole group. The very slow start limited the technical success of the project. However, efficient cooperation tools, chosen by the group, compensated for the lack of leadership.

Case 5: In this fifth story, the project manager was a rather good manager and leader. The project was a success. But, an event prior to the project disrupted the evaluation phase. A student wished to “give a lesson” to another by taking advantage of the freedom to individualize the marks, in order to sanction her. He managed to federate a majority of the group around him and organized a meeting “as a court". He took advantages of some late deliverables to justify the penalty. The project leader saw the problem coming, came to seek advice, but could not prevent the split in the group. He reduced the punishment by secretly giving some of his own points to the sanctioned student.

Case 6: In this group the project manager was again the only (reluctant) candidate. He already practiced project management in his company. However, while running this project he did not adapt and sometimes opposed the requests of the Steering Committee because “he did not practice them at work”. He said and showed that his role did not really interest him but nevertheless persevered. The group was much divided. The project manager was isolated and only one out of the other fourteen members willingly accepted to help him in

1 https://fr.wikipedia.org/wiki/Management_équitable, last view 4/2017.

carrying out the tasks that he considered unnecessary. The management part was felt as a constraint. The technical sub-group almost became autonomous by doing the technical tasks and ignoring the management work. Finally, the project was a success from a technical point of view, but the management and the coaching of the group were a failure. The members of the technical sub-group criticised him for obtaining a mediocre score.
We have tried to classify the different cases according to the typology of the leader at the beginning of the project and the degree of success of the project: Table 1.

Table 1. Position of different cases

Choice of the leader / Project result	**Natural leader**	**Accompanied leader**	**Leader by default**
Successful management	Case 1	Case 2	
Hampered by the leader		Case 3	Case 4 Case 6
Hampered by the team	Case 5		

4.2 Analysis

Our first question is about whether such project management experimentation allows students to build on leadership skills. We complete our analysis with a quantitative study based on the students' perception of their skills in a technical approach to project management. We study skills evolution between the beginning and the end of this students' final year project course unit [7]. One question was: at what level do you consider your ability to lead a project?
In Figure 2, we can see the results for 4 student year groups (about 120 students). The graphs show a rise in self-assessed competency in the notion of leadership, with even some of students considering themselves experts in the question.

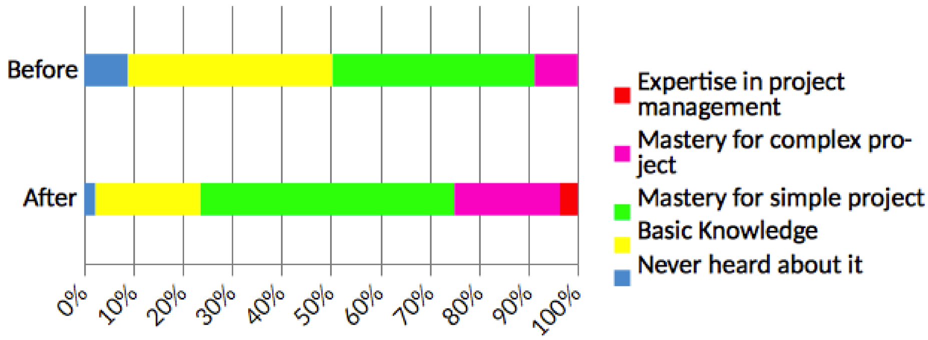
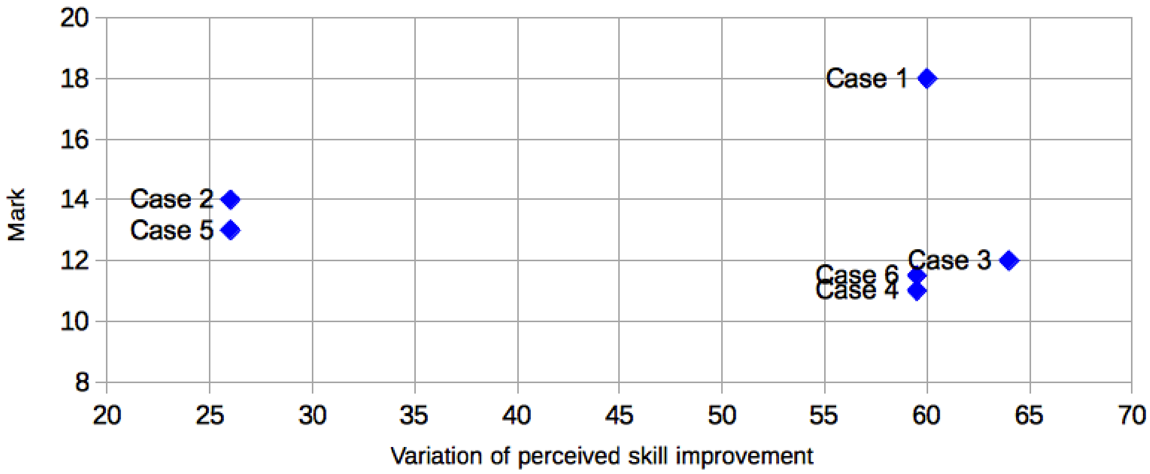


Fig. 2. Ability to hold the position of project manager (all cases 2013-2016)

In the appendix, we present these results, year by year, which make it possible to identify the different cases of study. We find that no student in the 2014 year group felt he was an expert in leadership, whereas for other year groups, the two leaders often replied that they had acquired expertise. In case 2, the steering committee considers that the leader took this role in order to test his competency in a learning situation but does not yet consider himself ready to do so in a professional situation. In case 5, the setting up of a court and the displayed support of the project leader to the "accused" person surely created a loss of confidence in his managerial skills.
Our second question considered the link between the group's results and the availability of a good leader. One way to consider the result is to look at the mark obtained during the

course. We do not have an objective criterion for what constitutes a good leader, so we have based our analysis on the evolution perceived by the students of their leadership competency. To do this we create a score that assigns an increasing number of points to the level of competency as perceived by the student. We have taken into account the difference in score before and after the project, case by case. We then evaluate the correlation between this score (which measures perceived improvement in leadership competence) and the final mark (Figure 3).



Case 1: the survey was not created at this time, so it is an approximation of skills variation.

Fig. 3. Comparing marks with perceived competency variation

We find that we cannot correlate the mark with the improvement in leadership competency. To start with, all the cases are different and also the mark considers competencies broader than the simply leadership, even if the starting hypothesis was that a project can't succeed without a good leader.
Other results, more qualitative, emerge from the individual student feedback, observations by the steering committee or debriefing sessions at the end of the course.
We had 6 different cases whereas the pedagogical framework was the same from year to year. Those who were project leaders undeniably learned more than those who were team members. Some project leaders made the effort to give regular feedback of their experience to members (case 3). Only one case had the curiosity to perform a bibliographic search on management methods and to share them with others (case 1).
It is then observed that managers use different strategies according to their personality and according to their experience. A certain project manager voluntarily delegated decision making power to the work package leaders while another decided for the group (Case 6).

We also found that project manager did not necessarily mean leader. Some team members were leaders in their behaviour, in their relationship to others. In such an exercise, it became clear that the peer-to-peer relationship prevented the project manager from implementing of the complete set of managerial incentive tools available in a company, due in particular to the absence of a hierarchical means of pressure.

5 CONCLUSION

The various stories that we, teachers, have observed over six years require several comments. First, taking into account initial parameters such as project group composition and project topic, project developments and group dynamics have continually surprised us. Hence, the Steering Committee has to react wisely and with humility as no predefined scenario was flexible enough to remain unchanged for more than a few weeks. Second, this project experience and the deliberate pressure that the steering committee puts on student groups often lead to the feeling that the project has partially or totally failed, leaving both teachers and students with the bitter feeling that results and achievements were small compared to the efforts made. Hence a debriefing session is mandatory but several weeks after: students realize with hindsight how much they have learned in terms of organization, behaviour, vision, reporting, etc. Third, the leader designation process is somewhat particular (group of classmates, many possible leaders, collective process to make a leader emerge) and does not correspond to what occurs in an industrial context. Leadership is then approached in a different way that is maybe more general, so the outcome is different.

This project course was designed primarily to teach project management methods in a practical way. There was no deep reflection on leadership and relations between leadership and management. After six years, it appears that this kind of project cannot be completed from a pedagogical point of view without a clear vision of what we intend in terms of leadership training. If we all agree on teaching good management methods and techniques, teaching leadership, if possible, poses the fundamental question: do we first train leaders, managers, contributors or all profiles at the same time?

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Contextualizing the teaching and assessment of engineering skills

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ABSTRACT

We are frequently being informed that Engineering graduates are not ‘work ready’, but lacking in a broad range of generic skills, despite these being mandatory for professional body accreditation. In this case study we present a newly developed second year undergraduate module which explicitly integrates the practice and assessment of generic skills with realistic technical challenges in ‘scenarios’ (week long intensive group projects). It is intended that this format would demonstrate the relevance of the generic skills to the students and hence improve engagement and learning. Observations by staff and feedback from students confirmed the success of this approach.

Conference Key Areas: Engineering skill; Curriculum Development; Attractiveness of Engineering Education

Keywords: Transferable skills; Contextualized learning

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INTRODUCTION

There are recurring calls for engineering graduates to be more ‘work ready’ than they currently are. The calls come from industry [1], and are picked up by the media [2]. Engineering has a reputation for being the worst subject area in this respect [3]. Accrediting bodies are well aware of the need for these generic skills, and they are prominent in the UK Quality Assurance Agency’s Subject Benchmark Statement for Engineering [4].

However, as Karatas *et al* found, when students come to university to study “engineering” their understanding of the nature of engineering is often lacking a significant number of the aspects which are described in literature on engineering practice [5]. Thus, as well as learning these generic concepts and ‘soft’ skills, students need to develop an appreciation of their importance. Without this many students will quickly disengage when faced with lectures or coursework on apparently unrelated topics, such as ethics, law and communications skills. This is consistence with research that shows that the subjective value assigned by students to a task or goal has a strong impact on their motivation and hence learning [6].

We ask how we can teach these subjects in a relevant and engaging way, early in an engineering programme.

1 BACKGROUND

A few years back, the Engineering Faculty of our university embarked on an ambitious programme review to tackle this issue [7]. This resulting in a tranche of changes including two new modules to be taken by all first year engineering undergraduates across 9 departments. These modules were intended to introduce generic engineering and work place skills from the first week of the degree programme, and give opportunities to practice them within open ended group projects. We were tasked with developing a follow up second year module, tailored to our specific degree programme (Biomedical Engineering), reinforcing some of the generic skills and introducing more.

A review of these first year modules[2] indicated that students liked the ‘scenarios’ (intensive one week group projects, during which all other teaching stops), however there was too much other assessment in the modules (individual assignments addressing one soft skill at a time, e.g. ethics) and the students did not always understand the relevance of the taught sessions. Staff were also broadly supportive of the scenarios, seeing their benefit in developing the student’s team work and project skills at an early stage but there was some concern that they left less time for teaching technical engineering skills, such as analogue electronics.

2 DESIGN OF THE MODULE

Our response was a module where each of the taught soft skills was explicitly linked with, and assessed within, and only within, one of four scenarios *Fig. 1*. In addition, we worked closely with leaders of modules covering technical engineering knowledge and skills, so that these skills, too, were reinforced and practiced within the scenarios.

[2] Review based on feedback questionnaires by ~700 students, student focus groups and interviews with contributing academics.

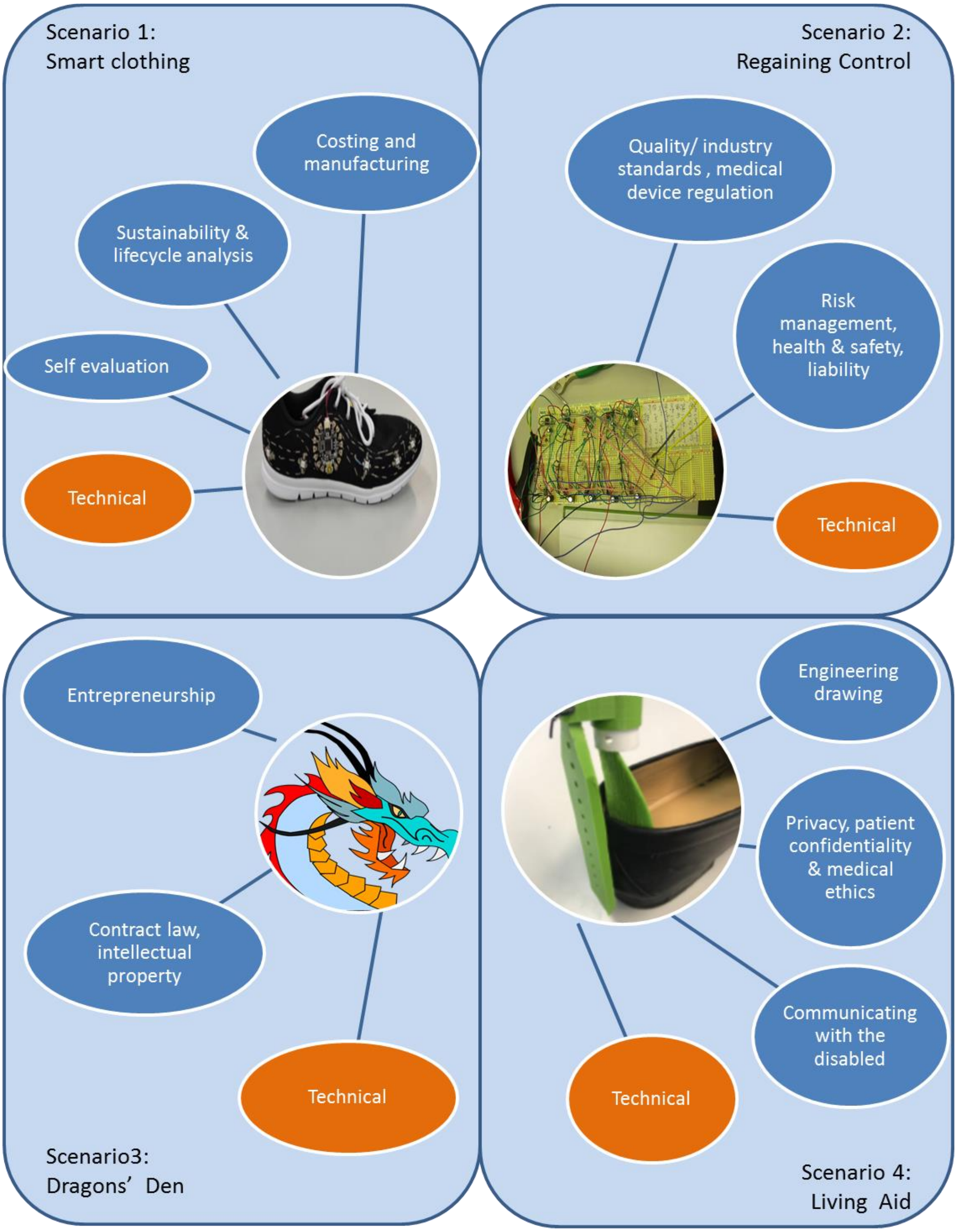

Fig. 1. Schematic diagram of the mapping between professional skills and the four scenarios

Prior to each scenario, students had 3 or 4 2-hour seminars where the linked soft skills were taught. A further way in which we contextualized these generic concepts was the extensive use of relevant case studies and guest lecturers within the seminars, and maintain a focus on why the subject was important to working engineers. For example the CEO of a spinout company taught about costing and manufacturing based around his industrial experiences, and, in another session, a clinical industrial engineer considered medical device regulations and its impact on a product he had developed.

Each scenario was designed with a realistic story line to contextualise the skills and illustrate how these must be used together within the work environment. In fact the final scenario involved students working with the charity REMAP (http://www.remap.org.uk/) to design a product for a disabled client[3], with the assessment covering their interaction with the client and their use of the design cycle, as well as the technical quality of the final prototype device. Concepts of patient confidentiality, privacy and medical ethics were assessed with the aid of an online quiz in the style of role play with students required to state what they would say and or do in response to plausible conversations with the client *Fig. 2*. The students also had to communicate with three different audiences, adjusting their language and style to match:

a) Discuss with a slightly deaf elderly lady of average education – the client - with respect to details of the design specification;

b) Produce a user guide for the device written in ‘easy read’ – a format designed for people with learning disabilities [8];

c) Give detailed instructions for making the product, aimed at an amateur craftsman.

All three represent audiences they are likely to interact with in their working lives, but all are different to the peer-to-peer and peer-to-lecturer communication students are used to.

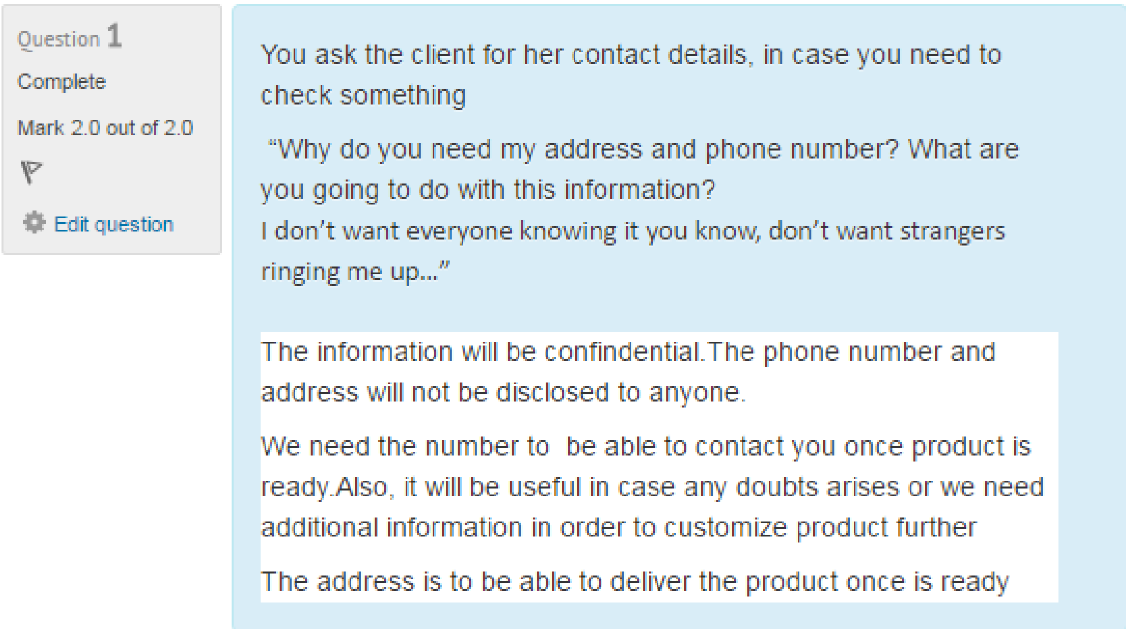

Fig. 2. Example question and student answer from patient confidentiality, privacy and medical ethics quiz.

Each scenario contained individual and group elements of assessment, and one of two mechanisms of moderating group marks to reflect individual contribution:

[3] For the first year the client required a product to enable her to fit and remove her glasses, despite being unable to lift her hands to her face. In the 2nd year the students sought to design a shoe fitting aid for a client whose specific bending and balance constraints made commercial devices inappropriate.

a) Team contribution questionnaire
b) Manual moderation by lead facilitator where there is was demonstrable inhomogeneity in the commitment/performance of the students in the group

3 FEED BACK

We have just completed our second year of running this module with mean overall module grades of 66% for the 1st cohort and 69% for the 2nd. The lowest mark was 55% for the 1st cohort and 60% for the second, despite individual components to each assessment, and individual adjustment of group marks where necessary. Being engineers, we followed the design cycle, seeking feedback from students (10 & 21 in 1st and 2nd cohorts respectively) and staff (4), and improving aspects in light of this. Students completed the department's standard module review questionnaire, and were encouraged to comment informally during personal tutorials and with the module lead during the scenarios. At least one member of staff was present, in the lab were the students were based, for the duration of each scenario, and we would informally brief each other as to the observed group dynamics and productivity. Some of these briefings were by email.

The first year that the module ran, students commented that it was the "first time that ever had to work as a proper team to get something done" and that they had "learnt much more than just electronics and programming skills". However as a teaching team we realised that we needed to be more explicit to the students, with respect to the role of the soft skills in the scenario and related assessment. It was also important to incorporate the soft skills and generic concepts into the story line in a plausible manner, to prevent the associated assessment from feeling like contrived add-ons.

So we made some minor changes to our plans for the next scenarios. These were evidently successful because at end of the third scenario (styled like the TV series 'Dragon's Den'[4]) our judging panel, which included an industry specialist, were impressed with the student's engagement, and one of the research groups we had partnered with asked the students to come back and share their findings.

Unsurprisingly, in the second year the module ran more smoothly, though we will be continually refining it in the years to come. Indicative of its success was the way the students handled the final scenario:

a) They were fully engaged and scored well in those sub-tasks which explicitly tested the generic skills assigned to this scenario.
b) It was observed that they required less intervention by the facilitators, and managed their time and interpersonal relationships markedly better than in their previous scenarios[5] – skills taught in the first year, but which, it was found, they needed further advise on.

Themes in the student feedback, free comments section, included preparation for "real life" ("In general, the module was rather helpful in placing me in real life

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[4] Students, acted as entrepreneurs, developing and presenting a business plan for the commercialisation of a research output from a UCL research group.

[5] For example. During Scenario 2 facilitators noted, with concern, the disunity and poor group dynamics of one team. Despite intervention, this continued and was also commented on in the report of an independent staff member who assisted with part of the assessment (a mini viva). Individual debriefing/counselling sessions were held with the two students affected and when (the random generator) placed them together for the 4th scenario, they were observed by facilitators to be in a functional working relationship.

situations, allowing me to grow in teamwork.”),enjoyment (“I really enjoyed the scenarios”) and a positive sense of challenge (“The module was quite challenging but we learned a lot and used different skills in each scenario”). The only negative comment was from one student who felt that the group mark did not adequately individual effort. Additionally, in a general feedback session, a second year student responded to a first year’s concerns about the relevance of taught material by describing how they had thought the same at end of their first year, but having subsequently used those skills, they now understand their importance, as well as the relevance of the generic skills taught this year. This further confirms the importance of teaching generic skills in context, and the success of our integrated approach.

4 SUMMARY

Generic skills are an essential part of engineering education, but teaching them in a meaningful way which engages students can be difficult. We have shown that by incorporating them into technical scenarios which give them plausible real-life contexts, students more quickly realise the important of these topics, and hence engage with learning about them.

5 ACKNOWLEDGMENTS

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Recommendations for Electronic Laboratory Notebooks in Undergraduate Engineering Faculty:
A student-led case study

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ABSTRACT

Industry and academic research labs increasingly use Electronic Laboratory Notebooks (ELN). In engineering education, the ELN affords new laboratory technologies and pedagogies requiring embedding rich data and supporting virtual labs. We present a student-led design of a prototype ELN based on Microsoft OneNote software for our undergraduate engineering programmes. The solution addresses the requirements for lab redesign aspirations around new laboratory pedagogies requiring entirely digital workflows. To enhance the solution's ecological validity, students themselves developed it while undertaking their existing undergraduate labs. The result is an ELN based on the digital notetaking software Microsoft OneNote. We make available a requirements and design tool that includes a set of 21 use cases, 102 requirements, and 32 failure modes. Staff and student feedback is reported. The work will assist engineering and science faculty looking to introduce an ELN solution into their curricula.

Conference Key Areas: Open and Online Engineering Education, Curriculum Development, Skills and Engineering Education.

Keywords: Electronic Laboratory Notebook, Microsoft OneNote, Educational Technologies, User acceptance.

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INTRODUCTION

Digital notetaking is becoming the norm in personal and professional endeavours due to the maturity and ubiquity of software and hardware devices which provide capabilities beyond paper. In the laboratory or workshop in undergraduate engineering education, paper notetaking and capture is common and often preferred; sketching is perceived as easier on paper [1], there are several competing technology options for digital notebooks with no obvious winner [2], and faculty staff can be late and/or cautious adopters of new technology [3].

The Electronic Laboratory Notebook is commonly used in industrial research laboratories where there is a strong requirement for capturing Intellectual Property (IP) [4]. ELN use is less common in engineering education; the IP requirement manifests itself chiefly for assisting assessment logistics and plagiarism detection, the latter which is primarily deterred by designing it out of assessment [5]; retaining paper notes may in fact reduce student motivation to plagiarise through increased effort compared to “copy and paste”.

Several recent studies have evaluated the perceived benefits of ELN using contemporary hardware devices such as laptops and tablet devices with stylus. A non-exhaustive list of ELN benefits from these studies includes graph plotting; rich media use; connecting to equipment for control and data capture; embedding and analysing raw data; automatically saving progress; revision capabilities, standardisation and neatness via templates, multiple device access; collaboration and sharing content remotely. For staff, ELN benefits include remote assessment; annotation capabilities; auto grading potential; aggregation and searching of students’ work [6] [7].

In this study, we are interested in what student-driven recommendations could be made to engineering faculty for adopting an ELN solution. To answer this, undergraduate students with at least 2 years’ higher education from faculties of biosciences, civil, mechanical, computer, electrical and chemical engineering were tasked to develop an ELN solution based on their experiences. In addition to prioritising feature expectations and evaluating user acceptance, we asked them to consider broader lifecycle issues including training, operations and maintenance. The work was undertaken in the context of developing a contemporary learning space – the Collaborative Teaching Laboratory at the University of Birmingham [8]. We describe the resulting prototype ELN based on Microsoft OneNote software from design and requirements perspectives. We report feedback received from several evaluations, and we conclude with lessons learned and a requirements tool for faculty looking to develop their own ELN.

1 REVIEW OF ELECTRONIC LAB NOTEBOOKS

ELNs have existed since desktop computers first appeared in research labs. The 1980s locally networked computers lead to a focus on developing collaboration possibilities around shared file stores. The hardware and software advances of the 1990’s stimulated increased focus on function and usability such as inputting, capturing and analysing data. The advent of the internet afforded information mining and meta-data to maximise IP value [9].

Their use in Engineering undergraduate education has a smaller pedigree. Several recent case studies have been reported that give a mixed picture in terms of the benefits of an ELN over paper. Notably in [1], students did not generally make use of rich media such as images and video to enhance reporting. In [6], staff and student ratings of a commerical ELN “Lab Archives” were positive in terms of its function, however training requirements were highlighted as a key barrier to uptake. Many ELN benefits come only after the initial note input, such as searching and revising past entries, which may not always be required. The structure to input that the ELN can impose could also be at the expense of the flexibility that a blank sheet of paper affords [10]; structured templates in ELN, e.g. defined sections and autofilling tables with correct formulae, can prevent students from “being able to produce their own structure and engage in organise their work” [2]. These previous works motivated us to develop the requirements and design tool reported here to evaluate potential ELN solutions.

There are numerous commercial ELN softwares used in research activity across sciences and engineering. These include SciNote, LabFolder, LabArchives, LabWare, Docollab and LabGuru. In contrast to these softwares, general digitial notetaking solutions such as Microsoft OneNote and Evernote can be adapted to serve as an ELN, particularly when teaching activity takes precedent over project-oriented research activity. These general softwares benefit from no imposed lab structure, cross-platform support, and mass-market maturity; e.g. in [11], OneNote – the software used in this study – enabled an ELN to be accessible on a newly released smart watch to free up users hands during practical.

The ELN is a part of the bigger challenge to evolve engineering educcation laboratory pedagogy in the digital age. In [12], the proposed Electronic Lab Assessments with Tutoring Enhanced Delivery (ELATED) laboratory pedagogy is typical of modern lab redesign efforts, highlighting the requirement for lab assessment combined with reflective portfolios, demonstrations and reports. All of these outputs contribute to an entirely digital lab profle for every student.

2 REQUIREMENTS AND DESIGN

2.1 Lifecycle and project scope

The ELN solution (*Fig. 1*) was developed by undergraduate student interns over summer 2016. The project consisted of students developing a solution based on Microsoft OneNote for use on tablet devices (Microsoft Surface Pro 4s and Ipad Air 2) and mobile phones and desktop computers while they undertook existing labs from several STEM disciplines. Use cases and detailed requirements were captured. Evaluation activities included failure modes analysis, and user acceptance trials. Students were tasked to consider operational aspects of the solution. These included fault handling and maintenance procedures, and student/staff training requirements including user manuals and training videos.

2.2 Requirements and Use Case

Initial observations and run-throughs of labs resulted in the identification of 21 key use cases with the associated actors, goals, pre-conditions, success scenarios, extensions and post conditions. The use cases are: adding students to notebooks, creating ELN, printing ELN, marking ELN, erasing input, using templates, excusing attendance, creating search queries, viewing content libraries, graphing, adding feedback, viewing feedback, login, logout, adding assignment, view individual student ELN, collaborate, seek assistance, change page layout and view revision history. From these use cases, 102 requirements are identified which are grouped into several sections: User interfaces, functional, performance, hardware, security, software quality. Furthermore, 37 failure modes are identified for consideration during design testing. These are available in the requirements and design tool described in section 4.

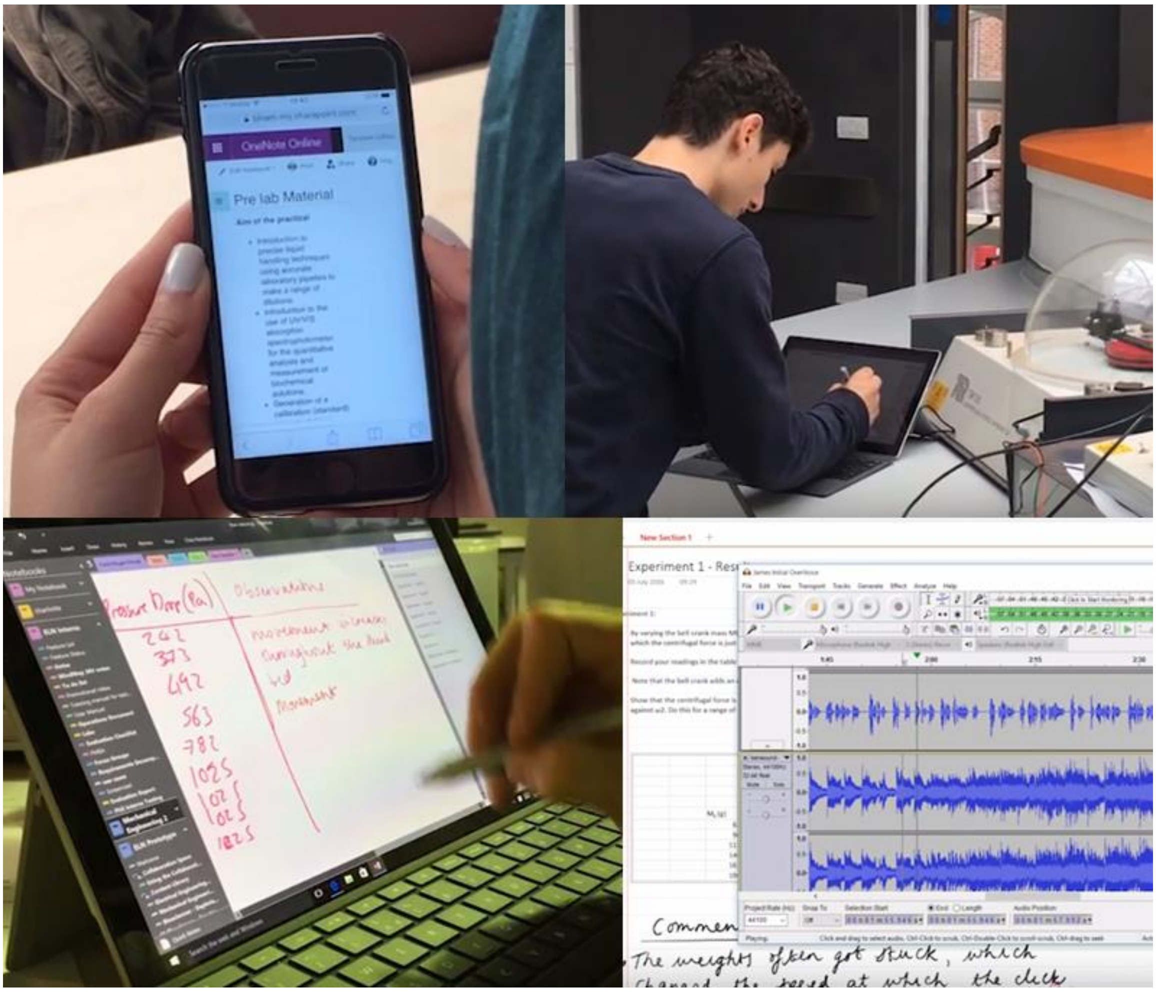

Fig. 1. ELN Solution – smartphone access to pre-lab materials (1a top left), data logging capabilities (1b top right), sylus input (1c bottom left), data embedding (1d bottom right)

2.3 Design

Fig. 2 outlines the ELN solution architecture, illustrating how users interact with the three primary components – notetaking software, cloud service and the Virtual Learning Environment (VLE). The first component is the notetaking software - Microsoft OneNote 2016 with class notebook add-in. It conforms to a traditional notebook with sections comprising of ordered pages. It supports stylus and keyboard input, and the embedding of other objects in-line with text such as rich media, data attachments and spreadsheets. The second component is the cloud service - Microsoft Class Notebook / OneDrive cloud. Rather than students downloading personal copies of the notebook, they all work on this same cloud-based notebook. Student's individual sections are not visible to one-another, and the cloud solution enhances data security and eases assessment logistics; making updating and distributing content efficiently. Important functionality is provided by the Class Notebook plugin. It gives students access to a shared content library and collaborative sections, along with their own individual working spaces which the teacher can access and grade. The third component is the VLE – in our case, Canvas by Instructure. Faculty teaching staff have the choice of marking the notebook through the VLE, or through Class Notebook plugin in line with local policy.

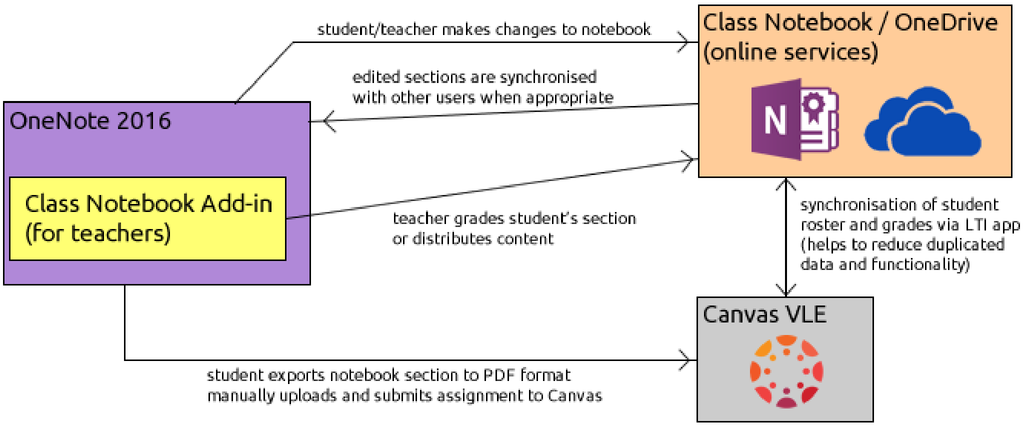

Fig. 2. The ELN architecture based on Microsoft OneNote**.**

3 EVALUATION

3.1 Outcomes from observational analysis

The student developers conducted several laboratory sessions in diverse subjects including chemical engineering, mechanical engineering, electrical engineering, biosciences and chemistry. They made detailed observations during the sessions to ascertain the benefits of the ELN over existing laboratories. A representative sample of the key benefits they observed are summarised in *Table 1*.

Table 1. Key benefits of ELN identified by developer from prototype lab sessions

Existing paper-based Laboratory - observation	**Enhancements provided by the ELN**
Demand by students on staff for orientation and support e.g. locating materials.	*Prelab material in the ELN assists in orientation e.g. VR walkthroughs. The ELN should not to reduce interaction opportunities but instead orient them towards intended learning outcomes.*
Many exercises require students to submit diagrams.	*The stylus functionality appears neater than paper for free-hand drawing but more cumbersome.*
Evidence of lab progress relies on the quality of final answers.	*Students can demonstrate progress by inserting media into the ELN but few do unprompted.*
Lab sheets have a linear structure – students step through them methodically during labs.	*The ELN include pre- and post-lab activity work and also allows students to hyperlink to different sections allowing a non-linear workflow.*
Tables typically require hand written input and the use of calculators to compute values.	*Data is input directly into spreadsheets and tables, allowing for automatic calculation of derived quantities and graphing.*
Students bring a USB stick to the lab to save the data recordings.	*Data logging software can sit on the same platform as the ELN*

3.2 User Acceptance

We conducted several user acceptance studies. 30 undergraduate engineering students were given a demonstration of the solution outside of the laboratory. They were asked to rate it overall on a five-point Likert scale. The average rating was *4.8* with a standard deviation of *0.4*. All but 2 students from this cohort said that they would recommend the solution. 9 academics who teach undergraduate modules were individually presented with the ELN software solution at the laboratory bench. They were asked to run through a mechanical engineering experiment on centrifugal forces shown in Fig. 1b. They each scored the ELN on a five-point Likert scale in comparison to paper notebooks against 14 key features adapted from existing evaluations in the literature [1]. Correspondingly, 19 3rd year undergraduate engineering students undertaking a third-year laboratory in Virtual Reality were asked to use the same ELN software and complete the same questionnaire. Overall students rated the solution higher than the academics (*Fig. 3*). Both student and academics rated most functions higher than paper, assumed to be a mean score above 2.5. The weakest comparisons with paper were “1. making handwritten notes”, “2. adding formulae”, and “3. sketching diagrams”. This is despite the use of tablet devices equipped with a stylus, and it suggests that core notebook functions of data entry are still preferable in paper despite recent hardware advances. There is a smaller variance in the student scores compared to academics which may be attributed to the greater number of participants.

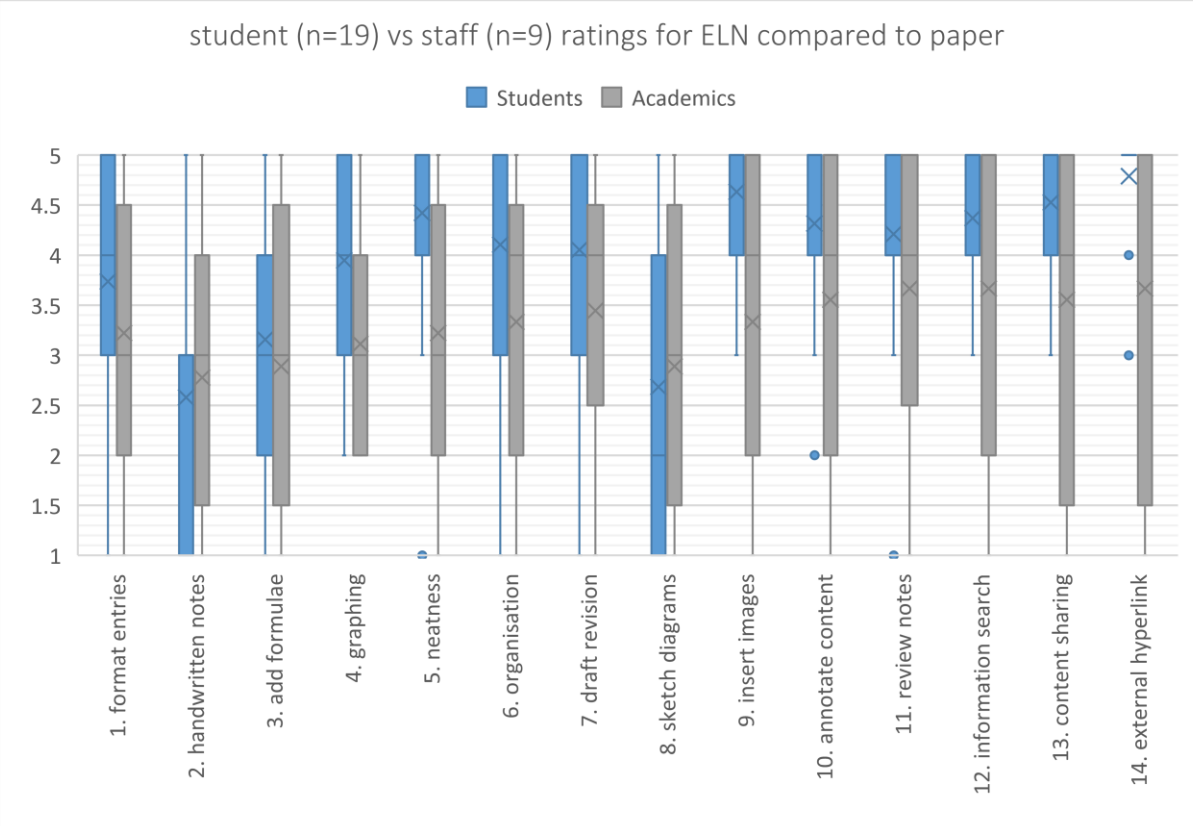

Fig. 3. Student and Academic ratings of ELN Feature benefits over paper based laboratory.

Academics were further queried on assessment of notebook, and all respondents considered grading the work via the VLE more important than grading the work within the ELN solution to ensure common practice with other non-laboratory assessments. Positive comments from academics included “Set out of information is good, input of data occasionally fiddly”; “It prepares students for the next academic and professional levels”; “Minimises paper use, allows rich content, interaction and data sharing.”; “Makes it easier to prepare the lab work and facilitates group working.”; “Easy to mark”;

"easy to keep protocols/instructions updates". Negative comments from academics included "The benefit should be on the lab itself and its redesign to take advantage of the ELN.". Positive comments from students includes "Easier to organise, share and implement pictures, videos and record audio" and "It is neater. Straight lines are easier to draw, easier to copy image". Negative comments from students included "Computer could crash midway through notetaking". Finally, 6 students undertaken a mechanical engineering laboratory in fluid dynamics were given the ELN to make notes instead of a paper, which was used by the other 12 students in the cohort. The key difference between the groups was that a key component of the experiment – graphing pipe pressures and flows – was automated by spreadsheet. This reduced the time taken by students to produce results and lead to more time available for results analysis.

4 ELN DESIGN AND EVALUATION TOOL

We have made a tool to assist engineering faculty in evaluating their own ELN solutions. It consists of a set of 21 use cases for ELN, 102 associated requirements, 32 failure modes for designing against, and the architecture and user manual for our OneNote based solution. It is available on request to faculty from the following URL: http://www.tinyurl.com/SEFI-ELN-REQUEST. A student-produced video of the solution is also available at this URL.

5 SUMMARY

An ELN for Engineering faculty is presented and evaluated. It encourages rich media use and makes data processing and manipulation efficient through e.g. embedded spreadsheets. Collaboration capabilities are a key strength which allow sharing of data and notes. Software for many types of lab equipment can be installed on the hardware platform which runs the notetaking software to facilitate data embedding. The ELN simplifies the submission of lab work and eases marking burdens. Against this, like all cloud-dependent solutions, collaboration functions require stable network connections, and there is an outlay required in terms of equipment, maintenance and training. Despite these shortfalls, it reduces the quantity of paper required reducing carbon footprints, and promotes digital literacy.

With the current advances in mass-market tablet devices with stylus and cloud-based mass-market notetaking software that operates on multiple hardware platforms, ubiquitous ELN in undergraduate engineering education is now realisable. Future work includes enhancing the laboratory sessions that currently use the ELN to take advantage of the graphing, data embedding and collaborative features that the technology affords.

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Peculiarities of economics and business studies in technological faculties

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ABSTRACT

The purpose of this study was the investigation of peculiarities related to the education of managerial competence and to the need of economics and business knowledge for engineering studies students. According to business representatives, many engineering graduates lack of managerial competence and knowledge of economics. The study was performed at Kaunas University of Technology (KTU). A complex investigation consisting of three parts, i.e., an evaluation of students' attitude, an academics' approach analysis and an estimation of the attitude of business representatives as potential employers for high school graduates, has been chosen. The need for economics and business courses for students studying in technological faculties, the features of psychological environment of economics and business studies in those faculties, as well as weaknesses and strengths of learning economics and business subjects were revealed during the research.

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Conference Key Areas: University – Business cooperation, Curriculum Development Engineering Education Research, Engineering Skills.

Keywords: managerial competence, economics knowledge, psychological environment, engineering education.

INTRODUCTION

There have been widely discussed about a changeable nature of the studies in higher educational institution under the circumstances of information technologies development and economic globalisation in recent years. The study programs are responsively associated with the changes in labour market, so that the majority of business schools, universities and colleges declare significant differences in the study process. One of the most prime accents is the development of competency education [1], [2]. Competence is an expression of human qualification or ability to act conditioned by the individual's knowledge, skills, attitudes, personality features and values [3], [4]. A public talk with employers indicates that many engineering graduates lack of managerial competence and knowledge of economics. There are very few researches on this subject in Lithuania [5], [6]. Therefore, it is particularly important to find out the competency education problems that Lithuanian higher education institutions faces within the framework of engineering studies realization and with a special focus on the physical and psychological learning environment.
The present study aims to investigate the peculiarities of economics and business studies in technological faculties.
The objectives of the research**:**

1. To explore the need of economics and business subjects to engineering studies students.
2. To disclose the features of physical and psychological environment of economics and business modules studies in technological faculties.
3. To reveal the ways to improve the cooperation between students, academics and employers**.**

1. RESEARCH METHODS

The research was accomplished at Kaunas University of Technology in Lithuania. The data were collected with survey questionnaires in 2016. The method of the research includes a complex analysis: 1) the students' attitude to the need of business and economics studies, to learning and psychological environment in technological faculties and to the cooperation between students, academics and employers, 2) the academics' attitude to the need of economics and business knowledge for students studying in technological faculties, to learning and psychological environment in technological faculties and to the cooperation between students, academics and employers, 3) the attitude of business representatives to the need of business and economics studies for students of technological faculties, to the readiness of young professionals to the labour market and to the cooperation between students, academics and employers. The self-administered questionnaires were consisted of statements and questions. Respondents were asked to indicate levels of agreement with statements using a 5-point Likert scale, which provided following response options: "1 = Disagree", "2 = More disagree than agree", "3 = Neither agree nor disagree", "4 = More agree than disagree", "5 = Agree". Questions based on Likert scale allow to get more useful for the research information and to reduce the amount of questions.

Paniott's formula (1) has been used to calculate sample size (number of respondents), i.e., to ensure reliability of research of 95%:

$$n = 1/ (\Delta 2 + 1/N), \quad (1)$$

Where:

n – Sample size;

Δ – Allowed calculation error;

N – Size of population.

Statistical analysis of research results was conducted by employing the software of statistical data processing, *SPSS* (v23.0) and *Microsoft Excel* (2010).

2. RESEARCH RESULTS AND DISCUSSION

2.1. Students' approach

Purposeful sampling has been used for the formation of an investigative group. Individuals that are most representative in regard of an investigative feature were selected to the formative group. There were involved students studying Engineering Economics (economics subject) and Fundamental of Corporate Management (management subject) in the technological faculties of KTU. The subject of Engineering Economics was chosen by 122 students in the spring semester. The subject of Fundamental of Corporate Management was chosen by 150 students in the spring semester. 170 students, studying in the Faculty of Chemical Technology and in the Faculty of Mechanical Engineering and Design, participated in the investigation (170 questionnaires were handed out). The survey questionnaire was divided into three parts. First part was designed for the evaluation of the need for economics and business studies in technological faculties. Second part was made for the evaluation of learning and psychological environment of economics and business studies. Third part was designed for the study of students and employers relations.

2.1.1. Evaluation of the need for economics and business studies

For the evaluation of the need for economics and business studies in technological faculties, the students were asked whether they would like to study more economics and business subjects. The distribution of responses is shown in Figure 1.

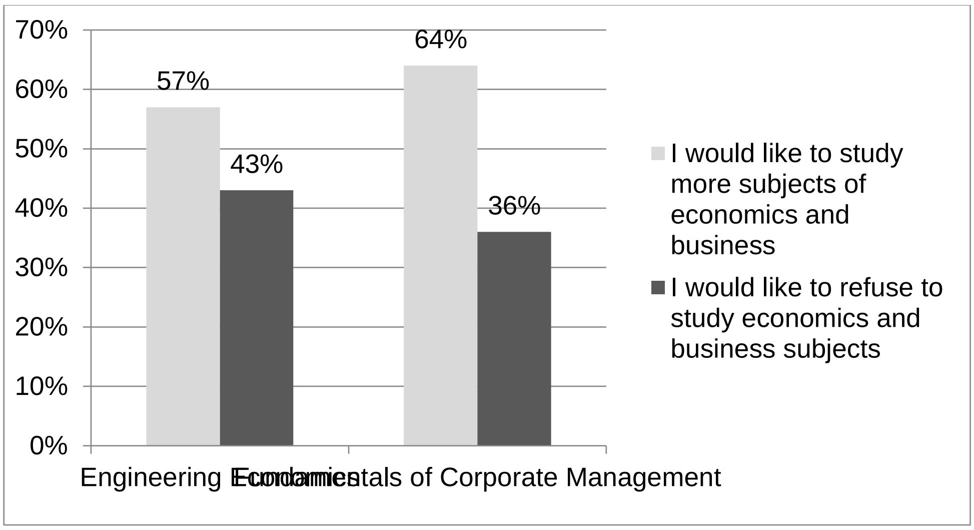

Fig. 1. The need for economics and business subjects, in percent

A large proportion of students would like to study more economics and business subjects. They took the view that it is necessary for their future career and for the integration into the labour market. It is important to evaluate the expectations of students by offering economics and business subjects. The next question was designed to find out whether students have gained the additional competences in studying economics and business subjects. In students' opinion, the studies of economics and business subjects provided the additional competences like a perception of economic terms, common knowledge about an economy and market, and the ability to prepare a business plan. 54% of the respondents believed that it will be easier to take decisions after the studies of economics and business. 61% of the respondents stated that they gained knowledge that would let them to deal with economic and business problems. 52% of the respondents maintained that they have learned to prepare a business plan. 57% of the respondents gained knowledge that will be possible to apply in their specialities.

2.1.2. Evaluation of learning and psychological environment of economics and business studies

For the evaluation of learning and psychological environment of economic and business studies the statements describing these environments were submitted to students. The statements have been made with reference to other authors' [7], [8] researches about the educational environment and its impact on study results. The results of this research indicated that the engineering studies students rated the learning and psychological environment of economic and business studies quite positively. The students took the view that they are physically and psychologically safe during time of lectures. Students have been communicated with academics by email, during outing-lectures to companies, at the time of Medium or KTU events and during time–out between lectures. Most of the students would like to make more contact with academics in the informal environment, i.e., to drink coffee and to discuss on economic and business issues. Students would like more sports holidays, cycling races, orienteering contest and etc.

2.1.3. Students' attitude towards the communication with employers

The purpose of the study of relationship between students and employers was to find out whether the communication with business representatives is relevant for students and what forms of communication are most acceptable for them. The results showed that there are necessary students' meetings with business representatives during the study process. 66.5% of the respondents stated that the communication with business representatives has allowed a better understanding of the practical things. 47.1% of the respondents had it that such meetings have revealed new business opportunities and new market trends. 58.2% of the respondents maintained that such meetings have allowed for better understanding of employer needs and requirements for employees. 58.2% of the interviewees communicated with business respondents during lectures, 62% – at the time of the excursions to company, 14.7% – at the time of business plan contest. The students suggested the following possible communication with business forms as joint projects, product development (business representatives' participation in the process of study), students' projects mentoring, excursions to companies, practical lectures of business representatives, practice.

2.2. Academics approach

10 academics from Kaunas University of Technology participated in the survey. The academics, who were involved in the research, teach Chemistry, Design, Mechanics, Mathematics, Informatics, Electrical and Electronics, Energy and Construction.

2.2.1. Evaluation of the need of economics and business knowledge for engineering students

First and foremost, the aim of the survey was to find out academics' attitude to the teaching of economics and business disciplines in technological faculties. The opinion of academics participated in the study on this point is represented in Figure 2. There are shown the averages of the statements scored up accordance with a 5-point Likert scale. The academics, participated in the survey, had quite a solid positive opinion (average of scores was 4.6) on the need of economics and business knowledge to students studying in technological faculties.

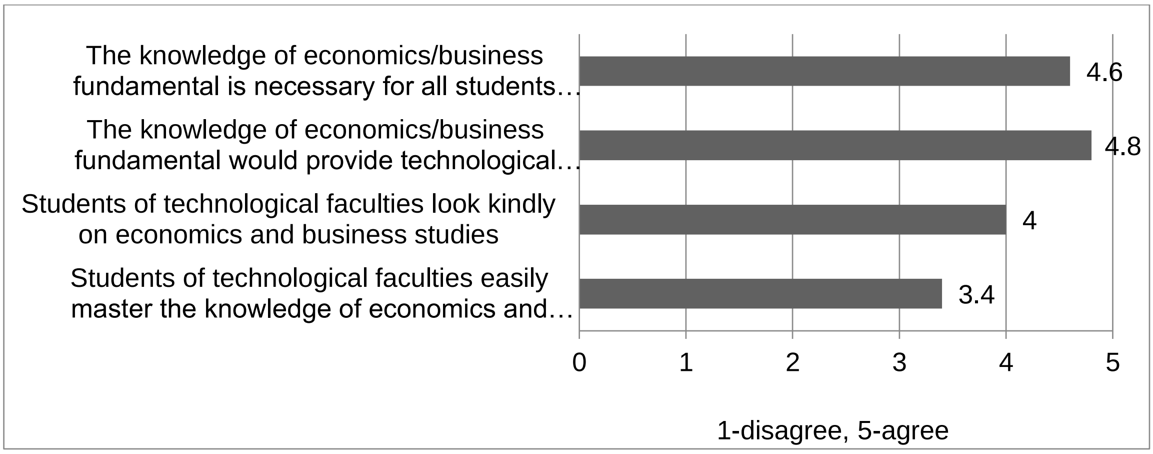

Fig 2. Academics' approach to the need of economics and business knowledge to students studying in technological faculties, in scores

Most of survey participants (average of scores was 4.8) agreed that economics and business studies would provide students with additional competences such as team work skills, the ability to analyze the market situation, the fundamental of corporate financial management, the understanding how to develop a business project, the basic knowledge of business creation, establishment and etc. In opinion of academics, the students of technological faculties look kindly to the studies of economics and business (average of scores was 4), but moderately (average of scores was 3.4) master the knowledge of economics and business.

2.2.2. Evaluation of learning and psychological environment in technological faculties

The next part of survey was aimed for the evaluation learning and psychological environment in technological faculties in terms of teaching economics and business subjects. A proper communication between students and academics plays a significant role in the creating of good social–psychological climate in higher educational institution. However, academics did not have one opinion (average of scores was 2.9) whether students of technological faculties and lecturers teaching economics and business modules communicate after school time. It could be seen from the survey results that academics could not give unequivocal expression whether the informal communication between lecturer and student influences to better results of study subject (average of scores was 3.6). The respondents noted that informal communication between students and academics is available and can take a variety of mutually acceptable ways such as joint visits to companies, business plan contest, joint sports competition and etc. Talking of the adaptation of learning environment for the economics and business studies in technological faculties, the academics quite unanimously (average of scores was 4.1) stated on its relevance and applicability for these studies.

2.2.3. Academics' attitude towards the cooperation between students and employers

The further part of survey was aimed for the evaluation of the opinion of academics lecturing economics and business modules in technological faculties about cooperation with the business representatives at study time. The survey showed that there was given the opportunity to meet with business representatives at the time of economics or business lectures for the most of technological faculties' students (average of scores was 4.3). 90% of academics participated in the survey agreed that such cooperation between students and business representatives is useful. The academics noted the following possible cooperation forms as lectures of business representatives, excursions to companies, career days, business contest, joint events of students and business community and etc. The academics quite unanimously shared the opinion that it is required closer cooperation with the business community not only for students but also for lecturers. It is useful for preparing young professionals who will be in character with the ever–evolving requirements of the labour market. However, it should be noted that not all academics, teaching economics and business subjects in technological faculties, constantly communicate with business representatives (average of scores was 3.8). The academics pointed out the following cooperation ways as lecturer traineeships in companies, roundtable discussions, joint projects, cooperation in the formulation of the topics for course and final works, the solution of real business problems with the participation of students, academics and business community, and etc.

2.3. Business representatives' approach

The purpose of business expert survey was to evaluate the approach of business representatives to the need of business and economics studies for the students of technological faculties, to identify the psychological readiness of students to meet the challenges of the labour market and to find out the ways for the intensification of students and teaching staff cooperation with the business community. 8 experts participated in the research from different companies who hire engineers.

2.3.1. Evaluation of the need of economics and business knowledge for students studying in technological faculties

First and foremost, the aim of the survey was to find out the attitude of business experts to the need of economics and business knowledge for engineering students. The expert opinion on this subject is shown in Figure 3.

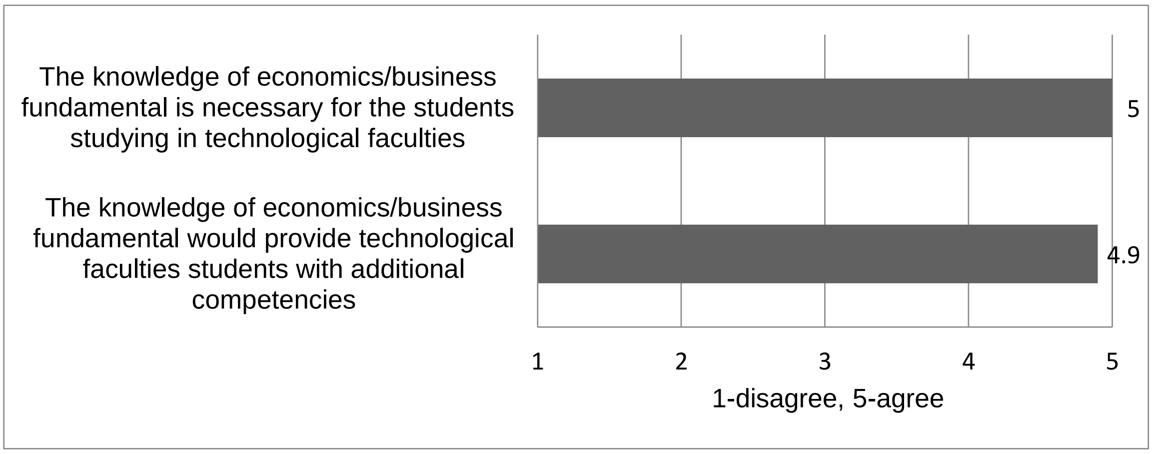

Fig 3. Business representatives' approach to the need of economics and business subjects for engineering students, in scores

The business representatives quite unanimously (average of scores was 4.9) agreed that the knowledge of economics and business fundamental is necessary for the students studying in technological faculties. 100% of business representatives agreed that such knowledge would provide the students with additional competencies. Experts pointed out that the teaching of business and economics subjects enables students to acquire knowledge, which are necessary for the development and marketing of products. In the opinion of the business representatives, such professionals could have a higher chance to take key positions where needed not only professional but also managerial skills. Even if a technical creative work is more acceptable for professional, the understanding how money appear in the company's account and the knowledge of basic economic calculations increase their competencies. The experts pointed out that such staff more objectively looks at their functions and at business, faster and deeper understands the market processes, and the management of business processes. Also they are able to hold forth ideas. That helps them to climb up the career ladder.

2.3.2. Evaluation of the readiness of young professionals to the labour market

The next part of survey was aimed for the evaluation of the opinion of business representatives about the readiness of young professionals to the labour market. According to the business experts, most of the technological studies graduates have the sufficient proficiency knowledge (average of scores was 3.8), which they are able to apply in practice. But more often employers desiderate other competencies of young professionals. Mostly employers desiderate communication skills, good usage of Lithuanian language and courage in making independent decisions. An insufficient knowledge of business and economics, which is an integral part of any business, was mentioned between wants. The business representatives rated ambiguously (average of scores was 3.1) the statement that high school graduates are psychologically ready to take various challenges at work. The analysis of the employers' approach revealed that the young specialist's work opportunities are usually limited by the lack of practical skills and personal characteristics. The majority of young people do not have personal purposes related to the professional activity and are minded to change workplaces. The issues of young professionals' motivation and education of personal motivation, i.e., self–control and pursuit of the objects, remain relevant for employers.

2.3.3. Business representatives' attitude towards the cooperation between students and employers

The further part of survey was aimed for the evaluation of the respondents' approach to the need of cooperation with students and lecturers. The business experts agreed that the cooperation between students and business representatives is essential on purpose to improve the readiness of future employees. The forms of cooperation may be various as lectures of business representatives, student visits to companies, business contest, practice in the company, career days, analysis of case studies, creative workshops, Brain Fights and etc. It is very important cooperation of business community not only with students but also with academics for better understanding the needs for the labour market. All of business representatives agreed with this point. They offered the following cooperation ways as academics' visits to companies and business managers visits to universities; joint projects; academics' involvement in creative workshops organised in companies; Brain Fights; University Open Days; the business section in University's Web page and etc. The business experts noted that it is important to act, i.e., to cooperate in any form.

3. CONLUSIONS

According to the accomplished research the majority of students are satisfied that they have economics and business studies and would like more subjects that educate and motivate their competency of entrepreneurship. This approach was accepted by academics and employers also. With reference to the results of the evaluation of psychological environment, it can be stated that students are enough satisfied and feel psychologically well studying economics and business subjects. A good psychological climate during time of lectures helps to master the study material much better. The performed survey revealed that the majority of engineering graduates have sufficient knowledge of speciality, but their employment opportunities are limited by the lack of practical skills, economics and business knowledge. In summarising the employers' attitude to the young professionals, it can be stated that new graduates lack of common competences as skills of introducing themselves, communication skills, courage in making independent decisions. In addition, according to the business representatives, most of them do not have personal ambitions with a professional activity and are minded to change workplaces frequently. The issues of motivation, the pursuit of the objects and self-control of young professionals remain relevant for employers and for higher education establishments. The importance of economics and business studies in technological faculties was endorsed.

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AN OUTLINE TO OPTIMIZE THE QUALITY ASSURANCE AND ROLE OF THE EXAMINATION COMMITTEES IN HIGHER EDUCATION

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ABSTRACT

Since the adjustments in the Dutch Law on Higher Education and Research Act in 2010, the Dutch universities have initiated an overall operation to optimize the mechanisms to monitor the quality assurance of examinations and the regulations. At the Eindhoven University of Technology (TU/e) in the Netherlands, the Examination Committees (EC) have modified their positions accordingly. The ECs in all Engineering study program at the TU/e operate in an independent and proactive manner and hold expertise in a number of fields such as legal, quality assurance, research and statistical analysis on quality of exams, among others.

Within this legal framework of changes the Examination Committee at the departments has taken an even more important role in monitoring and safeguarding the procedures. To strengthen the position of the Examination Committee new tasks and roles have been carefully defined. The EC is now to determine objectively whether the student meets the end qualifications of the study program and curriculum; to establish procedures and regulations within the Education and Examinations Framework of the department regarding the assessment and determining the results of examinations; to safeguard the quality of the organization and examination procedures, including Bachelor and Master thesis; and to take measures against fraud, among others.

In this paper, we will present a case on how the Applied Physics (AP) department has made changes regarding the quality of assessment specifically, and in general in the organization of the Examination Committee to accommodate the new demands by the law. We will outline how the AP Examination Committee has given form to its role to pay attention to assure the quality of examinations and assessment. In addition, we will explain with examples the methods used to research the quality of examinations.

Conference Key Areas: Quality assurance and accreditation; Curriculum development; Skills and engineering education

Hungarian engineering students' perceptions about their employability shortly before graduation

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ABSTRACT

The aim was to explore the perception of engineering students of BME (Budapest University of Technology and Economics) on the competencies relevant to their employability shortly before graduation. The survey has been conducted in wider context in three European countries with the same limited number of interviews in a pilot project and the tendencies are being compared.

Following a literature review, in frames of a qualitative exploratory study, the engineering students have been asked about their expectations on future employment and perceived ability to meet the employers' requirements. We have analysed the discrepancy between the students' visions and the employers' needs.

Empirical evidence was collected on skills and competencies required by the companies from the point of view of engineering students. The students were interviewed and the talks were tape-recorded for further analysis. Students were chosen randomly, and so far, 14 students have been interviewed. Thematic content analysis was conducted to better understand the students' competencies.

The paper approaches what motivates students when starting a career. It is clear that both employers and employees claim that hard skills are needed, however, soft-business skills, known as interpersonal competencies would be vital too.

Conference Key Areas: Engineering Education Research, University-Business cooperation, Engineering Skills

Keywords: employability, competencies, engineering graduates, qualitative exploratory study

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1. INTRODUCTION

In more and more countries throughout Europe, increasing attention is paid to the concept of knowledge-based economy, and within it, to the key role of higher education. Following the Bologna Declaration (1999), higher education has been considerably restructured, with its role becoming more appreciated. Research has proven that European universities have lately been forced to produce graduates who are able to adapt to the latest demands. (Molnár, 2016) The quality of graduate workforce is more and more in focus just like whether graduates are capable of meeting labour market demands. '*…In spite of all the efforts made so far, there is a considerable gap between the skills and competencies of new graduates, leaving higher education institutions and employer requirements…*' (J.A. & H.H., 2008)

In 2016, BME got involved in an international comparative study where it was interesting to experience that this issue does not only concern the students of Hungarian universities of technology but also those of leading European ones. The objective of the research project launched in 2008 was to get a comprehensive picture of the competencies acquired by new graduates of technology. The repeated research launched in 2016 was a longitudinal continuation of the one conducted in 2008, completed with a comparative analysis between the participating countries.

The study involves three European countries: Great Britain, France and Hungary. This paper presents representative research data primarily with respect to Hungary. The target group comprises students of engineering shortly before graduation with focus on their employability, employment opportunities and demands. The students selected belonged to two groups: those participating in the traditional engineering programmes and those who aim for a degree in management parallel to their studies.

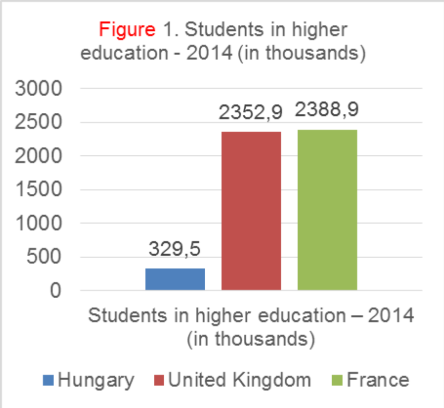
Graduating engineering students were asked about their visions, their employment opportunities and acquired competencies, and then it is investigated how this complies with the requirements of European employers. In the research, the empirical experiences of engineering students concerning employer requirements were collected. At the same time, it was also investigated what skills and competencies are needed for their successful career building. Finally, current tendencies are noted, and competency areas for development are explored.

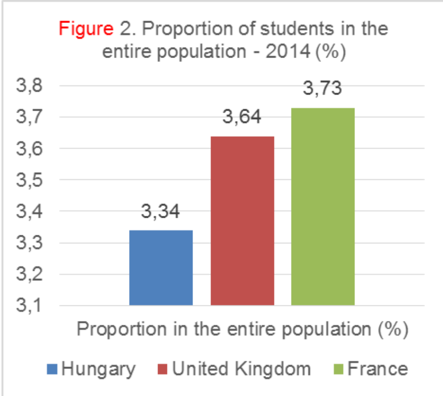
Research methodology applied: personal interviews were made with graduating engineering students using a structured questionnaire, which was identical in all the participating countries. After preliminary arrangements were made, interviews were planned to last 30-40 minutes, which turned out to vary greatly depending on personal motivation level and the individual's personality.

In the first 'pilot' phase, interviews were continuously made from September 2016, involving the adapting, editing and fitting the questions to the traditions of the country parallel with the analytic processing of the results gained. Following the recording of responses, results were analysed in view of the hypotheses.

1.1 Research background

Each of the three countries studied has a quite different higher education structure. In France and Great Britain, about the same number of students (2.4 million) take part in higher education programmes while in Hungary, there are approx. 330,000 students in higher education (see Figure 1). If the proportion of students in the entire population is considered, the difference between the countries is no longer big.





(Source of data: https://goo.gl/8pdVXK)

There is a slight difference in the data amounting to some tenths of percentages in the proportion of students in the three countries. Parallel with this, it is important to reveal what requirements employers have throughout Europe towards the newly graduated. *'In order to be able to define student employability, both their personal and knowledge-related skills should be explored.'* (Knight & Yorke, 2004)

1.2 Hypothesis

In formulating our present research hypotheses, we relied on 2008 research results, and formulated our assumptions accordingly. Engineering students formulate more clear and concrete ideas so they apply for fewer but better definable jobs.

It was also assumed that engineering students apply for fewer jobs and spend longer time with a single employer than their peers who completed a parallel management programme, and that the amount of salary is an important consideration for them in job-seeking. It was also expected that in the field of skills, time management, communication and teamwork will require the greatest development.

2. RESULTS

2.1 Career intentions

Most of the volunteers are not actively seeking jobs at present as many of them are already working in some form or other. It is common that future graduates choose one of the companies more closely attached to the university for their internship but after earning their degrees, almost each of them would like to find another job.

The overwhelming majority of the interviewees want to go on working in Budapest or near the capital (Pest county) in any case, and none of them would like to spend more than 2 hours/day commuting. Several of them would like to move to a suburban area near the capital. There was only one volunteer who thought that the location is not important for him as long as accommodation costs are covered by the employer.

Almost all of them wish to try working abroad, many only for the experience, for just a few years but there are also students with much more serious plans: they aim to set up a company abroad and move there with their families. Those who considered having an international career had it in common that they would only go to western countries. Germany, France, Canada, the USA and Finland were mentioned as potential destinations (note that the last one is geographically in the north).

On the basis of the pre-formulated hypotheses, I expected the amount of salary to be an outstandingly important consideration for jobseekers. The first significant difference between technical managers and ’traditional’ students of technology was revealed with this question. Technical managers considered the amount of salary much more important. They have not applied for jobs or accepted offers if they feel that their knowledge is ’worth more’ than the amount offered. In contrast, this is not yet a key consideration for most of the engineering students at all. They are much more concerned with the ’nature’ of their future jobs and the opportunity to gain experience. Some interns said that their salaries were ’ridiculous’ despite the fact that they spent a relatively long time at the workplace in addition to studying. As they said, this approach of theirs is likely to change after they earn the degree, and will only seek jobs above a certain minimum amount of salary.

The survey also revealed that many of them also seriously considered accepting jobs far from their original fields. For many, the working schedule and the workplace atmosphere are decisive factors: they prefer part-time jobs, and a good and direct relationship with the superior and the colleagues. As a demand, several respondents mentioned the methods already widespread and proven in Northern Europe, which could have a motivating effect on new employees, e.g. free coffee, kitchen use, ergonomical, modern working environment and free Fridays. ”*In the Norwegian culture, it is particularly important to strike a balance between work and life. They rather have the ’We work to live’ than the ’We live to work’ approach therefore they finish work very early on Fridays.”* (New In Norway - http://www.nyinorge.no)

2.2 Job seeking

Most of them have started to apply for jobs relatively late, only during this year, mainly in order to complete the obligatorily required professional practice. There are only a few students who have already been working for years: they typically started to submit applications before or simultaneously with starting their university studies.

The Internet is regarded to be the major source of job advertisements. Facebook and www.profession.hu are two of the most preferred websites. Almost everybody was aware of the functions of the LinkedIn page although few had actually used it before. They are considering actively using the page in the near future as they think it is a network with many advantages. They regard it to be the ’Facebook of jobseekers’.

In addition to the webpages, the different job fairs were mentioned by many as an opportunity for orientation. However, opinions were mixed about their usefulness. Many only go there to look around and see the different employers. Many consider it a problem that in job fairs, companies place professionally unprepared people in their stalls, who may not show empathy towards jobseekers as they often have no idea whatsoever about the students’ knowledge, skills and professional fields.

When asked about jobseeking strategies, most of the respondents said that they apply the proven tips and tricks, and are afraid to deviate from them, let alone develop a new strategy of their own. Some of them think that they will certainly get a position if they know somebody who already works or has recently worked for the company. Those who have such a connection have so far had 100% success when applying for a job, and they consider it likely that they will make use of their connections on other occasions, too. To quote one of them: *'You have a straight path if you know somebody... Unfortunately, this is the only safe method nowadays.'*

Before starting the interviews, I thought the majority would want to work for a multinational company but the results showed a completely different picture. Most of the respondents completed their internship in a multinational company. In the future, the vast majority of the interviewees would not like to work for giant companies. Some would like to start their own enterprises. Many regard multinational companies as an opportunity to gain experience but many realized that a smaller company might also be suitable for gaining the same kind of experience.

The second significant difference between engineering students and technical managers was revealed in the number of the applications submitted. So far, respondents have submitted 25 CVs on average but the technical managers have submitted many more applications than engineering students. It was typical for engineers that the number of their applications submitted varied between 1 and 10. They tend to spend a long period with one employer as a frequent change of jobs is not at all typical of them. On the other hand, the same number varied between 70 and 110 for technical managers. They are characterised by frequent job changing as they make use of the best current offer. They regard themselves as experts who the employers need. Consequently, if they are dissatisfied with something, they leave their current jobs without any scruples and start jobseeking again.

It was typical that the students had about 70% as many interviews as the number of their applications submitted. Most frequent types were telephone and personal interviews which meant a positive experience for them. Only one respondent spoke about going through several rounds of interviews, where English language competence was in focus. It is typical that a significant proportion of the interviews were conducted in an informal atmosphere. Those students who also talked to the foreign managers of the company almost had the impression that the atmosphere was friendly so their previous fears generated by gossip and beliefs proved to be totally unfounded. Following the job interviews, only one student asked the employer for feedback. The others considered it enough feedback whether they had been hired or not, and were not interested in any underlying reasons. Some of them received some unsolicited suggestions to help their development. Two volunteers only realized during our interviews that some feedback from the employer would have been useful for the future and expressed their regret about missing out on this opportunity.

2.3 Competencies

Many thought that professional knowledge, adaptability, language proficiency, flexibility, problem solving and good communication skills belong to the competencies/skills which are most required by employers. Irrespective of faculty, volunteers were of the opinion that only their basic disciplinary knowledge must be extremely solid because students have diverse interests and therefore believe that they acquire the necessary skills/competencies by working for various companies.

Despite agreeing on the crucial role of adequate professional knowledge, they differ sharply in their opinion about the rest of the programme depending on which faculty and which field they belong to. Students of technical management and environmental engineering thought that the knowledge they acquire during the training is far from sufficient. They think that discontinuity is one great disadvantage of the programme;

they just touch upon each professional field, which means that they do not obtain a comprehensive picture or deeper knowledge of any field. This they thought may create obstacles after graduation. This problem is further aggravated by the fact that employers have no idea about the enormous differences between two technical managers graduating from the same institution. Furthermore, it poses further problems that a retiring technical manager cannot be replaced by a newly graduated one owing to the differences between the various training programmes and the lack of expertise. This problem could be solved if they chose a specialisation much earlier as most of them know very well by the end of the first year which fields they would like to pursue and which ones fall outside their sphere of interest.

The results of the interviews supported my assumptions about time management. With the exception of a single student, each pointed out time management as the field in need of major development. In their own view, they are likely to procrastinate, especially at home where they are under no direct supervision. There were, however, some who would be scared of flexitime working hours due to procrastination. As they said: '*if I were given freedom, I might delay everything so much that I wouldn't even get to my workplace.*' *'Procrastination is the vice of human life…' (Dr Ildikó Takács)*

As a cause of procrastination, many identified the unpleasant nature of the task or the constant fatigue they suffer from during the semester. They find it difficult to start working on the task. Many also find it hard to maintain continuous focus, and they do not know how to improve in this. They all agree that this ability of theirs has changed considerably during their university studies, but they do not find this sufficient.

The second most frequently mentioned field to be developed was communication skills. The reason for this was seen in the special nature of the programme, which requires in 90% of the cases individual work from students, and they rarely need to give presentations. This problem leads straight to the third most problematic shortcoming, i.e. teamwork. Many thought that at the beginning, they would find it hard to work in a team because communication between team members would be difficult and university studies did not prepare them for this. Among mechanical engineers, preparation for teamwork has become more and more widespread, which means that students must solve problems in small teams. They favour this practice because instructors can devote more attention to each student and these tasks are considered much more 'lifelike'.

The fact that they are struggling with the above shortcomings is of particular interest since the respondents completely agreed on the utmost significance of good communication skills, and that of the ability of presenting and promoting themselves and being convincing. To summarise the opinions, having good professional knowledge was considered most important alongside the ability 'to sell themselves' as well as being proficient in English and presentation skills (even in English) while German language skills were considered an advantage.

Similarly, everyone thought their individual skills had developed greatly in the last year. They especially stress that subject courses were much more professional and field-specific. This was when the components started to fall into place, and the bachelor programme courses, the necessity of which had been questioned before, started to make sense. By the end of the BA programme, most emphasised their development in presentation, communication skills and time management. Generally, they found the last two semesters of the seven-term programme the most useful.

2.4 Employers' views on competencies

The tendency to almost exclusively hire graduates for vacant or newly created posts is becoming increasingly characteristic of European employers. This tendency is discernible in Hungary, too, in the various job advertisements and in the statistics provided by the Central Statistical Office: in 2015 in Hungary, 82.1% of those with a higher educational degree were in employment, while it was 69.9% of those who had secondary level qualifications and merely 47.1% of those with no secondary school leaving certificates (Hungarian Central Statistical Office, 2015).

Employers give the following reason for their preferences: *'Skills and competencies which graduates acquire during their university training are especially important.'* (UK employer) *'We prefer graduates because they are able to understand and analyse complex facts.'* (Slovenian employer) (J.A. & H.H. Graduate Employability…)

Moreover, graduates are considered much more mature who need less supervision and can accommodate and adapt to the work environment. *'Having studied at degree level makes them more mature… and more employable.'* (UK employer) *'Someone who is flexible and who has the ability to prove themselves*.' (Romanian employer)

In recent years, employers have experienced that the knowledge of newly graduated technical professionals has been lacking in the fields of business and social sciences. This is why they give preference to graduates who have also had such training during their university studies. Furthermore, employers require excellent communication skills in addition to professional knowledge, and the ability to work in teams. Often, however, graduates do not meet these requirements. Employers suggest that by requiring students to do more 'compulsory' teamwork during their studies, students could overcome the lack of communication skills and learn how to work in teams.

3. CONCLUSION

Although the research is still ongoing, some results have already become clear:

Students of engineering are much less interested in the amount of salary they can get than the students of technical management. The former consider obtaining experience as well as studying of primary importance but they think that in the future, they will probably attribute more significance to the amount of money they can make.

Both 'traditional' engineering students and technical managers struggle with time management issues. Many make the mistake of underestimating the time required for a certain task. Many have the problem of procrastination, sometimes they suffer from a lack of motivation to carry out a task. Most often they experience the negative consequences of this: they run out of time during the day, which they try and adjust in the evening, which in the end has a harmful effect on the amount and quality of sleep. Another problem is that many do not have the communication skills employers require. Most European companies are looking for innovative graduates with ideas and initiatives, who are proactive and driven by the wish to bring about a change.

Engineering students submit considerably fewer job applications than their fellow students of technical management. Characteristically, they work for longer periods of employment at a workplace and do not want to change jobs if not necessary. In contrast, technical managers like variety and wish to try themselves with different employers of various kinds. They often look for a new job if they are dissatisfied with something. In some cases, they change jobs every few months.

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Gamification to engage engineering skills in technical higher education: an experimental approach

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Randy Kerstjens

ABSTRACT

The mechatronics industry is fully under development in every area. With the upcoming era of Industry 4.0 things will change in the industry. While the industry is focussing on being ready for the industry 4.0, also the universities are preparing students for this new era. Projects inside the university are very important for creating the attitude and skills that are required, where the V-model (VDI-2206) is used as designing technique. Systems engineering is more than applying the V-model, it's also having the right mind-set and attitude in the various phases during a project. In the first year of the mechatronics department students need to apply systems engineering in the projects, where the age of the students are between 16 and 20 years. In the first years project called, "Smart Industry Mechatronics (SIM)", gamification is used as an experiment to optimize the systems engineering process, where students and teachers are getting familiar with the world of Industry 4.0, and to use and optimize the talents of the students. This paper describes the process and methods that are used for implementing gamification inside the SIM project.

Conference Key Areas: Mechatronics, Systems engineering, Gamification

Keywords: Mechatronics, Systems engineering, Gamification

INTRODUCTION

Industry 4.0 is currently the trend in automation and data exchange in manufacturing technologies [1]. Industry 4.0 describes cyber-physical systems and combines them with technologies like the internet of things and cloud computing. By applying these techniques it's possible to create a "smart factory". In the Netherlands the industry 4.0 is called "Smart Industry" [2].

For education it's important that students can combine knowledge with technical skills. The University is applying systems engineering as a way of working during projects. Students cooperate in project groups, with different roles and tasks. In 2013 the department of mechatronics did a project with local industrial companies to find out which way of working needs to be implemented in the education. The outcome of the project is that students need to apply a systematic approach that covers all the aspects during a project [15]. From the results of this project, the university has chosen to implement the V-model [3] inside their mechatronics projects.
Students who start at the university of applied sciences have minimal knowledge about the latest techniques and designing methodologies. To engage the motivation of the students, gamification is used in the first years to do research about the technical aspects and to learn and to implement technical knowledge in the project combined with systems engineering.

1 SYSTEMS ENGINEERING

One of the greatest stumbling blocks during any product development is the enthusiasm demonstrated by group members who, after reading the assignment, immediately set to work on construction, only to discover at a later stage that they have forgotten something. The more advanced the stage the project has reached, the more complex and the more expensive it becomes to still make changes. It is therefore extremely important to work systematically during the development process. As improvements are achieved in the way in which the steps are taken, the project will advance more smoothly, and at the end you will reach the finishing point faster. However, the most important point is, that if you work through the steps in the V-Model correctly, you will arrive at a guaranteed good design.

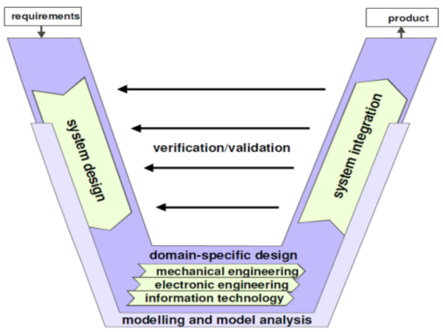

Fig. 1: General overview V-model

The input for this model consists of the requirements of the assignment given to develop, these are the user requirements and system requirements. On the left-hand side of the V is the system design. In other words, here is determined what the system will look like. Here is decided which issues will be solved through mechanical engineering, which through electronic engineering, and how the relationship and communication between these disciplines will be structured. At the bottom of the V-model, the actual development process takes place. The mechanical components take on their real form. The electrical components are selected and designed. The logistics (software, protocols, instructions, etc.) that enable all components within the system to function and communicate are described. However, because this is an industrial standard, it also simultaneously considers the manufacturability, the distribution of the products around the world, the useful life, the maintenance, etc. A product of which a million units are to be produced must be designed differently from a product of which just ten are to be produced. A product that needs to last 10 years will be designed differently from a product for a single use. One can imagine that with an extremely costly product, suitability for repair is more important than for a relatively cheap product.

On the right-hand side of the V, implementation, testing and checks are carried out. No matter how hard the designers try, every design always contains some errors.
This model is therefore produced to provide an answer to the complexity involved in mechatronic systems. Within the university projects, however, far less emphasis will be placed on reproducibility, investments, maintenance, etc.; instead, more focus will be placed on the single production of a functioning model. We have therefore somewhat simplified the V-Model by specifically designating the steps which must be taken.

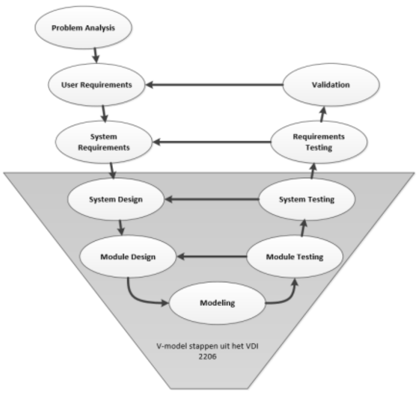

Fig. 2: Simplified version V-model.

2 GAMIFICATION

Gamification is a relatively new term, but the concept of gamification is not new. Gamification is used for all kinds of different purposes. From training purpose for economics, till education purposes, but gamification is never used in relationship till systems engineering.

The term gamification has many times been defined by various persons. The most commonly accepted of gamification is “Gamification is the use of game mechanics to non-game activities in order to influence people’s behavior” [4].

Game mechanisms are constructs of rules and techniques that are used for implementing gamification. Typical game mechanism that can be used are: points, levels, challenges, trophies, badges or achievements [11] .

A second game technique that guides and motivates players are game aesthetics. Game aesthetics are the desirable emotional responses from the player while he interacts with the game. Emotions like fun, trust, surprise and satisfaction are able to drive action and engagement [6].

To integrate gamification in systems engineering it is crucial to understand why and how mechanisms to positively influence people. To understand these mechanisms models of motivation and behavior from the field of psychology needs to be investigated. Wu (2011) analyses Maslow hierarchy of needs [8], b.F. Skinner’s behavior model and Csikszentmihalyi's Flow theory [9] and concludes that needs and motivators are similar to game dynamics and mechanism [8] .

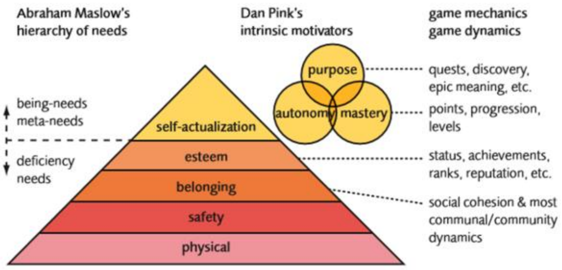

Fig. 3 Maslow/Pink Model – created by Micheal Wu PH, scients Lithium Technolgy (Wu, 2011)

According to Beza, gamification techniques needs to be done in an well-defined environment [6]. The main question that needs to be answered for applying gamification is: "What kind of behavior do you achieved, and how are you going to implement that" [11].

3 FOGG BEHAVIOR MODEL

For implementing gamification several canvas models can be used as a base platform [14]. However a lot of canvas models can provide a lot of details which can be used for setting up the game. For the SIM project, the fogg behavior model can be used as a starting point for gamification [12]. The fogg behavior model shows that three elements must converge at the same moment for a behavior to occur: motivation, ability and trigger, as can be seen in figure 4. When the Fogg Behavior Model (FBM) is used as a guide, designers can identify what stops people from performing behaviors that designers seeks and it also helps academics to understand behavior change better.

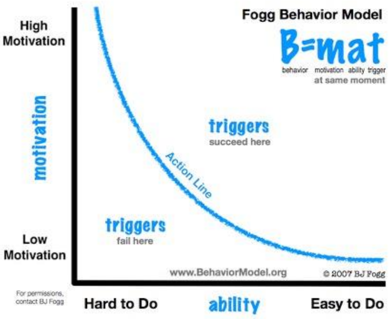

Fig. 4   Fogg's behavior model, created by dr. BJ. FOGG

The FBM highlights three principal elements, motivators, simplicity factors and triggers. These three elements have all specifically subcomponents. According Fogg, triggers might seem simple on the surface, but they can be powerful in their simplicity.

The FBM has three main elements, one of which is Ability. In order to perform a target behavior, a person must have the ability to do so. According Fogg designers of persuasive experiences sometimes assume people have more ability than they really do. There are two paths to increasing ability. You can train people, giving them more skills, more ability to do the target behavior. That's the hard path. The better path is to make the target behavior easier to do. Fogg calls this simplicity [12]. In his behavior model sometimes the term ability can be swapped with the term simplicity. Ability is the correct general term in the model, but in practice simplicity is what persuasion designers should seek. By focusing on simplicity of the target behavior you increase ability. Simplification of the assignment is necessary to keep the motivation and the right window according Fogg's motivation. The third element of the Fogg Behavior Model are triggers. Without a trigger, the desired behavior will not happen. Triggers can be useful to activate a human behavior. Triggers can be external, like an alarm sounding. Other times, the trigger can come from our daily routine. An effective trigger for a small behavior can lead people to perform harder behaviors. According Fogg, it's a natural chain of events that an effective trigger puts into motion [12].

According Fogg, simplification of the assignment is necessary to keep motivation. Simplification is only needed when the ability doesn't match with the expectations and the chosen triggers. The SIM project is using several types of simplification, so that groups can go through all aspects of the V-model.

Groups are formatted by the project coordinator. The groups exist between 6 and 8 persons. The groups are formatted inside a class, with a maximum of 32 students in class.

4 FIRST YEAR PROJECT MECHATRONIC

The department of mechatronics, of the university of applied science has strong connection with the high-tech industry. Most of the graduated students will be junior employees in those companies. That's why the systematic approach behind a project needs to be developed on the university. The main goal of the first years project of the mechatronics department is that students, needs to cooperate in several project groups and get familiar with process that's behind the development of a mechatronic system. The first years project theme is the “”Smart Industry”.

The curriculum of department of mechatronics contains four quarters. Every quarter exist of 10 weeks. The duration of the whole SIM project takes 30 weeks, where the projects is divided in three parts; SIM1, SIM2 and SIM3. The total amount of European Credits are given with by every project, and the total workload for every student is 15ECTS divided over these three periods.

To optimise the maximum result out of a project group a competition can be very useful. Competitions as First Lego League (FLL), First Robotic Competition (FRC) and Robocup are examples whereby technical assignments inspire students [10].

For the SIM project 25 teams will compete in game. The game is to create an autonomous driven vehicle which is capable of picking up objects and to place the objects on a scale. All the weight that is collected and placed on the scale will result in points. The groups have a maximum of 5 minutes to collect as much as possible weight.

The use for gamification inside a project is to stimulate a certain behavior. Focussing on the process will result in a better product of the group. In SIM1 the group must realise an autonomous driven vehicle which is capable of following a black line on a white surface.

In SIM2 the group needs to develop a gripper which is able to pick up objects from the floor, place them on the vehicle and eventually place them back on the floor. The technical specifications are given at the beginning of SIM2. In the game more advanced grippers can be rewarded if they are capable of picking up objects from various heights and distances. In SIM3 group needs to integrate the solutions of SIM1 and SIM2. In SIM3 the assignments of the SIM1 and SIM2 are placed in a different context.

At the start of the project students have mostly no idea how to start a project or what to do. This often results in a slow start of the project, and that generally effects the final result. Gamification techniques can help groups at the start of the project, but it gives tutors also the possibility to give feedback earlier in the process.

5 IMPLEMENTATION SIM PROJECT

For the setup of the SIM project a canvas model is used [13]. To make this project functional and fun, the theme “Smart industry” is chosen. By adapting this theme students will automatically try to make a link with the new industrial era. Groups will work on different assignments in SIM1 and SIM2. In SIM3, the parts of SIM1 and SIM2 will be integrated in a final product. Another requirement was that “systems engineering” was applied in every SIM-project. The implementation of the game mechanism is bounded to the environment of the university of applied science.

The university environment facilitates workshop areas, a shop, meeting rooms and workplace per group. In the mechanical workshops students can work under supervision on machinery or can print 3D components in our print lab. Other mechanical and electronics parts can be ordered through a shop. A group gets a fixed budget per quarter, which can only be spend within the FHENG environment. For general meeting purposes FHENG facilitates several meeting rooms for groups. Having special meeting rooms makes it possible to have a weekly meeting between a group and a tutor. By having all these facilities, the university environment simulates the industrial way of working on a very basic level.

As described, the main goal during the SIM project, is that students learn to work in a team and to develop a systematically approach for developing a mechatronic system. To optimize the workflow, groups needs to get familiar with the university environment. This means that at the begin of the SIM project, the focus of the project is more in exploring the environment and to see what is possible inside the environment, then on the technical product. Once the group knows what is possible inside the environment to group can think about setting up the technical requirements.

The mechanism of the SIM project is based on the V-model. Groups can go through the V-model by doing task in levels. The V-model is divided in ten levels, as can be seen in Figure 5. After every phase of the V-model a new level is introduced. On this way the tutor is able to give earlier feedback.

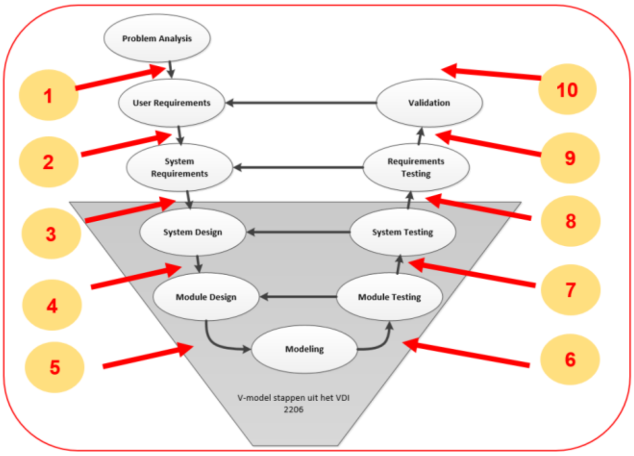

Fig. 5: Simplied V-model linked to gamification levels

At the start of the SIM project students have a basic knowledge and are unfamiliar with the habits of procedures inside a new school. In that perspective the scope of SIM1 is in the early levels of the project not only focussing on the technical aspect, but also exploring the environment. In SIM1 and SIM2 students get a full description of what to do. In SIM3 groups are familiar of the way of working, and need to merge the solutions from SIM1 and SIM2 in a final solution. If the solution of SIM1 and SIM2 doesn't match the requirements, groups can improve or fix their solution in SIM3. In this way groups can learn from making decisions by analysing the process. Early made decisions can have a huge impact on the final product. Analysing the process can result in new insights on how to approach a problem and how to improve the quality of the process or product.

The triggers are used to go to next level. In the SIM project the triggers are divided in four categories: general tasks, technical work, documentation and evaluation. In every category groups can score points by doing tasks in every category. Per level you groups can earn maximum 20 points. For every average task, one point can be earned. Complex tasks, or larger tasks, can be rewarded with multiple points. To align the triggers with the ability and talents of the students, a mechanism is created. Groups can go to the next level by succeeding a couple of tasks in every category. This means that there are more tasks written than needs to be done. Triggers works best, when a group believes they are in control. Having options means that group can control the situation. By creating multiple categories, the group can control the situation on several elements. By doing different tasks, students can create their own route to reach the next level.

Triggers can help to increase the ability, but in some situations the needed ability is too big. In these kind of situations simplifications can be applied to a certain task. Other possibilities in this model is that the minimum score that's required for every category can be adapted.

To insure that groups can finalize every project, simplification of the main goal of every project is necessary. Simplification for the SIM project where mainly technical simplifications. In SIM1, for the autonomous driving, all basic hardware was provided by the project organisation. The basic hardware consist of, a vehicle, a microcontroller, a H-bridge for controlling the motors of the vehicle and a battery. To make it easier to realize an autonomous vehicle, a black line was taped on a white surface which they could follow.

In SIM2 essential information about grippers and mechanics was provided. This was for Increasing the technical spectrum of the students and to stimulate them. In SIM3 no technical simplifications where introduced. Chosen concepts in SIM1 and SIM2 need to be integrated, fine-tuned and tested in SIM3.

During the SIM project a weekly meeting took place with the tutor. The tutor monitors the process of the group and gives feedback about the tasks. In these meetings the students simulate a company meeting and the tutor will be there as an observer. During the meetings the tutor can decide to give feedback or feedforward information to the group.

6 CONCLUSION

A canvas model can be used for setting up a technical project where gamification techniques are integrated in a systematic approach. One of the key elements to successfully wrapping up a project is the project environment. The university has an environment which simulates processes inside a company. These facilities contribute to the behavior of students and how to approach tehcnical projects. To keep students connected with the industry, the theme "Smart Industry" is chosen for the first years mechatronics project. The smart-industry theme was leading for setting up the technical roadmap for the project. The project is divided over three projects. The results of the first two projects will be integrated in the final product. In every project groups needs to work with the V-model. The gamification techniques are mainly applied on the systematic approach. The V-model is divided in ten levels. Going to the next level can be achieved by doing tasks. Tutors evaluate the levels. By creating ten levels, ten evaluations moments are created. This lead into earlier feedback from the tutor and groups that know what to do. By applying gamification in the SIM project, we experienced a positive contribution to the development of skills, attitude and knowledge for the first year students.

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Connecting staff expectations and student understanding of professional engineering skills in a multidisciplinary design challenge

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ABSTRACT

This paper discusses the evolution of an active learning assignment [1] for second year undergraduate biomedical engineers. An arc of assignments throughout the first two years of their study supports their understanding of the design cycle and aids in assimilation of material taught in lectures and more structured laboratory workshops [2]. The assignment – to create an item of 'smart' clothing for an athlete – was primarily designed to reinforce student learning in the areas of physiological monitoring through transducers, basic electronics and Arduino programming.

A misalignment was observed between teaching staff's preconceptions of students' skills and knowledge, and the experience that the students actually bring to the assignment which influences how they approach the work, echoing the concept of the hidden curriculum [3]. This led to the team aiming to improve support of students' skills in debugging, their awareness of laboratory health and safety and links between different strands of their education through pre-assignment material, changes in teaching vocabulary and small changes in assessment. The impact of the changes has been evaluated through teaching team discussions and analysis of short pieces of individual reflective writing done by every student as part of their assessment before and after the material's introduction.

Conference Key Areas: Engineering Education Research, Curriculum Development, Skills and Engineering Education

Keywords: Professional engineering; design; group project.

1 INTRODUCTION AND BACKGROUND

1.1 An active learning assignment

A key enabler for undergraduate students to make the transition from passive learner to competent practitioner can be to support the development of their problem solving and design skills through active learning [1]. This can be done through providing open-ended design projects structured to support the arc of the design cycle [4]. We have done this during our engineering undergraduates' first two years through a series of six week-long assignments that consolidate engineering knowledge taught prior to each assignment while encouraging students to apply their new knowledge to an open-ended design task [2].

For this assignment, Biomedical Engineering students work in groups of three to use wearable Arduino technology [5] and a free choice of electronic sensors and outputs to create a prototype item of clothing that will monitor an aspect of an athlete's condition, chosen by the students, and provide an alert if an unacceptable level of injury is likely to occur. The published Learning Objectives for the assignment cover the students' knowledge and understanding of physiology, biomechanics, digital and analogue electronics and microprocessor programming alongside the professional engineering skills required to meet a design brief such as time and budget management and working effectively in a group.

1.2 Research methodology

We have followed an action research approach in the evolution of this student assignment and look at differences between two separate cohorts of students taking the assignment in consecutive academic years – known as cohort A and cohort B. Cohort A consists of 11 students who were set the unaltered assignment; cohort B has 21 students who followed the modified assignment one academic year after cohort A.

While teaching cohort A, the teaching team discussed problems they perceived with the students' approach to their work, and this discussion led to the reflection and research used in the process of developing the assignment that was then undertaken by cohort B. Our initial hypothesis is that the students were unaware of their apparent shortcomings in the perceived problem areas noted by the staff. This was tested by considering a short piece of reflective writing on the assignment that each student carries out as part of the assessment. These pieces have been analysed to assess the students' own awareness of the perceived shortcomings.

Changes were made to the assignment between the two cohorts to address the perceived problem areas and the effectiveness of these changes has been assessed both by discussions with teaching staff on their observations of the class and their views on whether this disconnect between staff expectations and the students' performance had been addressed, and by looking at the reflective writing from cohort B.

2 ACTION RESEARCH ON AN ACTIVE LEARNING STUDENT ASSIGNMENT

Second year Biomedical Engineering undergraduates work in groups of three for five days to fulfil a design brief to make an item of 'smart' clothing for an athlete that can monitor an appropriate physiological parameter of their choice and give a warning should that parameter fall out of pre-set safety parameters. The clothing should be safe, reusable, customisable and fall within a set budget. The students receive an introductory end-user design requirement and question and answer session with an athlete (an ultra-runner) before starting the assignment, and have previously had teaching on the design cycle, technical drawing, physiological monitoring, transducers, Matlab programming and digital and analogue electronics. The students have had no formal teaching while at university in Arduino programming, but some may have prior experience outside of their studies. The intended learning objectives are given in figure 1.

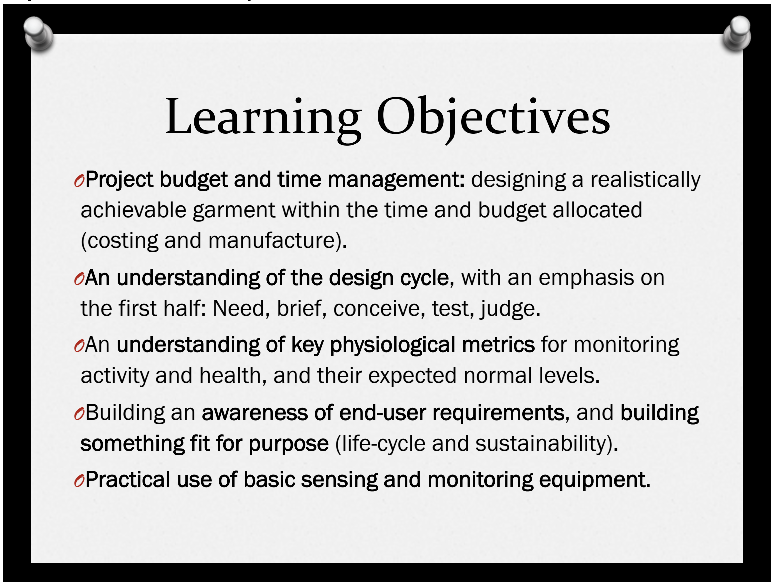

Figure 1. Learning Objectives given to the students before the start of the smart clothing assignment.

The assignment is the first very open-ended design and making project that the students encounter in their degree programme. Any type of clothing can be designed and built to monitor any parameter to give any signal so long as the students can justify how their choices meet the design brief. One student noted in their feedback:

"The [assignment] was by far the most fun I have had. The possibilities that we could have come up with were endless, only limited by time and budget" -Student B_6_2

Students are given access to the full range of facilities on offer in the undergraduate teaching laboratory and university maker-spaces. A wide assortment of electronics and sports clothing is available for instant purchase from the teaching team, but students also have the option of asking to purchase anything the laboratory does not have in supply. Adafruit Flora Arduinos have been stocked by the laboratory due to their robustness, wearable nature and the large amount of supporting code and maker projects available on the internet.

Between the two cohorts, the students have designed and built (with varying success) 2 pairs of pressure sensitive gait analysis trainers, 3 sweat concentration monitoring tops, 2 temperature sensing armbands, a temperature and humidity sensing top, a UV sensing cap, a core temperature and respiration rate monitoring sports bra and a GPS distance tracking wristband

Most groups chose to use coloured LEDs to indicate changes in the parameters they are monitoring.

Assessment for each cohort was based around the initial design, the end produce and short pieces of written work.

2.1 Cohort A pre-work and assessment

Cohort A received an introductory lecture for the assignment a few weeks prior to the week spent in the laboratory carrying out the assignment. This consisted of delivery of the brief, a presentation by a researcher working in the area of wearable assistive technology, and a discussion with a member of the teaching team who is a runner. The students were also shown two items of smart clothing developed by a previous student [6]. They received a list, and costs, of the electronic components readily available in the teaching laboratory and were told to research the available components and consider how they might meet the design brief. Links to information on Adafruit components and examples of wearable electronics were made available on the university VLE.

Cohort A's assessment is shown in Table 1:

Table 1. Assessment structure for Cohort A

Design Phase	*Decision matrix* using appropriate choices of criteria	5%
	List of physiological parameters the clothing aims to measure, and their expected ranges.	5%
	Design and estimated cost. A technical drawing full enough for someone else to be able to make your clothing	10%
Prototype Clothing	*Quality of prototype*, and closeness to meeting brief	30%
	Aesthetics – peer assessment	10%
Written report	*Full final costing* including broken components	10%
	Short reports on one area of: product life cycle, sustainability, scaling up manufacturing and costing	10%
	Individual reflection justifying any deviations from original design and plans. Reflections on how the week went and any changes that the student might choose to make if the process was repeated.	20%

2.2 Staff observations on Cohort A

Discussions with the teaching staff indicated that, on the whole, the class met the Learning Objectives shown in figure 1. However, staff felt there were shortcomings in areas where they had assumed students would be able to draw on prior experience of system troubleshooting and debugging, and be able to identify links between this assignment and previous classwork.

- All groups in the cohort, regardless of previous measures of academic ability (examination results and staff reports), attempted to completely construct and hard-wire their designs before testing any individual components and had to be encouraged regularly by staff to build their systems' complexity step-by-step rather than taking a 'plug and play' approach. The staff spent a significant amount of time teaching repeatedly concepts of basic debugging of coding and electronic circuits to individual groups of students.

- The students failed to identify the sensors available to them as transducers, despite having previously worked in structured laboratory sessions to characterise a set of transducers. The teaching team had to remind all groups of this work that they had carried out in the previous weeks, and encourage them to look back at their notes to draw parallels between the two assignments.
- The class also exhibited limited attention to heath and safety considerations when working on these self-led projects compared to the usual levels of conscientiousness that they adhere to in heavily structured mass cohort laboratory work. They did not appreciate that the use of un-insulated conductive thread would increase the risk of short circuits, and forgot very basic laboratory safety concepts (figure 2).

Figure 2. Students forgot basic lab safety, such as not jumping on a narrow piece of wood while attached by a cable to a laptop.

2.3 Changes implemented between Cohort A and Cohort B after discussion of staff observations

Changes were made to the preparatory work and resources given to the cohorts and some of the assessment was modified. The teaching team were also encouraged to use vocabulary echoing that in other parts of the undergraduate programme of study to reinforce links across the syllabus.

2.3.1 Preparatory work and pre-assignment resources

The introductory lecture for Cohort B again took place a few weeks before the assignment. The students did not receive the additional lecture from a researcher, but spent more time discussing the prototypes made by previous students and also received more instruction on the importance of health and safety and building a complex system in steps for ease of debugging.

Additional material was prepared by the teaching team and made available to the students on the VLE. This included:

- A guide to Adafruit wearables
- A quick guide to C++ Android programming showing common functions for Arduino
- A troubleshooting flowchart, with brief accompanying notes to aid in successfully producing working electronics.

Cohort B were told that cohort A had lost time during the assignment due to problems with debugging and understanding basic coding concepts, and were encouraged to read this material before beginning the assignment. They were also explicitly told that they would be using transducers and should revise any previous learning in this area.

2.3.2 Assessment

Much of the assessment for cohort B remained as in table 1. However, 10% of the prototype marks were allocated to the production of a plot of 'transducer characterisation' and 10% to 'health and safety' in an aim to use the backwash effect [7] to modify student behaviour regarding health and safety. Cohort B were not allowed to hard-wire any components until the teaching team had seen evidence of a transducer characterisation that indicated that a group had knowledge of the correct circuit required to obtain data from the transducer(s) of their choice.

2.3.3 Staff-student interactions during the assignment

The teaching team were encouraged to use vocabulary throughout the assignment that mimics the rest of the students' education – 'technical drawing' rather than 'design', 'transducer' instead of 'sensor', and 'digital electronics' rather than 'Flora' or 'Arduino'. Staff also ensured that the student groups had worked through the troubleshooting flowchart before offering assistance in the laboratory. These protocols aimed to encourage students to make links between their learning, and to facilitate movement towards independent troubleshooting and debugging.

3 RESULTS

The individual reflection written by each student as part of their assessment was used to appraise their overall awareness of the three areas of weakness perceived by staff: system debugging and troubleshooting skills, making connections to the rest of their curriculum and awareness of health and safety.

3.1 Cohort A

Cohort A consisted of 11 students in total split into three groups of three and one group of two. Seven (64%) students used the terms relating to debugging, troubleshooting, and iterative processes in their reflections. Three (27%) students mentioned other parts of their curriculum – two referencing transducers and one the design cycle. Three (27%) students mentioned safety and comfort of the end-user.

3.2 Cohort B

Cohort B consisted of 21 students split into seven groups of three. 13 (61%) students used terms relating to debugging, troubleshooting and iterative processes in their reflections. Nine (43%) referred to other parts of their curriculum – seven referencing transducers and two the design cycle. Nine (43%) students mentioned health and safety, although only one mentioned it in the general context of their groups work, with eight discussing health and safety purely from an end user context.

3.3 Staff perspective

Three members of the teaching team were asked to report verbally on their personal comparison of the two cohorts. Overall, it was stated that cohort B required 'less help' in debugging their systems and were more engaged in troubleshooting processes. However, it was also noted that the cohort did not appear to make copious use of the troubleshooting pre-assignment resources during the week-long assignment. Cohort B was reported to show a slight increase in their awareness with other parts of the curriculum. Staff reported no change in the proportion of groups, in their estimation, who lacked awareness of laboratory health and safety requirements.

4 DISCUSSION

Overall, this work has involved small cohorts of students: 11 and 21 in the two groups. This means that the statistics on the data are poor. An additional student adds 9% onto any quantitative values for cohort A and 5% onto those for cohort B.

We have made changes to the assignment reported in this work. However, it is possible that other university teaching staff have also made changes to the students' wider programme between delivery to the two cohorts that could also contribute to the changes in the students' skills and understanding reported in this paper.

4.1 System debugging and troubleshooting skills

Assessment of the students' written reflections shows no increase in phrases relating to system debugging and troubleshooting between the two cohorts. 64% of cohort A and 61% of cohort B use terms relating to this area. Staff reported that cohort B required less help in this area, but this has not been quantified.

It was noted by the teaching team that the students did not appear to regularly refer to the troubleshooting material provided by the teaching team during the week. It is possible that they read and understood the material prior to beginning the assignment. It is also possible that the act of introducing clear summative assessment for the transducer characterisation and not allowing hard-wiring of components before showing evidence for this assessment created additional structuring to the assignment that supported the students to de-bug before full construction of their prototypes.

4.2 Making connections to the wider curriculum

Cohort B showed an improved awareness of the links between this assignment and their wider curriculum. The ratio of those relating the assignment to the design cycle and those relating it to their transducers learning was ~1:2 for both cohorts. No student mentioned both the design cycle and transducers.

4.3 Awareness of health and safety

There was an increase in the awareness of health and safety requirements for the end-user seen in cohort B. However, staff noted no improvement between the two cohorts' general awareness of laboratory health and safety guidelines.

5 SUMMARY

This paper considers the efficacy of changes made to protocols and material related to a second year undergraduate assignment between the 2015/16 and 2016/17 academic years.

The assignment took place during the 2016/17 academic year with this new material and protocol in place. Staff noted that this class appeared to be more engaged with awareness of connections across their wider curriculum and debugging. No change was seen in awareness of laboratory health and safety. Reflective writing by the students showed no increase in discussion of debugging between the two cohorts, but an increase in discussions regarding links to the design cycle and classes on transducers, and a greater awareness of health and safety for end-users of their prototypes.

Action research will be continued for this assignment and further changes will be made for the 2017/18 academic year:

- The lecturers on the transducers course will be included in the preparation of this assignment with an aim to increasing integration between different parts of the overall programme.
- The teaching team will continue to highlight laboratory health and safety – pre-assignment quizzes in this area are being considered.
- We will continue to monitor the response of cohorts to troubleshooting and debugging, with an aim to facilitating a movement towards independent and confident use of these skills. One student stated:
  "I have primordially learned on the importance of having a vision by starting very simple. Breaking down the idea on multiple layers and starting with the foundation. Once that is working, you can add layers of complexity one by one.." – Student B_7_2

We aim to reach a point where the majority of students show awareness in this area.

We believe that, in a wider context, the work supports the concept of the backwash effect - the use of an assessment scheme that explicitly allocated marks for an awareness of a given area (in this case health and safety) led to an improvement in students' self-reported awareness of the area. The work also shows that integrating the vocabulary used by teaching teams across students' entire education can reinforce the process of making links between separate areas of learning.

6 ACKNOWLEDGMENTS

We are very grateful to the cohorts of students who took part in this study, and our teaching and education research teams especially Adam Gibson, Pilar Garcia Souto and Mikael Brudfors.

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Wooden Boat Building for Modern Naval Architecture Learning

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ABSTRACT

Current naval architecture curriculum in Taiwan focuses on building theoretical knowledge and scientific research skills through teaching mechanics and mathematics in the early years. It's believed that shipbuilding involves complex systems thinking and that therefore design should be engaged after one has acquired solid theoretical knowledge. Students struggle however to establish integrated understanding about ships from diverse knowledge sources and various learning methods. Architecture education, on the other hand, starts with introducing students to design and model making at an early stage and these topics retain emphasis throughout their entire education. Inspired by the restoration of an old Chinese junk, the authors wanted to investigate the relevance of wooden boatbuilding for modern naval architecture learning. We designed a hands-on curriculum where students built a western sailboat model following standard procedures. Students learned about modern timber, basic carpentry skills and could exercise their spatial intelligence. We also involved a highly experienced local shipwright master. Students have reported to gain integrated understanding of design, construction, material, mechanics, aesthetics, societal and historical aspects of wooden boats. The class has elevated interests in shipbuilding and facilitated active discussions about using wooden boat building as an agent for modern shipbuilding knowledge construction.

Conference Key Areas: Engineering Skills

Keywords: engineering education, hands-on learning, naval architecture, wooden boat building,

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The role of entrepreneurial skills in engineering education:
A case study performed in Denmark, Japan, Korea and Sweden

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ABSTRACT

The importance of teaching entrepreneurial skills has been on the agenda for several years. But how do engineering education institutes (EEIs) serve as institutions facilitating the learning of these skills? In this study, we compare four EEIs from four countries located in two global regions, East Asia and the Northern Europe, in order to identify models for how education in entrepreneurship can be implemented according to each country's situation. We use a modified version of Dahlöf and Lundgren's frame-factor theory to analyse how the universities understand the internal and external driving forces for the development of this kind of education. We also address how these frame factors affect the development processes at each EEI. The study identifies differences in these processes, which depend on how pressures originating outside the universities are expressed.

Conference key areas: skills and engineering education

Keywords: entrepreneurship, innovation, frame-factor theory, engineering-education institutes

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INTRODUCTION

Globalisation, the digitalisation of society and other trends are expected to lead towards a different work situation for many people. A more turbulent work environment is expected, where more short-term jobs and project-oriented jobs are created and where people change work tasks more often.

This is one reason entrepreneurship has been on the agenda in education development for the past 20 years. Already at the beginning of the 1990s, OECD (the Organisation for Economic Co-operation and Development) published a report that pointed to entrepreneurial skills as a crucial ability for people who wanted to pursue continuous technical development (Blanchflower & Oswald 1998).

However, the entrepreneurship and enterprise are difficult to define. The entrepreneurship concept has its origin in an economic tradition and is derived from the French word *entreprendre*, which refers to an active person who gets things done. The Oxford Dictionary defines an entrepreneur as someone who 'sets up a business or businesses, taking on financial risks in the hope of profit'. Recent literature has extended this concept to cultural and social contexts (Skolverket 2015). A broader approach is also taken by Shane and Venkataraman (2000), who explained that entrepreneurship involves discovery, invention, creativity and, of course, ways of bringing the new ideas into a market. In an effort to cover all aspects of entrepreneurship, we refer to the general capabilities associated with entrepreneurship as 'entrepreneurial skills' and to the special capability of knowing how to establish a business as 'knowledge about enterprise'.

Over the past 20 years, enterprise education and the training of entrepreneurial skills have been the subject of a great discussion and debate in OECD countries. Strategic plans for entrepreneurship education at different levels of the educational system have been developed in some countries (Regeringskansliet 2009, Ministeriet för Vitenskap etc. 2010). Engineering-education institutes (EEIs) play an important role in entrepreneurial development; engineers often have positions in which entrepreneurship is a highly regarded skill, because they work in areas were technical development is moving very fast. The last 10 years have witnessed the formation of centres for entrepreneurship and enterprise and professorial appointments at engineering universities. These academic developments are meant to ensure that entrepreneurship is fully realised at the university level.

However, there is a lack of empirical studies that address how engineering education actually provides entrepreneurial education for engineers in a structured way. Although we have seen many examples of entrepreneurship courses, our impression is that entrepreneurship is not always taught in a coordinated, strategic and continuous fashion.

In this study, we take the first steps towards creating a model that can inspire and help EEIs to develop strategic and coordinated programmes for the teaching of entrepreneurial skills and enterprise. The model will be based on our comparison of cases from four countries representing two OECD regions. The case comparisons address how the EEIs in these countries include entrepreneurial skills and enterprise in their education. The two global regions in which the EEIs are located are very high-tech regions, but they are significantly different with respect to both educational and work culture.

The comparison will be conducted by analysing how engineering faculty, including both management and teachers, interprete the integration of entrepreneurial skills and enterprise from a university perspective. The analytical approach is based on the frame-factor theory. The results will be used to develop models for how engineering education can become a strong link in the engineer's development of entrepreneurial skills.

1. BACKGROUND

1.1 The frame-factor theory

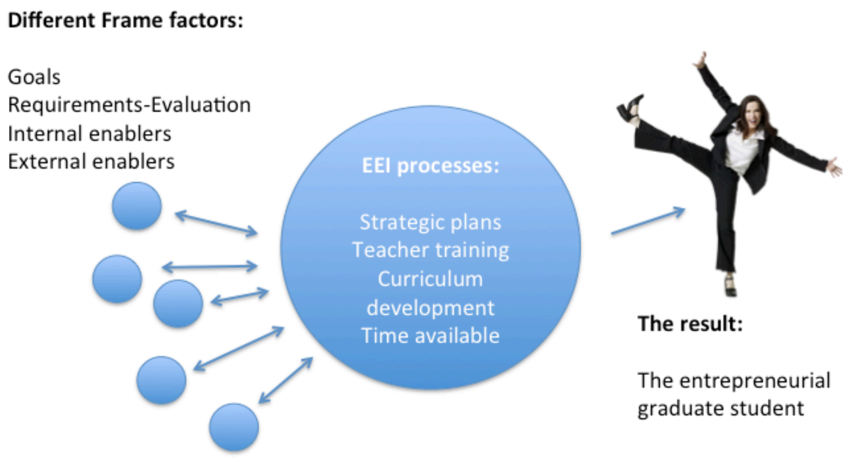
In this study, our perspective resembles the classic frame-factor theory, developed by Dahlöf and Lundgren in the 1960s and 70s (Broady, 1999). They used this theoretical framework to analyse the factors influencing teachers' teaching situations.

This theory posits that a teacher's ability to influence a teaching situation is relatively limited and is controlled by a variety of external factors that are difficult to change directly. Although we do not use the theory as such, it serves as an effective basis for our approach to the development of the teaching of entrepreneurship. We investigate the process of educating entrepreneurial citizens not through the eyes of the teacher, but through the eyes of the EEIs. The frames are seen as the factors of entrepreneurship education that EEIs cannot directly influence. These factors are defined in terms of each country (in this case each EEI) in order to create an awareness of which factors constrain the development of entrepreneurial-skills education at specific EEIs.

We investigate the processes undertaken? at each EEI to implement and run entrepreneurial or enterprise education. By studying the combination of these two types of factors, we hope to explain how and by whom the educational-development processes in this area are controlled.

In our approach, the *frames* are understood as the laws and regulations that affect entrepreneurship education and that enable engineering education. The *processes* refer to what is going on at the universities, such as faculty-training programmes, the development of strategic plans and the creation of good preconditions for the teaching of entrepreneurial skills and enterprise. The *result* is a student who has learned the skills necessary for becoming an entrepreneurial engineer (see Figure 1).

Figure 1: An overview of the described aim of the study.



2. METHODS

Two professors from the engineering faculty of each EEI were selected as informants for the survey. The EEIs studied were Aalborg University (AAU), Denmark, University of Tokyo (UT), Japan, Korea University (KU), South Korea, and the Royal Institute of Technology (KTH), Sweden.

In total, eight informants were included in the survey. One of the informants, the dean of an engineering department/college, represented high-level management. The other informants were professors engaged in the work of entrepreneurship education. A risk of the study was that the selected informants represented a group that had significantly greater competence in entrepreneurship education than other faculty members.

The faculty members were interviewed according to a semi-structered interview technique, in which a questionnaire was used as the question base. Each interview lasted about an hour.

Our analysis of the interview transcripts focused mainly on the questions associated with the frames and the processes taking place at each EEI.

3. RESULTS

3.1 External and internal enablers

In Denmark, the informants expressed the experience that society is changing. They described engineering as a field in the midst of a change in which more employees will work as consultants in smaller enterprises rather than as employees of large companies. This, in turn, requires that engineers be trained to handle this type of employment. The community in general has been aware of this change for at least the last 5–10 years, and a number of promotional activities have been launched during this period, including activities and competitions organised by various associations not related to the university. The informants also expressed a willingness to support the competence shift that needs to be achieved in order to successfully adapt to this change at government level. For instance, there has been funding for projects that can be applied for by individual teachers or teams of teachers in order to improve entrepreneurial and enterprise education. There have also been opportunities to apply for larger contributions that could be used to support broader changes in university education. Private donations were also mentioned as a basis for strengthening entrepreneurial education at universities.

In Japan, the informants gave a somewhat contradictory picture of the approach to implementing entrepreneurship education. On one hand, Japan has a strong desire to become more entrepreneurial, that is, to be a country where new ideas are developed and where new enterprises can start up. On the other hand, Japanese culture maintains in rather strong terms that it is almost impossible for a person to succeed after having failed, which means that in practise it is more favourable for engineers to work in the same company for the entirety of their careers. The informants expressed that companies would like engineers to develop more intrapreneurial skills; that is, companies would like EEIs to teach future engineers to play entrepreneurial roles within the company and to have the ability to develop new ideas that strengthen the company. As a result of the Japanese way of looking at career life, it is not really important to educate students in entrepreneurial skills and enterprise at the university level. In the future, this can be done at the companies themselves. The informants said that UT may be in a special position, because UT students quickly and easily get jobs at large, respectable companies. Therefore, the importance of having entrepreneurial skills might be more prominent in the context of a smaller university.

The government supports initiatives like EDGE-Global and Entrepreneur-Dojo, which are global venture activities in which engineering students can participate. The problem with these activities and competitions is that they do not give university credit and are therefore seen as less attractive by the students.

In Korea, there is strong external pressure to develop entrepreneurship and innovation competencies in engineering education. Industry has influenced this process by exerting strong pressure to improve this part of engineering education, which in turn has prompted the government to see entrepreneurship education as very important. The informants described government support for student venture competitions and projects designed to strengthen engineering education as such. In South Korea, there are also some mechanisms of direct control. In the accreditation process for engineering education, universities have to show that they offer courses on entrepreneurial skills as capstone design courses. There are also upcoming plans for the government to link funding of research based on the presence or absence of entrepreneurship and innovation education, often referred to as capstone design courses, in which social issues are dealt with in teams, together with industry/society.

The Swedish informants expressed disappointment regarding the development of entrepreneurial and enterprise education. The topic has been on the agenda for many years, but without being lifted to the next level in engineering education. There is undoubtedly pressure from industry and other associations, as is evidenced by the many activities—such as competitions for students—that are supported by companies or associations. Swedish industry also sees intrapreneurship as an important part of the development of those skills, which means that there is a desire and a need for these kinds of skills within the companies.

A popular initiative funded by a private foundation in Stockholm, the Stockholm School of Entrepreneurship Education, is partly devoted to engineering students from KTH but has the overall aim of strengthening entrepreneurship education for students from different areas. The informants did not see the government as directly supporting the development of entrepreneurship in engineering education, but there is authority that holds money for investing in entrepreneurship in Sweden through available research funds.

3.2 Processes within universities

At AAU, in Denmark, problem-based learning has been the basis for education for a very long time (Xiangyun et.al. 2009) This pedagogical methodology fosters some of the entrepreneurial skills to be developed over the course of the students' education career, because students work in teams with companies closely linked to their projects. Despite this fact, the informants expressed that faculty do not necessarily know how to educate students about entrepreneurship. Most faculty members have never worked outside the university, and therefore they most often lack 'real experience'. The aim at AAU is to give all engineering students the opportunity to learn entrepreneurial skills and enterprise, but the university's strategy for developing entrepreneurial competence is not yet clear. It may include hiring teachers from industry and/or training faculty already at the university. AAU has a centre for innovation, where engineering students can take elective courses in entrepreneurship, which often include learning outcomes such as competencies for developing a new idea and building a start-up company. The students frequently take these courses. The university also runs a master's programme in entrepreneurship, in which students work on, among other things, innovation ideas over a two-year period.

UT also has a centre for innovation and technology, where elective courses are offered to students, although this centre does not currently have much space available for engineering students. For engineering students, it is mandatory to take courses that contain some education in entrepreneurship and innovation, such as the courses called GMI and GMSI. For these courses, UT hires teachers with industry experience.

KU is pressured to develop capstone design courses for all engineering students, and these courses are therefore developed within the School of Engineering. No clear strategy for building up the competence among faculty was described by the informants, but the teachers of capstone design courses are now predominantly teachers with industry experience. KU has a centre for innovation, which is used to pursue entrepreneurial activities. The Business School offers elective courses for all students in the area of innovation and entrepreneurship. It has been difficult for engineering students to enter these courses (because the Business School has to prioritise its own students), so the Business School now offers two courses devoted exclusively to engineering students.

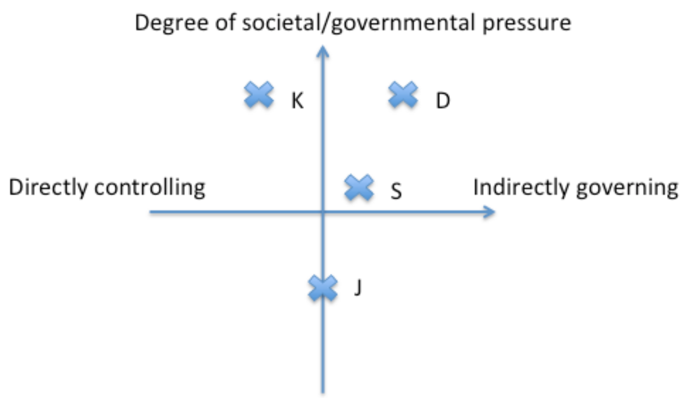
As in Denmark, at Sweden's KTH, no legislation makes it mandatory to teach entrepreneurship in engineering-education programmes. But the external forces have led to the development of a master's programme in entrepreneurship and innovation. There is also a link to the Stockholm School of Entrepreneurship, where engineering students can take elective courses in this field. Enthusiastic professors, with support from management, have also initiated projects like the Open Lab, where students work in interdisciplinary teams on real-life problems, or the Global Development Hub, where teachers and students work on problems in developing countries together with students and faculty in the relevant countries. In those projects, there are elements of faculty training with designed courses for faculty on how to teach entrepreneurship.

4. DISCUSSION AND CONCLUSION

This study shows that the driving forces for developing entrepreneurship education vary across the four countries. It is also plausible that these differences have led to the different approaches/strategies taken by each EEI.

An important area of difference is how much pressure is put on the universities from the surrounding society and how this pressure is expressed. Figure 2 shows an estimated degree of pressure directly controlling the university and, on the other hand, if they are more indirectly governing by promoting activities The figure shows that in the development of entrepreneurship education, both Korea and Denmark experience strong pressure from society as well as relatively strong support from government and other actors. Korea stands out as the country where there is also direct pressure on engineering education; the government partially controls the presence of entrepreneurship education in the form of capstone design courses. In Sweden and Japan, social pressure seems to be somewhat weaker than in the other two countries, although there are similar activities supported by governments and authorities to a lesser extent.

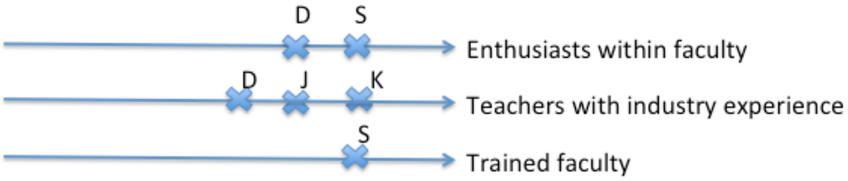
Figure 2. External pressure to develop entrepreneurship education.
DK = Denmark, J = Japan, K = South Korea, S = Sweden



We argue that the different approaches taken at the different EEIs are related to what kind of working force is or has been involved in the processes of developing entrepreneurship education (see Figure 3). In the two Nordic countries, the development of entrepreneurship education in the universities has relied very much on enthusiastic faculty members who believe in its importance. This might be due to the relatively long history of having entrepreneurial skills and enterprise on the educational agenda.

In the countries where we find strong pressure from society, we also see a high degree of involvement from people in industry. This is also true for Japan. Sweden stands out as the country that has come the furthest in the planning of developing the faculty in charge, even though this does not seem to be a well-defined strategic plan.

Figure 3. Persons involved in the work of entrepreneurship education. D = Denmark, J = Japan, K = South Korea, S = Sweden



In conclusion, this study indicates that two of the universities, AU and KU, are working harder than the other two to ready themselves and their students for important changes in how engineers work—changes that will necessitate a broader competence in entrepreneurial skills and enterprise. The other two EEIs, KTH and UT, seem to be aware of the important changes on the horizon, but they are not making proactive attempts to change engineering education accordingly.

These differences may depend partly on the country in which the EEI operates, but the differences may also depend on the characteristics of the EEI itself. Potentially crucial factors are the size of the university, its ranking, and whether it is a private or state university. We will investigate these factors more deeply in our next study.

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Project Management Software Tools for Education

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ABSTRACT

Most universities pursue efforts to provide students with the best skills to tackle the employment market by offering subjects that fulfill market needs**.** By doing so, young engineers will find on the job site a reduction on its learning curve when confronted with similar subjects or even tools. Project management tools are increasingly used in the IT Market but unfortunately, are not widely taught or even applied in the academic context. In order to encourage the teaching of such tools and by having in mind the sustainability of engineering education, we have done a survey on well referenced free project management tools that have the capability to follow some of the PMBOK practices. In this context, we tested and compared the following project management tools: Bitrix24, Zoho, and Wrike.

Conference Key Areas: Sustainability and Engineering Education, University-Business Cooperation and Engineering Skills.
Keywords: Project Management, Free Tools, PMBOK

1 INTRODUCTION

The use of collaborative tools, such as project management tools, have shown greater success in software delivery due to the proper planning that project management tools offer. In a time where only 16,2% of software are successfully delivered on time and on budget, the Standish Group [1], a research advisory organization that focuses on software project performance by discovering why projects fail and how they can better succeed, states that one of the top 4 project success factors is the proper planning.

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IPM Global, a Project Management software development company integrated with Microsoft, SAP and Sage managed by directors working in this field for over 20 years advertises that the use of automated project management tools not only reduces project risks but also enables several other advantages like the centralization of project documentation and the standardization of processes [2]. Allured by the benefits of project management tools, IT companies have been increasingly using project management tools to support project management and to track software development.

These project management tools are used by all project´s stakeholders including software developers - one of the most likely jobs for young computer science engineers – to report their work. Therefore, disclosing project management tools that might be used by students´ future employers it is promoting the teaching of actual professional practices in computer science engineering and better prepare computer science engineers for the competitive IT market [3]. By doing so, young engineers will find on the job site a reduction on its learning curve when confronted with similar project management tools, and consequently, its higher education will be certainly well perceived by the employers.

Even though project management tools are used by all project´s stakeholders. Its principal administrator is the project manager who can follow diverse management practices like the project management body of knowledge guide PMBOK [4]. This guide is a worldwide de facto standard in the project management field that gathers a sum of good practices within the profession of project management.

Nowadays, there is a varied choice of project management tools. Thus, choosing the right project management tool to teach can be overwhelming. In this context, we are interested in the evaluation of free project management tools - most universities have limited budgets - with the capability to follow some of the PMBOK practices – most likely used by IT Companies. Furthermore, we have focused on proprietary tools that have a free version with an unlimited time of use, to enable students to learn and use it at the university. The drawback of these free proprietary versions is the limitation of features compared to the complete paid version. On the other hand, the significant reduction of the young engineers´ learning curve on the job site, when confronted with the same tool, is the biggest counterpart and advantage - basic features are displayed in the same manner than the paid version.

Therefore, this paper aims to guide Professor´s choice by presenting our evaluation of the following free project management tools: Zoho [5], Bitrix24 [6] and Wrike [7]. These tools were selected due to the good feedback that the IT consultant Capterra gave in 2017 [8], as well as its wider coverage on PMBOK´s suggested features. By Capterra´s ranking, Bitrix24 stands at the 1st position, Wrike at the 5th and Zoho at the 8th position but the PMBOK guidelines were not considered for the ranking of these tools which leads us to a deeper assessment.

The remainder of this paper is structured as follows. In section 2, project management tools are described regarding its principal features and its strengths and weaknesses are exposed. In section 3, the methodology used to test the tools is disclosed. In section 4, the tool's comparison is presented and the best project management tool to teach is suggested. In section 5, related work is briefly presented and finally, in section 6, conclusions and future work are exposed.

2 PROJECT MANAGEMENT TOOLS

In this section, we describe the selected tools: Zoho [5], Bitrix24 [6] and Wrike [7]. In order to portray these tools, we describe its principal features as well as its main strengths and weaknesses.

2.1 Zoho

Zoho [5] is actually used by 15 million users worldwide and has a set of free features that can be considered, among others tools in the market, pretty complete. Its main free features are user assignment, user profile configuration, file upload – up to 10MB - and generation of notifications. Notifications can be sent to the user´s e-mail or to the online platform wall, which enables to at a glance see all recent activities.

In spite of not having a tracking of the worker´s time spent on its task neither a CRM, all basic features from the PMBOK guide exists: tracking a project with a Gantt chart, managing tasks and subtasks with dependencies and priorities, graphically visualize the tasks and the whole project achievements, and provide the communication between stakeholders.

During our tools´ evaluation, we have seen that Zoho presented a better dashboard than Bitrix24 and Wrike. In fact, in an appealing graphic form, Zoho displays the percentage of tasks, subtasks and project lifecycle phases that are completed, as well as the percentage of completion of the overall project.

In *Fig. 1* we present the interface of the Zoho tool. At the top center of the print screen, we can see the name of the project that we have created to test this tool. At below left we can see the menu of the tool and at below right a part of the Zoho dashboard where in this case the number of open, closed and total of tasks of a milestone is seen graphically with a donut chart and the task completion percentage with a line chart.

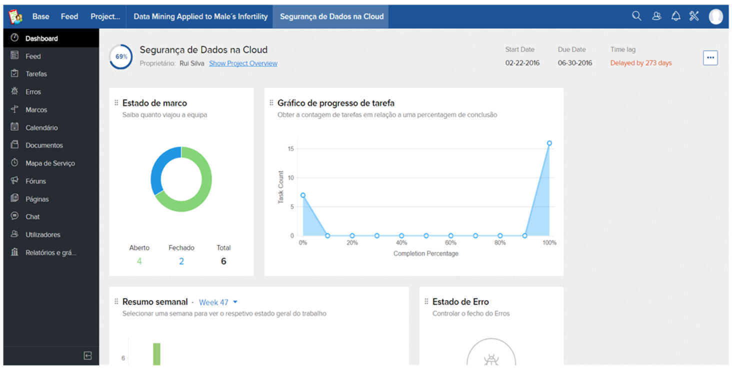

Fig. 1. Zoho Dashboard

The major advantages of this tool are:

The existence of a dashboard; The unlimited number of users that can be assigned; The error feature – project errors can be registered; The unlimited time of use.

Its major weaknesses are:

The number of projects that can be managed - in the free version only 1 to 5 project; The unavailability to track the worker's work time - the tool does not have a timer to track the labor-time.

2.2 Bitrix24

The Bitrix24 [6] is one of the most complete free project management tools seen on market and is also well classified by the IT consultant Capterra [8].

It covers most of the features that we have analyzed but it does not have the capability to graphically visualize the tasks or the whole project achievement, nor set prioritization on the tasks to be done.

Among the tools presented in this paper, it is the only one which has a timer to track the labor-time. This is useful to monitor and control the time taken to execute project´s tasks and consequently, manage the labor-time.

The Bitrix24 interface is shown in *Fig. 2* with the time tracking active: at left, Bitrix24 menu is shown, at center, task´s time management is seen and in the top menu, at right of the presented hours, the timer is shown.

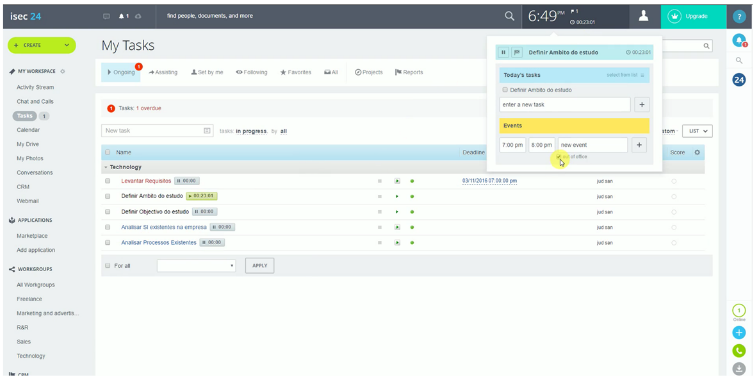

Fig. 2. Bitrix24 Time Tracking

The principal advantages of its use are:

Appealing interface; Wide set of features; Having a Customer Relationship Management feature (CRM) – this system allows to manage business relationships; Having a labor-time tracking and an unlimited time of use.

Its principal weaknesses are:

It is not possible to set task´s prioritization and it does not have a dashboard to in a glance track the progress of the project.

2.3 Wrike

The project management tool Wrike [7] has been named a 2014 “Cool Vendor” in social software and collaboration by the IT Consultant Gartner, and many renowned companies, like PayPal and HTC, relies on it.

One of our interests to analyze this project management tool was its possibility to integrate with the Windows, the most common operating system used by IT companies, through the Microsoft Office 365 version [9]. Therefore, it is a project management tool that goes with the aiming of this paper – the disclosure of project management tools that are more likely professionally used by IT companies to promote the teaching of actual professional practices.

Nevertheless, during our tool´s evaluation and comparison, we have seen that Wrike covers fewer features in its free version than Zoho and Bitrix24. Furthermore, the most important ones, like the Gantt Chart, is only available for 30 days. Therefore, we can say that it is a limited platform in its free version. However, its simplicity and good capacity on performing are better than the other two in the sense that all covered features were highly scored during our experiment.

In *Fig. 3* the Wrike interface can be seen: at left we have the Wrike menu and at right, its Gantt chart where dependencies are seen between the inserted tasks.

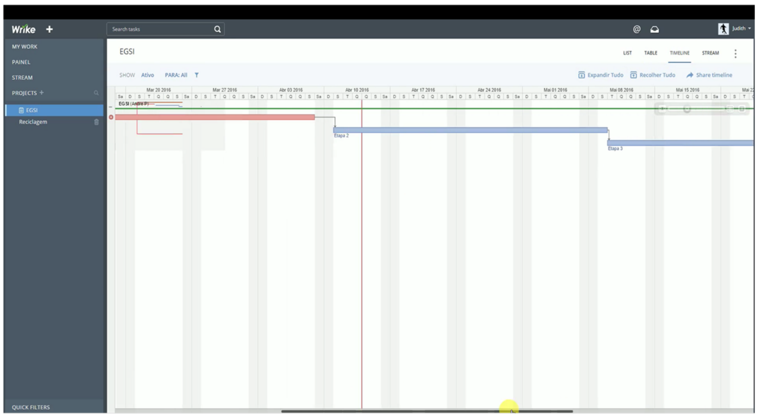

Fig. 3. Wrike Gantt Chart

The main advantages of the Wrike tool are:

The functional stability in its features, in part due to its simplicity; The unlimited dependencies that can be created between inserted tasks; The ease of use.

Its main weaknesses are:

Feature´s limitation; The 30 days' time limit for the use of the Gantt Chart feature.

3 TOOL TESTING METHODOLOGY

By considering most online free project management tools, a set of common features was identified. To those features, we added some of the PMBOK basic methods, specifically the ones suggested for project time management. Afterward, we have tested each tool regarding the existence, the utility and the ease of use of each selected feature, and have evaluated it by assigning a score from 1 to 5 to each feature. Finally, we have added up the features scores and the best tool was identified. This testing methodology was inspired by the Project Management tool selecting criteria proposed by the author Lornel Rivas et al. for small to medium enterprises [10].

For the scoring of the assessed features we have defined the following criteria:
0 = The tool does not have the feature; **1** = The tool has the feature, but it is not useful and its use is difficult; **2** = The tool has the feature, but it is not useful in spite of its ease of use; **3** = The tool has the feature, it is useful but it is difficult to use it, not well conceived or does not work properly; **4** = The tool has the feature, it is useful and easy to use; **5** = The tool has the feature, it is useful and intuitive.

The selected features that we have used to assess the free version of Zoho [5], Bitrix24 [6] and Wrike [7] were:
Add users - possibility to add at least 3 users to the project management tool.
User Profile - possibility to configure user´s different accesses to the online platform.
Task Timer - tracking of the worker´s time spent on its tasks (employees can start in the platform a timer function by the time a task is started).
Chat - possibility to have written online meetings or discussions with the added users.
Upload up to 10 MB - capability to store documents, at least up to a total of 10 MB size, on the online platform to share among added users.
Manage 12 tasks - capability to manage at least 12 tasks that have a duration bigger that one day long.
Manage 4 subtasks - capability to manage at least 4 subtasks.
Task dependency - dependency between tasks and subtasks to establish an execution order to ensure that team members follow the project sequence that was initially planned.

% of task´s conclusion - capability to track the achievement of the tasks by graphically consulting the percentage of its conclusion.
Task prioritization - capability to define tasks´ priority and track it graphically.
CRM - Customer Relationship Management feature that provides the possibility to record, manage and analyze customer interactions and throughput of the customer lifecycle [11].
% of project´s conclusion - capability to track the achievement of the whole project.
Gantt chart - capability to graphically manage the tasks of the project. A Gantt chart represents schedule information where activities are listed on the vertical axis, dates are shown on the horizontal axis, and activity durations are shown as horizontal bars placed according to start and finish dates [4].
Notifications - informs when a task is assigned or overdue by email and/or by adding a post on the online tool wall.

4 TOOLS COMPARISION

By following the tool testing methodology presented in section 3 we have assessed the Zoho [5], Bitrix24 [6] and Wrike [7] Project Management tool and built a comparative analysis that Table 1 depicts.

Table 1. Project Management Tools´ Comparison

Features	Tools		
	Zoho	**Bitrix24**	**Wrike**
Add users	5	5	5
User Profile	5	3	5
Task Timer	0	5	0
Chat	5	5	5
Upload up to 10 MB	3	5	5
Manage 12 tasks	4	5	5
Manage 4 subtasks	3	5	5
Task dependency	5	3	5
% of task´s conclusion	4	0	0
Task prioritization	5	0	0
CRM	0	5	0
% of project´s conclusion	5	0	0
Gantt chat	5	5	2
Notifications	5	5	5
TOTAL	**54**	**51**	**42**

The focus of this paper is to assess free project management tools; thus, the selected features were analyzed and tested regarding its capabilities to perform freely. It is important to say that these selected tools are basically proprietary platforms, which means that are monthly paid, but all of them have a free version, with less functionalities than the paid one that is worth to analyze and consider because of its unlimited time of use. Its limitation is the working context in which they can perform.

During the assessment of the selected tools we have identified the following limitations for each tool:
Zoho - Only works for 1 to 5 projects depending on the number of users added - for every person assigned to the platform one project is added, up to 5 projects. Which means that all tasks can only be related to 1 to 5 projects regardless the number of

users assigned. It can integrate with Google Drive or Dropbox so the 10MB file storage limitation seen in the free version is not an issue, in our point of view.
Bitrix24 - Works with up to 12 users and 5 tasks dependencies. Other than that, its free version is very interesting: it has a CRM and it provides a good user experience given by its appealing interface. Its biggest drawback is its impossibility to define unlimited task dependencies. Furthermore, its users´ profile configuration is very limited.
Wrike - Works with up to 5 users, independently the number of task dependencies recorded or projects mounted. The major drawback is the lack of features, even after migrating to the paid version, comparing to Bitrix24, or even Zoho. The other important drawback of this tool is the 30 days time limit for the use of the Gantt Chart feature, which was the reason for the 2 score given.

By considering the features scores presented in Table 2, Zoho finished with 54 points, Bitrix24 with 51 points and Wrike with 42 points. By weighting them up with them working limitation and user experience, Zoho was identified as the best tool to teach among the ones tested. Zoho election was not only based on its higher score, but also on its capability to better track the scheduled work through the tasks prioritization and project follow up that this tool provides.

5 RELATED WORK

There are actually various published papers in the field of project management tools that can be classified in one of the following types:

- Disclosure of Project Management Tools – popular [12][13], open source or proprietary ones [14].
- Exhibition of open source tools capability analyses vs. proprietary ones [15] [14].
- Presentation of tool´s selection models – [16], AHP model [17] or specified to small and medium enterprises (SMEs) [10].
- Importance of use [18] [19].

This paper falls into the disclosure of project management tools but in the area of studying proprietary project management tools that have a free version that follows some of the techniques suggested by the PMBOK standard. From the best of our knowledge, no other paper approached this topic.

6 CONCLUSIONS AND FUTURE WORK

This paper enabled the identification of the project management tool Zoho, among the Bitrix24 and the Wrike solution, as a suitable tool to teach future computer science engineers. Its free version and wider coverage in features that support PMBOK techniques makes it suitable for universities with budget limitations and for future computer science engineers that aim to thrive in renowned IT companies since they usually follow the PMBOK management techniques. Thus, disclosing the selected project management tools was promoting the teaching of actual professional practices and better prepare students to the competitive IT market.

The selected tools´ evaluation was only made upon its free version, the eventual gap between free and paid versions, regarding features availability, can be bigger in one tool than in another. Thus, the selection of a project management tool with the only purpose of reducing students´ learning curve at the job site, could eventually lead to the identification of another solution. However, we have found, during our testing period, that Zoho offered a bigger functional feature stability than Bitrix24, which justifies the minimal score that separates one tool from the other. As future work, we intend to evaluate the complete paid version of the selected project management tools.

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Are We Transforming Engineers Into Vendors?

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ABSTRACT

The development of Ethics depends on the development of Values, which are shared by a given group and aids people to decide in many situations in compliance with the preferences of the same group. The Ethics in Engineering Education can, in the same way, establish the Values that need to be taught and shared by the Engineering Community. As soon as the society identifies and accept those Values, the Engineers would benefit from a higher evaluation in the society assessment. But Engineering education is suffering from the weakening of its Values motivated by private interest. Currently, the big engineering companies want to reduce the Engineer to a catalogue selling employer. In this paper, we offer the perspective of the relationship between the Engineers and their local communities.

Conference Key Areas: Ethics in Engineering Education, Engineering Skills, Continuing Engineering Education and Lifelong Learning.
Keywords: Engineering Education, Ethics.

1 INTRODUCTION

The education of the new generations of Engineers is no longer a compromise between the society and the University. In the past, the society knew exactly what to expect from few branches of professions. The physicians, the lawyers and the engineers were respected by their behaviours in the applications of their specialized knowledge and skills to solve the problems of the society. Therefore, the notion of Utility was clear and the professionals were praised by this.

Some people may argue that the Professional Values of the Engineers are no longer recognized, because of having much more branches of professions and many

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specializations of Engineering. But the impact of having many different tags for the Engineers is internal: the perception of common pertinence is weakened, because the Engineers from different branches do not recognize each other. By this way, to stablish Ethics for the Engineers became much more difficult, but it is not the cause for losing the Values that were stablish in the past.

The downfall of the Ethics in Engineering is much related to the fact that the Engineers may act in different sides of the same issue motivated by the different intentions of their contractors. We may have a Civil Engineer of a Building Company against the interests of a Civil Engineer of the Supervision of Constructions of some Government. As the notions of regulation, contract and payment became much more important, the Ethics in Engineering no longer plays any role in Engineering Projects.

If we want to present to the society that the Engineers have a Code of Conduct, we need to convince the Engineers that the success in the carrier is not a matter of the consumption power they may acquire, but the solutions and well-being they provide to the society, which is the main responsible for the Education they received.

In this paper we analyse the present lack of Values in the Engineering Education and draw the attention to the fact that Engineers must become aware of the ethical and epistemic values embedded in all components of their work. It is also necessary warning the Engineering Schools to avoid the fast exposure of its own students to the interests of the Big Companies. One of the solutions is the inclusion of Ethics subject and Codes of Conduct in all the Engineering courses.

The rest of this paper is structured as follows. In section 2 it is analysed the present lack of Values in the Engineering Education. Section 3 presents the interference of the big companies in the education of the engineers and the corresponding result in their professional carriers. In section 4 we present the Codes of Conduct effort many Engineering Associations conduct as a reaction to sustain Engineering Ethics. Finally, section 6 presents the conclusions and some future work.

2 LACK OF VALUES

In the past, the most prominent experience on professional Values were the “Guild” [1]. They were constituted to organize the labour, the quality and the prices of a given activity in a particular city. The “Guild” respected each other and did not compete. Internally, the members needed to obey many rules to avoid competition, to assure quality and to support the elderly. The professional Values were explicit and the notion of Justice was clear for the society.

According to Tuana [2] Values serve as a guide to action and knowledge. They are relevant to all aspects of scientific and engineering practice, including discovery, analysis, and application. She argues that ethics education should be used in science, technology, engineering, and mathematics (STEM) fields and propose the following main groups of values:

- *Ethical values*: the good of society, equity, sustainability;
- *Aesthetic values*: simplicity, elegance, complexity;
- *Epistemic values*: predictive power, reliability, coherence, scope.

Epistemic and ethical value decisions have important social implications. This fact is reflected in the National Science Foundation broader impacts criterion and its view of the role and purpose of ethics education: “Ethics education is particularly critical to the science and engineering community as it faces an increasingly competitive funding environment; rising collaboration with international colleagues who may follow different guidelines; and growing recognition of the relevance of science and engineering to social, economic, and ethical issues of wide public and political interest." [3].

Nowadays, according to Chomsky [4], we live in a time where people don't think they are able to organize themselves. On the other hand, the media push people to believe the Moral Values need to fit into the constraints of the Individualism. This way, Engineers are free to compete with each other to maximize their profits and to offer lower quality for the solutions the society demands.

In this sense, the labour relationships tend to a single value: the price. But the price is the common agreement between the parts in a negotiation. For this reason, the Engineers are mostly like to worry about their propaganda, not about the quality they offer.

In this sense, according to Bauman [5], the person is the product to sell. And the Engineering title works more as a propaganda item in the curriculum vitæ in the market. We only need to observe the number of Engineers in the Financial institutions to confirm that assertion. Engineers are not always aware of relevant values and ethics education should be designed to promote values identification and analysis.

3 BIG COMPANIES

The dream of the pharmaceutical industry is to transform the physician into a drug vendor. The notion of the cure has shift from a body natural process into a drug manipulation recipe. To achieve this, the pharmaceutical industry need to change the physician formation, the legislation and to make people believe the cure is not in their hands.

In the same way, the dream of the Big Companies is to have highly educated vendors, which are able to convince the local market that the only solution is to buy from its product catalogue.

As the Big Engineering Companies have money to pay more for internships and opportunities to better jobs, the Engineering students starting competing with each other. In the end, the better students are selected to earn higher incomes.

In the process, the student starts to believe in the propaganda of the big companies and in the rules of the market as the only truth behind the scenes: the competition will define their success.

The students have little access to the idea that they can help their own local communities. Those kind of problems, are left to local government only. On the other hand, the local community have little dialogue with the Engineering Faculties to present their problems. Without high internship earning, is hard to find any Engineer student.

After being convinced that about the market rules, the Engineer student, in the middle of its own formation start deciding about the disciplines to follow. At this point, the interest for high-tech products the big companies sell drives the Engineer students out to basic scientific foundations of the Engineering. They tend to follow the propaganda of the dominating Big Engineering Companies. If The Big Companies say that the future is the Storage Technology, then the students are mostly likely to search and demand disciplines related to it. In this situation, after a while, when the Storage Technology becomes commodity, the graduated Engineer will have hard times to change his/her education.

We may see, for example, in the Cisco Engineer Incubator Program in Poland, the interest of a Big IT Company on the education of young Engineers (see Figure 1). The final result of this program is to put the mind set of Cisco in the young Engineers head. The characteristics of the program is given below [6]:

Figure 1: Big Company interest on the education

- ***What is Cisco Engineer Incubator?***

  Special educational program designed by Cisco engineers to support young, talented students and graduates interested in networking technologies and starting the career in IT.

- ***Who is it for?***

  Engineering students (preferably on their last year of studies), with CCNA (Cisco Certified Network Associate) -level knowledge of networking technologies, who see themselves as professionals in IT industry in the future.

- ***How does it work?***

  Free CCNP (Cisco Certified Network Professional) course delivered through technical seminars and webinars between October and May, with regular office visits and meetings with our engineers and managers.

- ***How do I join?***

  We will kick-off the recruitment for the Fifth Edition of the Incubator Program (2017 – 2018) in Spring 2017. Please monitor this webpage for the updates on the application process and the schedule of our university events in Poland.

The notion that the Engineering work may serve to the local community and the society as a hole is weakened. Sooner as acceptable, the Engineer start thinking that his/her work may only serve to a given company, specially the Big ones. We presume Poland need Engineers to develop the country, not only to serve a specific Company for market and profit purposes.

In the end the Engineer has more short term knowledge, as the technologies evolve, which leave them in a dependency cycle on the product catalogues of a given company. They are no longer able to create new solutions. They are only able to prescribe short term solutions the big engineering companies sell.

This intentional choice is not well observed nor controlled by the Engineering Schools. The students are not prepared to recycle their engineering knowledge on top of a solid scientific foundation. The Engineer is left alone on the market with a technology mind set which is condemned to be obsolete.

In this way, the Engineer start depending more and more on the market knowledge: finance, administration, commercial skill need to be developed as fast as possible to be able to survive. The sense of pertinence to the engineering professionals is weakened this way.

The result of all this process is the loss of creativity and social relevance of the Engineer work. The Engineer mental process becomes more and more tight to the available technology culture, including the companies catalogues and the corresponding names and brands. Many of those brands are accepted as a common word in the Engineer vocabulary and are used as buzzwords.

The Engineer then is converted into a complete vendor. The Engineer can only see the society problems as an opportunity to apply all of his/her knowledge: the buzzword of big companies. The Engineer is no longer able to comprehend the society problems first, in a scientific way. He/She is only trained to search in the available catalogues, the possibility of a solution.

On the other hand, this loss of creativity and competitiveness for the local engineers represent a gain for the big companies. They have highly educated vendors with Engineer titles, which act only in the benefit of a given company, not in the benefit of the society. This is an opportunity to broaden its local market dominance as the local Engineers vendors ease the selling communication to the local consumers.

Another interesting aspect of this loss of creativity is the reduced capability of local competition. The local solutions might be a barrier for the big company dominance. But the local engineers are make to believe that there is no solution, but to buy a high-tech product made by better engineers of the big company. And the dominance is reinforced.

One of possible solutions is the use of open source software, free of charge that reduce costs and enhance engineering education with these new open source technologies [7]. With open source software, students have the freedom to put their creativity in action. It is also possible to test and modify the software, simulating real enterprise environments, which improves student's skills [8].

4 CODE OF ETHICS

Nowadays there are many efforts to establish Codes of Conduct among many Engineering Associations, for example: Association for Computing Machinery (ACM), Institute of Electrical and Electronics Engineering (IEEE), National Society of Professional Engineers (NSPE), Engineers Australia and American Society of Mechanical Engineers (ASME).

One of first one's is the American Society of Civil Engineers - ASCE Code of Ethics, which is the model for professional conduct for ASCE members that is first adopted in 1914. The Code of Ethics was most recently updated on July 23, 2006. Pursuant to the Society's Bylaws, it is the duty of every ASCE member to report promptly to the Committee on Professional Conduct any observed violation of the Code of Ethics. In April 1975, the ASCE Board of Direction adopted the fundamental principles of the Code of Ethics of Engineers as accepted by the Accreditation Board for Engineering and Technology, Inc. (ABET) [9]. In October 2009, the ASCE Board of Direction adopted the following definition of Sustainable Development: "Sustainable Development is the process of applying natural, human, and economic resources to enhance the safety, welfare, and quality of life for all of the society while maintaining the availability of the remaining natural resources."

Another example of Code of Ethics is the ACM Code that provides guidance to ACM members about committing to ethical professional conduct. The Code identifies fundamental considerations for contributing to societal and human well-being. Every ACM member who renews a membership agrees to adhere to this code, a code that was written a quarter of a century ago.

The current version of the Code was approved in 1992. This version of the Code made significant advances over its predecessor. In its role of advancing professionalism and producing a positive impact on society, the ACM replaced the previous primary function of monitoring member behaviour with an emphasis on educating about the principles of ethical behaviour in computing and providing guidance in ethical decision making. Over the years, the Code was used as a guide to instruct students entering the profession, as a decision support tool for computing practitioners, as a standard for the public to judge the professionalism of practitioners and as an aid to address legal issues and ethical tensions. In the last few years, many questions arise related to artificial intelligence, machine learning, and robotics.

In the 25 years since the drafting of the 1992 Code began, there have been two significant, interconnected, and broad kinds of changes: 1) amazing changes in computing technology, and 2) important changes in how deeply that technology is integrated into social structures and into people's daily lives. The technical changes are substantial. The number of people impacted and the intensity of that impact have been astonishing.

In 1992 the number of people using and controlling computers seemed limited. Computers were typically in a fixed location, and were just beginning to connect via the Internet. Computers were used to print bills, to control some highly specified processes, and to guide military devices. They managed and recorded financial information, controlled some processes on our automobiles, and controlled micro-waves in the air and in our kitchens. It made sense for most scholars in computing to have a narrow focus on the analysis of algorithms and a study of the resources needed to execute them. Now computing is ubiquitous— controlling our transportation and communication, and facilitating many human interactions. Computing today is in our bodies—prosthetics, pace- makers, and insulin pumps. Computing is also integral to the ways in which societies wage war. Computers impact all areas of our lives and many life- preserving functions are relegated to a piece of computer guided machinery. Many of the newest impacts of computing are invisible. Computers make decisions about who is audited, who gets a heart transplant, and who gets targeted by dangerous devices, be they cars or missiles. The changes in technology and the kinds and number of impacted stakeholders are changing society in fundamental ways.

Recently, the ACM Code of Ethics and Professional Conduct: Draft 1 was developed by The Code 2018 Task Force and the preamble is as follows [10]:

> *"Commitment to ethical conduct is expected of every ACM member. The ACM Code of Ethics and Professional Conduct ("the Code") identifies the elements of such a commitment.*
>
> *This Code includes 24 imperatives formulated as statements of responsibility. The Code is designed to apply to practicing and aspiring computing professionals. Section 1 outlines fundamental ethical considerations. Section 2 addresses additional, more specific considerations of professional conduct. Section 3 pertains more specifically to individuals who have a leadership role, whether in the workplace or in a volunteer professional capacity. Principles involving compliance with this Code are given in Section 4.*
>
> *Each imperative is supplemented by guidelines, which provide explanations to assist members in understanding and applying the imperative. The Code is intended to serve as a basis for ethical decision making in the conduct of professional work. Secondarily, it may serve as a basis for judging the merit of a formal complaint pertaining to a violation of professional ethical standards.*
>
> *The Code as a whole is concerned with how fundamental ethical imperatives apply to one's conduct as a computing professional. The imperatives are expressed in a general form to emphasize that ethical principles which apply to computing professionals are derived from broadly accepted ethical principles.*

> *The Code is not an algorithm for solving ethical dilemmas. Words and phrases in a code of ethics are subject to varying interpretations, and a particular imperative may conflict with other imperatives in specific situations. Questions related to these kinds of conflicts can best be answered by thoughtful consideration of the imperatives and fundamental ethical principles, understanding that the public good is a primary consideration".*

The Engineering Associations offer a high value contribution to the establishment of Engineering Ethics. But those codes of conduct are limited to the scope of a given Association. It means that they do not have the same law enforcement power as the Guild in the past. If a professional of a Guild do not followed one of the rules of the Guild, this professional is left out of the city.

On the other hand, there are many different approaches related to the different codes of conduct efforts. In this sense, the same problem of having many Engineering branches arises: the notion of pertinence is restricted to a given Association. And how can one Engineer from one Engineering Association can trust other Engineer from a different Engineering Association as they have different codes of conduct? In this way, we tend to favour the Engineers relations of the same Association. There is little explicit mention on those codes of conduct about the mutual respect among different Associations.

5 CONCLUSIONS AND FUTURE WORK

Engineers must become more aware of the ethical and epistemic values embedded in all components of their work as well as their significance and role in research and practice through training for values transparency and coupled ethical-epistemic analysis skills.

The Engineering Schools should avoid the fast exposure of its own students to the interests of the Big Companies. They need to understand the value of the Engineer. The society need to develop solutions for its own demands. The Engineer is the professional to offer them. The Big Companies want to maintain its own Engineering skills, reducing the local competition for solutions. The Engineering vendors maximize their profits.

The Codes of Conduct efforts represent the hope in future to establish the Engineering Ethics. But they need to grow outside the Engineering Associations limits to become an essential part of the Engineering education.

As future work we propose a study about the relationship between education and the demands of the local communities. We believe that this relationship is stronger whenever a community believes it is own responsibility to solve its own problems.

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Challenges in the Curriculum Development
Steps to Collaborative Teaching

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ABSTRACT

The engineers need not only good knowledge of their special technical field but also e.g. social, analytical thinking, problem solving and language skills. Especially knowing how to learn and adopt new and how to combine their own knowledge with other specialists is important. All these require consideration when reforming the new curricula. This article describes the process of the curriculum development in the Mechanical Engineering Education.

The new curriculum is based on competence and problem-based learning. This new curriculum challenges the teachers to be more like counsellors in the students' learning processes. This new curriculum also motivates the teachers of different subjects to cooperate and teach together with each other. This makes the teachers plan, check, guide and assess the courses together. Competency-based curriculum considers the students more as individuals than as groups and this requires the students to be more active in their learning process.

In the department of Mechanical Engineering, the new curriculum consists of the academic year and semester themes. The academic year themes are *Learning about Work of Mechanical Engineers*, *Engineer's Toolbox*, *Creative Engineers* and *Pre-Engineers*. Every semester has a CDIO-type semester project course and all the other courses support this project course.

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Keywords: Curriculum Development, Competence and Problem Based Learning, Collaborative Teaching

INTRODUCTION

The development of the curriculums is a challenging and time-consuming process. How to anticipate, what kind of competence is needed in the working life in the future? The operational environment is changing so fast that it is hard for the educators to keep up with it. In different education fields, there are permanent topics in engineering education; it is necessary to teach natural sciences and selected subjects of the technical field but also social skills, analytical thinking skills, problem solving skills, language skills are needed in the working life. The students must know how they learn and adopt new and how they can combine their own knowledge with other students.

The new curricula of Lappland University of Applied Sciences are based on competence and problem-based learning. These new curricula challenge the teachers to be more like counsellors, not traditional teachers in the students' learning processes. These new curricula also motivate the teachers of different subjects to cooperate and teach together with each other; every course has to have more than two teachers. Competency-based curriculum considers the students more as individuals than as groups. These new curricula also require the students to be more active in their learning processes and this has to be emphasized and taught to the students.
The engineering education is not the most popular subject to study nowadays. If the students are not committed to the subjects they are studying, or they do not know what kind of work the engineers do, they may not be so motivated to study and they may drop out their studies. The thread of the mechanical engineering competence was in the center when the new curriculum of the Mechanical Engineering Education was reformed. The new curricula will be introduced in the fall 2017.

1 GENERAL

Lapland University of Applied Sciences (later LUAS) started at the beginning of 2014. Two different Universities of Applied Sciences (Rovaniemi University of Applied Sciences and Kemi-Tornio University of Applied Sciences) merged and it was necessary to start pedagogical development and combine different practises. One of the important tasks was to reform the curricula of the different degree programmes. The content of the European Bologna Process and the funding model of the Finnish Ministry of Education for the Finnish universities and universities of applied sciences also influenced the curriculum development and reform. The operation environment and working life expect from the future employees that they are able to learn by themselves, together and from each other and they can build new information combining their own knowledge with other specialists. The target of the new curriculum is to confirm a creative and learner-centered culture of learning. Fragmentary courses are integrated into larger modules and students together process the phenomena and problems of the working life.

The aim of the problem-based learning is to increase creativeness and communality in the students learning process. The individual students study as active team members resolving learning problems. The alternative proposition of the solutions expand the students' individual knowledge. The target of organizing the learning is to reduce teacher-centered teaching and increase work-oriented learning. The essential themes are interaction and co-operation between the students, communal learning, the guidance of the learning, invocation of the group dynamics in the learning process and developing evaluation.

The old curricula of the different education programmes are usually separate 3 credit courses including general studies, professional studies and line specific studies but they are rarely connected with each other; only some courses. This may produce some disruption in the students learning process where they do not see the meaning of learning of these different skills and the motivation of performing these courses may not be so high. With the new curriculum, these separate courses vanish or are reduced. In the curriculum of the engineering programmes, e.g. the general studies are connected more tightly to professional studies. The thread of the courses in the whole degree is more clear to the students, which may also enhance the study progress and reduce drop-outs.

Project-based learning is applied in the curricula of different engineering programmes. This new curriculum challenges the teachers to be more like instructors, not traditional teachers in the students' learning processes. The teachers have to learn a new role and instruct the students in their learning process and task. Instead of giving a lecture, the teacher introduces a problem and the students search for information and try to solve the problem. Therefore, information retrieval is essential in the learning process. This new curriculum gives the teachers of different subject the possibility to cooperate and teach together with each other. In this way, the individual teachers really get better overview of the education and have an insight into different subjects. Therefore, the integration between different subjects deepens. Earlier the teachers liked to teach alone so that the doors of the classrooms were closed and every teacher could give best information with his/her own individual expertise. The team teaching is the cornerstone of operations in the competence-based curricula. The team teachers plan, teach and assess the pedagogic learning process together. It is not easy for a teacher to change his/her teaching method to competence and problem-based one and act more like counsellor. In the curriculum process of the LUAS, there were quite many events and education session for the teachers on competence and problem-based learning and team teaching so everybody knew what that means in their own teaching. The students are not familiar with this kind of teaching method and that is why the teachers have to introduce the new curriculum to the students and explain the working method and assessments of the courses. Emphasising a student-centred approach will also speed up studies. In addition, recognition of prior learning will be improved, and work life orientation and teaching of entrepreneurial skills will be increased.

2 PROCESS OF THE CURRICULUM DEVELOPMENT

At the beginning, there were quite many events and education sessions to the teachers on competence and problem-based learning and team teaching in the curriculum process of the LUAS. Some of the events were hold to the entire staff together; some events were hold to the different educations (e.g. engineering education) only. This was a major investment of time and money from the LUAS to improve the teachers' competence of the new curriculum. All of these events also improved mutual work where different teachers of the education shared their expertise.

In every education programme, a teacher was named as a person in charge of the curriculum. These persons (in charge of curriculum) led and coordinated the work of the curriculum development in the education programmes. They had several meetings together regularly and shared each other the current phase of the curriculum development process of different education programmes. New information and practices were rapidly used in the development processes of the curricula. These kinds of activities also increased shared expertise inside the education programmes.

2.1 On the way to the new curriculum of Mechanical Engineering

Bachelor of Engineering studies take four years to complete containing 240 ECTS credits. The structure of the Mechanical Engineer curriculum consists basic and professional studies 180 ECTS (basic studies (50 ECTS) and professional studies (130 ECTS)), elective studies 15 ECTS, practical training 30 ECTS and thesis 15 ECTS.
First, the teachers, students, representatives of the surrounding industry, co-operative companies and other important partners, e.g. research groups, were asked to specify the competences of the mechanical engineers. A lot of time was spent on this work but it was also interesting and rewarding to analyse and anticipate the skills the future mechanical engineers need in the changing working life.

The new curriculum of Mechanical Engineering was created from a “blank slate” and it consists of projects and various study modules reflecting the competences. The names of these projects and study modules are inspiring and modern and try to illustrate better the theme of the academic year to the students. The competence of the Mechanical Engineering is based on the contents of the projects and the aim of the know-how of the study modules. The professional growth of the mechanical engineers proceeds gradually from the first academic year to the last year in every academic year and semester themes.
The learning and/or problem-based project is in the center of every semesters theme. The contents of the different study modules are integrated into the content of the semester project. The competence of the student is based on these semester themes. Figure 1 presents an example of a semester project, and how the study modules support this.

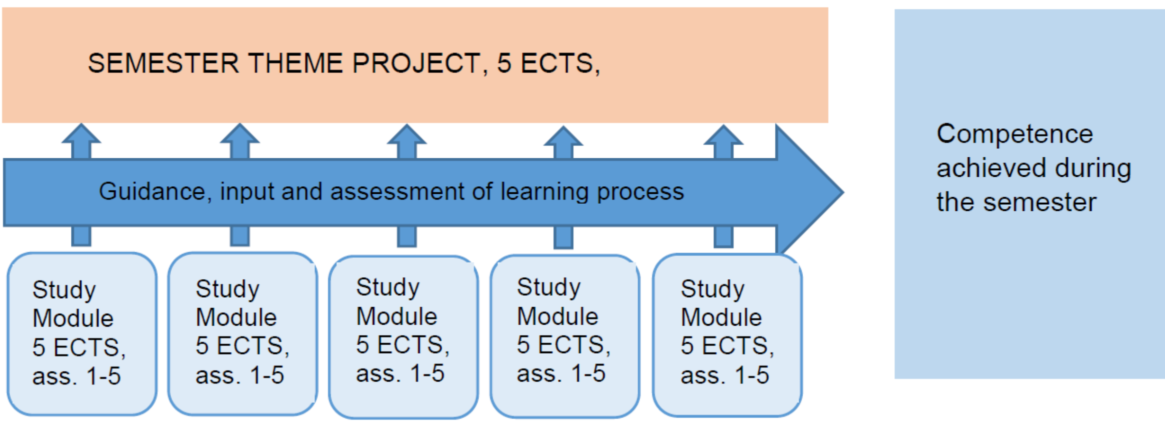

Fig. 1. An example of the semester theme.

In the region of Lapland, there are steel, paper, energy and mining companies and their needs of the future professionals were taken into consideration when determining these alternative professional studies. It is also important that there are possibilities to gain academic competence in the region. The people who live in the region are used to long distances of the services and artic condition. In the Mechanical Engineering education in the new curriculum, there are three different kinds of alternative professional study options and the students choose one of them in the third academic year. These alternative professional studies are: Industrial Professional, Product Development Professional and Mining Professional. All of these alternative professional studies contain semester projects, mandatory courses and optional courses. Figure 2 presents the description of these alternative studies.

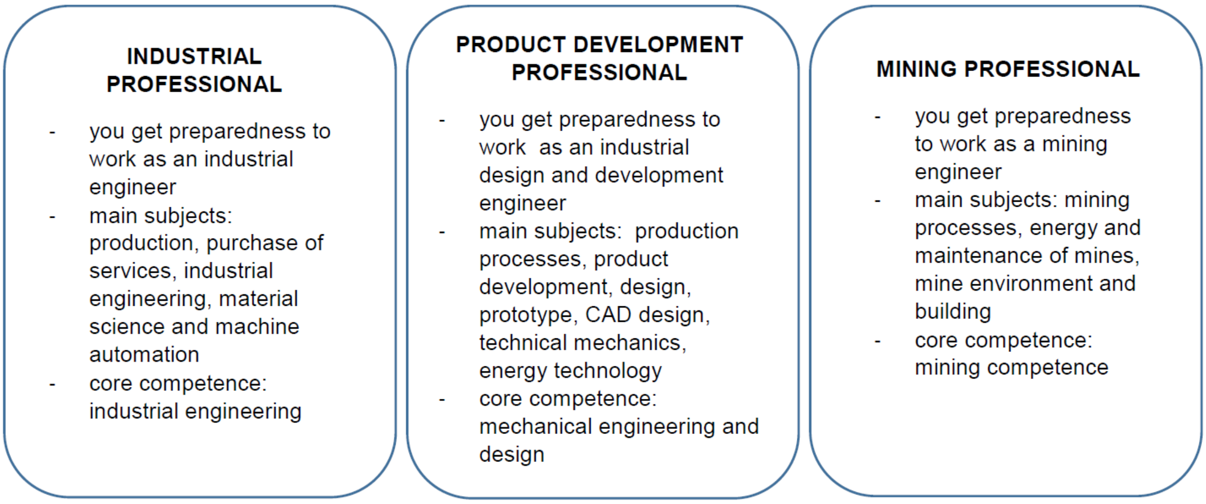

Fig. 2. Alternative studies of the Mechanical Engineering

3 EXPERIENCES OF THE COLLABORATIVE CURRICULUM PLANNING

In the department of Mechanical Engineering, the academic year consists of the semester themes. The academic years have the following themes *Learning about Work of Mechanical Engineers*, *Engineer's Toolbox*, *Creative Engineers* and *Pre-Engineers*. Every semester has a semester project course and all the other courses support this project course. These semester projects are like CDIO projects (Conceive-Design-Implement-Operate). The professional competence is developed by active learning and supervision methods.

The same curriculum is applied in young and in adult education, only some of the vocational subject studies are compensated with practical training. The students in adult education study in the evenings and on Saturdays, and so the number of contact lessons is smaller and this sets its own demands and restrictions in the teaching methods as well as in the curriculum. The students must be self-directive in order to manage their studies along with their work and private lives. The teaching methods can consist of e.g. flipped classroom, simulation, online teaching and independent studies.

Table 1 presents an example of the content of one academic year (first academic year). The first year is critical for the students if they are not motivated and they do not recognise and understand the professional field of the studies. Therefore, they are possible dropouts. In the new curriculum of Mechanical Engineering, there are many studies were the engineering work and working environments are demonstrated with basic and professional studies. In the old curriculum of the Mechanical Engineering, the basic, professional and elective courses were mainly 3 ETCS. The basic courses consisted of maths, physics, language, communication and learning skills. The professional courses consisted of different kinds of sections of Mechanical Engineering.

Table 1. An example of the content of the Academic Year.

1. Academic Year					
Academic Year Theme	Semester Theme	Study Module	Extent	ResponsibleTeacher	Other Teachers
Learning about Work of Mechanical Engineers	On the Way to Becoming an Engineer	**Project**: Familiarization with Arctic Working Environment	5	N.N.	A.A., B.B., C.C.
		Perspective on Work of Engineers	5	N.N.	A.A., B.B., C.C.
		Natural Sciences of Engineers	5	N.N.	D.D.
		Tools and Software of Learning	5	N.N.	E.E.
		The basic of Technical Design	5	N.N.	
		Basics of Industrial Engineering	5	N.N.	F.F.
	Language of Engineers	**Project:** How to Use the Tools of Engineers	5	N.N.	A.A., B.B., C.C.
		Tools of Mathematics and Physics	5	N.N.	G.G.
		Basic of Mechanical Engineering	5	N.N.	A.A., B.B., C.C.
		Manufacturing Processes and Material Science	5	N.N.	
		Basics of Technical Mechanics	5	N.N.	
		Projects and Workshops	5	N.N.	A.A., B.B.

The engineers need not only good knowledge of their special technical field but also e.g. social skills, analytical thinking skills, problem solving skills, language skills. Especially knowing how to learn and adopt new and how to combine their own knowledge with other specialists is important. All these require consideration when drawing up the new curricula. In the process of the curriculum development, a lot of effort was put when considering the themes and names of the semesters. It is necessary that students, mainly young people, understand what they study and what kind of competence they achieve. It is also important that all this is presented in "young people's language". The academic year and semester themes also portray well the idea of Mechanical Engineering studies.

In the first academic year, the field of Mechanical Engineering becomes familiar to the students. They practise basic subjects of the Mechanical Engineering combined to the natural science, language and social skill studies. In the second academic year the basic tools of the Mechanical Engineering become more familiar and the students learn how to apply all the knowledge they have achieved. The students also can work on the projects and they can apply different kinds of problem-based methods. In the third academic year, the students can together solve real working life problems. In the last academic year, the students deepen the Mechanical Engineering competence and at the end of the year they will graduate. The students can work in different kinds of Mechanical Engineering jobs, they manage in different situations and they can be supervisors.

At this phase of the curriculum process, the timetables for the autumn semester are being drawn up. The challenge is to combine the timetable of new curriculum and the old curriculum.

4 SUMMARY

The process have been long and it has taken much time to plan the curriculum together. Drawing up the timetables is challenging because you have to take into consideration the daytime and the adult students, studying according to the new curriculum and the old one.

The assessment of the courses or projects will give new challenges to the teachers, because it is based on continuous learning and the learning process of students and it will be done together with several teachers. On the other hand, the assessment is viewed from different perspectives and this is advantageous to the students. The challenge of the curriculum development processes is that the advantages and disadvantages will be seen when the first students graduate. Time will show.

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Classical Engineering Education Coping with Engineering Profession Demands

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ABSTRACT

The present world scenario shows that without any doubt there is an increasing recognition that leadership in technological innovation is key to the nation's prosperity and security in a hypercompetitive, global, knowledge-driven economy. Universities must cope with this need and change to reach the levels of required quality education in order to form the professional who will leave university to the work market. The Engineering Education Team of COPEC – Science and Education Research Council has designed this program that is knowledge centered and specially challenging, which integrates classical engineering approaches and real experience in order to achieve a high level of engineers ready to perform as professionals or researchers. The goal is to form the Engineer – a professional that is capable to learn for life and be creative in many ways.

Conference Key Areas: Engineering Skills, Engineering Education Research.

Keywords: learning/teaching tools, best practices, work market, intellectual skills, knowledge-centered.

INTRODUCTION

In general sense, engineers can be defined as problem solvers, creators of ideas and concepts, builders of devices, structures, and systems. They apply their knowledge of science and technology to meet the needs of society, to solve its problems, and to pave the way for its future progress. The intellectual activities of engineering are heavily based on synthesis, design and innovation through the integration of knowledge. However, engineering is more than an intellectual discipline, like physics or chemistry. It is also a vocation characterized by great diversity.

The key to the ability of engineers to develop products, systems and services that are essential to public health, and the economic competitiveness of the nation's business and industry is the knowledge base created by engineering research. The new knowledge, generated through research, drives technological innovation, which is the transformation of knowledge into products, processes, and services, which, in turn, is critical to competitiveness, long-term productivity growth, and the generation of human wealth.

Another aspect is that the current standard engineering education appears neither to provide the full set of skills that engineers are likely to need in the future nor attract the right numbers or types of people to engineering.

Based on these facts the questions that arise are: How can education institutions provide students a strong and valuable knowledge? What key skills and competencies do today's engineers need?

The answer seems to be: if students are taught the skills of learning, then they will continue to learn on their own for the rest of their lives. How is this possible? By the well-walked path of the tried and proven — the classical method of educating engineers. It means sufficient mastery of the basic tools of science and mathematics to address technological problems.

The way this can be achieved is by means of classical education, not as synonym of Christian education, but as an education with solid basis of knowledge in basic sciences and basic sciences of engineering. Students then will finish their course equipped with the right tools and a strong capacity of learning. Classical education then, in this sense, is a life-long process of applying the “tools of learning” - tools that are skills entailed in basic sciences, engineering basic sciences, and specific of engineering, which travels with the student through her/his career as professional or as an academic. In other words, the market seems to be ready for those who obtain a general engineering education and develop adaptable skills, which will serve them while their world continues to evolve [1].

Knowledge is a web, and so, there are no subjects that are unrelated to others. It happens the same with engineering training; the program is a web of knowledge, provided by studies, delivered in a time frame, interconnected and necessary to get the pertinent knowledge and development of skills that will enable them to learn by themselves. This is why students have to see the big picture from the beginning. It is important to show them, in the first week of classes, the whole program, as a big frame and its parts and the details of each part. It is a way to locate them within the program. It is hard, but not impossible and the effort is worth. The knowledge of the entire program has an effect in students who can see the value of solid knowledge in basic sciences as a start point for their formation and the importance of these as valuable tools.

Education is established in cultural economic, individual, philosophical, scientific and social advancement. In other words, education is the mean for developing the mind for the betterment of the individual and society. Advances in science and technology mean that the world will continue to change rapidly, so that the knowledge learned by students in specific careers will have a short lifespan. In contrast, those who achieve a general engineering education will develop adaptive skills, which will serve them while their world evolves. Since people tend to change jobs and occupational fields, several times throughout their lives, it is important to acquire a dynamic ability to absorb information, to adjust to organizational goals, and to navigate through complex work relationships; for this reason, a classical approach seems more useful for today’s work market.

The integrating part of the program comes from internships and practical projects, which are relevant for both: student’s studies and the real work scenario. The internship and the project offer opportunities to take the skills they are developing in the classroom to the real world. So, School provides internships in companies, in the field of student’s choice, during the fourth and filth years of college. They are then, at that time, more prepared to face these challenges [2].

The authors use "classical education" meaning knowledge centered education and refer to "classical method of educating engineers" as the same kind of approach. It refers to the choice of in class classes, with face to face interaction, strong and deep study, mainly in mathematics and physics, as the basis for the quality education that provide the tools that conception and application engineers need.

1. PROBLEM FORMULATION – NEW MARKET DEMANDS

The value of narrow specialization, at a time when engineering practice and engineering systems are becoming large and more complex, and involving components and processes from widely dispersed fields, is questionable. Many educators believe that the most important intellectual problems of our time will not be addressed through disciplinary specialization, but rather through approaches capable of integrating many different areas of knowledge.

This fact, added to competitiveness, made an engineering school, of a private University, decide to invest in a new civil engineering program, instead of opening a new program in another field, since this program is still the most sought course by young people in the region.

In order to overcome the difficulties of the hard competition and external evaluation of programs, the University has hired COPEC – Science and Education Research Team for Engineering Education, which has designed a program, which is knowledge centered and specially challenging. It is a program that integrates classical engineering approaches and real experience, in order to achieve a high level of engineers ready to perform as professionals or researchers. Their goal is to train Engineers able to learn for life and be creative in many ways.

The program has been specially designed, and aims to become the best one, in order to attract more students due to the competition in the region, that despite being a relatively small region, has five other universities offering the same program of civil engineering and faces also the external evaluation process by the Ministry of Education [3].

2. SETTING THE CONTEXT: TIMELESS EDUCATION

The classical/general education (and here as opposed to progressive education) is a type of education that has a history of over 2500 years in the West. It began in ancient Greece, was adopted widespread by the Romans, reduced after the fall of Rome, made a slow, but steady recovery during the Middle Ages, and was again brought to perfection in the Italian Renaissance. The main goal of classical education, in any level, is to form the whole person, in accordance with timeless intrinsic values; it is a very effective way to form free citizens, as opposed to controlled citizens.

The classic view of education states, essentially, that human beings are intelligent beings, which means that human beings want to know things, more specifically to know what things are and how they work. It is primarily focused on knowledge and not student-centered [4].

At University level, the classical/general education demands self-discipline and it produces intelligent curious young professionals, who can think, calculate, analyze, understand, solve problems and follow through on a wide range of perspectives. It is systematic and rigorous; it has goals and a method to reach the goals. It provides future professional the tools to learn and to adapt to the new work environment, as well as to the mutant work market of this millennium.

Looking at History, the classic engineering was responsible for the appearance of weapons, fortifications, roads, bridges, canals, tools, etc. In ancient times, in the eighteenth century, the first engineering schools emerged in France. They are: the École des Ponts et Chaussées (1747), the École de Mines (1783) and the École Polytechnique

(1794), it was the period when Science married Engineering. They all belong to the group of French Schools, that constitute mostly the so-called "generalist" Grandes Écoles, and the leading ones, of these groups, constitute the major part of the French scientific elite education system [5].

In the field of science research, what has been seen is that research work is not based on a top-down command-and-control hierarchy anymore. In this new virtual and complex system, scientists combine and recombine in research teams, based not on academic discipline or institutional affiliation or geographic location, but on the unique requirements of the problems they want to address. It means that researchers do not have to be in the same place of their collaborators, nor have they to be in the same place as the problems they seek to solve. There are international networks, which are more important to individual faculty members, than their departmental or institutional ties, since this network enlarges the possibilities of research and career success [6].

Besides this, the time is coming, when most people will have a number of jobs before middle age and when many jobs have not yet been developed; the question is: how can educational institutions form or train in a manner that may not yet exist? The classical/general education curriculum provides an answer.

3. THE APPROACH: THE CLASSICAL EDUCATION IN CIVIL ENGINEERING

It is estimated that today's college students will have over four jobs before the age of 30, and over ten jobs before they are 40. For core science, research, engineering and technology jobs specifically, around 78% of the net requirement between now and 2023 is made up of replacement demand, leaving 142,000 brand-new core science, research engineering and technology jobs being created. These new jobs are being created in a range of areas, with some sectors becoming much more science-focused over time. It means that there will be new opportunities and changing jobs is a very possible need [7].

In fact, many engineering graduates will work for small high-tech companies or consulting services companies, moving from organization to organization and role to role frequently. To adapt to this new work environment, engineering graduates must accept the personal responsibility for their lifelong learning through acquiring effective self-learning skills.

Perhaps, what is most missing in the current engineering education curriculum, crammed as it is increasingly with demanding technical material, is the opportunity for a truly liberal education, designed to enable young students to develop the deeper intellectual skills necessary to adapt to a world characterized by continuous change. So Classical Education can be a way to enable students for this new work market.

Classical/general education can be defined both: as a curriculum for broadening the mind—one of the hallmarks of an educated person—and as a way to prepare for active participation as a citizen. At present time, there is a sense that classical/general education should focus in the key attributes that employers value as needed by a generally educated person: critical thinking, writing, speaking, arguing, researching, and mathematical reasoning. In addition, to introduce a broad variety of subjects, classical/general education should exercise skills and habits of mind.

After the Second World War, with the cold war, and the run for the moon, education suffered a big change, added by the enlargement of students in University. These changes were necessary, however, due to the challenging and mutant educational environment as well as the global market and the scientific and technologic new achievements it is rather difficult to figure out what kind of engineers training will be necessary. In order to face the new challenges, the classical engineering training is an approach that provides new engineers the right tools to perform and to learn for life [8].

There are two facts that have driven the engineering faculties: first, private universities are struggling to attract good students for their programs, once it guarantees the continuity of the colleges and programs and so the employees. Besides the external evaluation, that programs and colleges have been facing, push them to enhance the quality of the programs that they offer.

Because of these reasons, to attend the necessities of an engineering college of a private university, COPEC's team has chosen to propose the pursuit of a classical/general education approach for the civil engineering program and so form the "Engineer". The engineer who has knowledge and self-taught skills - a professional who can think, calculate, analyze, understand, solve problems and follow through a wide range of perspectives - social, economics and of sustainability among others. It is a way to attract good students to their programs, as it ensures the continuity of colleges and programs.

The proposed program is essentially, what says a famous and very appreciated Chinese Proverb – "Give a man a fish and you feed him for a day. Teach a man to fish and you feed him for a lifetime".

The specific civil engineering program started in 2014 and the enrollment was low, comparing with previous years. However, after three years the results have been very positive taking into account the trend of engineering programs, choices in young generation and the universities competitiveness for students in the region.

4. ENGINEERING EDUCATION – FACING GLOBAL MARKET

Civil engineers must serve in a competent, collaborative and ethical way, working as planners, designers, builders and promoters of the economy and construction as a factor of social promotion. In addition, they are managers of the natural environment and its resources, innovating and integrating ideas and technology in the public, private and academic sectors. They are the managers of risk and uncertainty caused by natural events, accidents and other threats; and also leaders in discussions and decisions that shape environmental policy and public infrastructure.

The proposal of a classic engineering program came as a response to develop a new educational approach with the goal of strengthening a civil engineering course that saw its enrollment declining each year.

The key elements are:

- have a well conceived, coherent, sequential curriculum;
- have all courses with strong and pertinent knowledge;
- adjust other parts of the education system of the program to support the goals of learning;
- provide teachers with a carefully conceived curriculum, filled with challenging texts and materials;
- provide students where they are going and how they are going to get there.

It is necessary to challenge students to acquire the knowledge that they really need to become engineers; a professional capable to do any work and overcome the unpredictable future when it is becoming difficult to anticipate the new professions and opportunities that will be needed [9].

The process is long, implies many changes, including teachers trained for the program and the achievement of the main objective, which is to foster in the students the analytical and verbal skills, creativity and innovation, entrepreneurship, the appreciation of complexity and ambiguity, and leadership, very important for the formation of the engineer of this millennium.

The curriculum has been set and discussed with a set of professors, specialists in their fields of expertise, and in accordance with the Law of the Ministry of Education, the organization that regulates and accredits University Schools Programs.

The curriculum is organized in order to provide students with basic sciences courses, taught during the first two years; followed by basic sciences courses of engineering deployed during the second and third years and the specific courses of engineering, in this case, civil engineering, with emphasis in concrete constructions and eco building construction (following the trend of sustainable buildings – energy efficiency and use of low emission of Co2 materials) [10].

The figure below shows a block of different courses that were added and that have been taught in a period that has been named as Pre – Program, which happens two weeks prior to the year schedule, when students have classes of Language usage, Instrumental English (usage of technical English), Mathematics (review of high school content) and Psychology (aspects of competitive and demanding pressure environment).

So the program design is as follows:

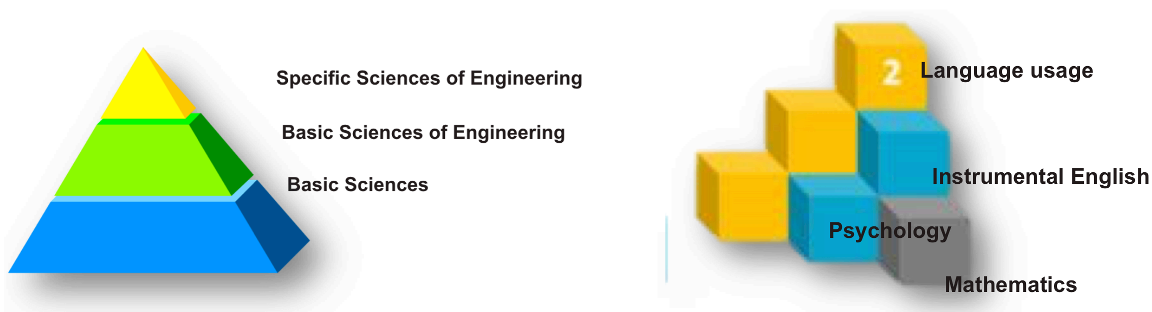

Fig. 1. Block of Different Courses that were added in a period that has been named as Pre-Program

5. THE CURRICULUM

Bellow, there is a chart of the basic cycle curriculum, that covers seven subjects in the first semester of the year of admission of the student in the Civil Engineering course and eight subjects in the second semester, totaling 27 credits in the first semester and 28 in the second semester. The content of subjects is taught deeply and with intense exercise sessions. It starts in the pre-program and lasts for all years.

Table 1. Basic Cycle Curriculum

	Discipline	CC	CW	TC	OC
1st	General Physics for Engineering I	4	0	4	

Semester	Experimental Physics for Engineering I	2	0	2	
	Introduction to Engineering Computing	4	0	4	
	Differential and Integral Calculus for Engineering I	4	0	4	
	Linear Algebra for Engineering I	4	0	4	
	Design for Engineering I	2	0	2	
	Introduction to Engineering	3	0	3	
	General Technological Chemistry	4	0	4	27
2nd Semester	General Physics for Engineering II	4	0	4	
	Experimental Physics for Engineering II	2	0	2	
	Numerical Calculus	4	0	4	
	Differential and Integral Calculus for Engineering II	4	0	4	
	Linear Algebra for Engineering II	4	0	4	
	Design for Engineering II	2	0	2	
	Mechanics I	4	0	4	
	Introduction to Materials Science for Engineering	4	0	4	28

CC – Credit class **CW** – Credit work **TC** – Total credits **OC** – Overall credits

6. FIRST RESULTS

2016 is the third year of this Civil Engineering program and the results are as follows.

Table 2. Civil Engineering Program

YEAR	Total of students that have entered in the Civil Engineering Program	Number of students of civil engineering that have opted for the Classical Engineering Program	% of enrollment rate
2014	180 students	89 students	49.44%
2015	180 students	100 students	55.56%
2016	180 students	136 students	75.56%

The table is based only on the enrollment number of students in the first and following years of program.

7. EXPECTED OUTCOMES

The initiative proposes specific learning outcomes and competencies such as:

- Applied learning: used by students to demonstrate what they can do with what they know;
- Intellectual skills: used by students to think critically and analytically about what they learn;
- Specialized knowledge: the knowledge students demonstrate about their individual fields of study;
- Broad knowledge: transcends the typical boundaries of students of higher education and encompasses all learning in broad areas through their solid knowledge in basic sciences and specific for engineering;
- Civic learning: enables students to respond to social, environmental, and economic challenges at local, national, and global levels [11].

8. DISCUSSIONS AND CONCLUSIONS

More than ever, it is necessary to form professionals equipped with tools that enable them to respond quickly to the changing work market and the unpredictable new professional expertise fostered by Scientific and Technological development. In fact, both, basic and applied engineering research, will be critical to the design and development of processes and systems on which every major sector of the country's economy depends. Both forms of research will be essential to meet the challenges and taking advantage of the opportunities that lay ahead.

While engineers are expected to be well grounded in the fundamentals of science and mathematics, they are also increasingly expected to acquire skills in communication, teamwork, adaptation to change, and social and environmental consciousness. The qualities most highly valued in graduates, beyond technical knowledge or skills, are: The ability to communicate well; a commitment to lifelong learning; the ability to adapt to an increasingly diverse world; the ability, not only to adapt to change, but to actually drive change. For this reason, a classic approach seems more useful for the demands of today's job market. It is at least interesting that the classic approach is being neglected, at a time when its product might be more interesting.

Currently, there are no surveys to determine if this group of students is better trained and/or has better skills, however it is estimated that during the internship period, they show better knowledge of mathematics, which seems to enhance their performance. This is the conclusion taken from the survey applied, every three months, to institutions which received students as interns, in which they grade students' performance during the internship. By better performance it means that students can cope better with the challenges and difficulties of problem solving and have a better understanding of the importance to search for the best solutions.

So far, the design and implementation of this program has been very positive. The first group of students, who will graduate in 2018, the students who are in internship at the 4th year have showed better performance, comparing to the other program, which is a first step to success. It means that the students have better grades, especially in the second and third years of the program so far. The Pre – Program, in special, has a good effect on students, since it provides them some elements that they can use such as Psychology and technical English.

The internship period, recommended in the 4th year of the program, has just started and the engineering college has been working to help students to find good training placements. It is crucial to advise them and to ensure proper conditions, in accordance with the law, in order to avoid waste of time and possible misuse of qualified labour.

This program, which is knowledge cantered, is responding very well in terms of students' enrolment and it is necessary to develop a survey to find out what are the elements that make students opt for this kind of education: the different approach, the strong knowledge basis or the possibilities of performing in any field of civil engineering, since the present job market is mutant and challenging. This shall be the next step for 2017, to develop a survey, which will allow us to refine the program and provide an input about the most relevant aspects of the program. Results shall be known at the beginning of 2018.

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Why Entrepreneurship education and training in Polytechnic of Porto graduated courses? Students' perception

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ABSTRACT

This paper analyses the perception of Polytechnic of Porto (P.PORTO) students about entrepreneurship education in the graduated and training courses. A survey was conducted, supported by a questionnaire followed by researchers' guidance. The perception of entrepreneurship education and training in students' curricula was studied. Statistical analysis was applied using SPSS tool. Due to de diversity of graduated courses in P.PORTO it was possible to analyse the perception of students from different educational areas: Engineering, Health and Social Sciences. The main conclusion was that students from all courses seem to see entrepreneurship education and training as an important issue for their future career. As future work this survey should be applied to other P.PORTO units to have an integrated perception. The results of this study will be presented to courses coordinators to promote future curricula improvements.

Conference Key Areas: Please select three Conference Key Areas

Keywords: Entrepreneurship; Perception; Graduated education; Training; P.PORTO.

INTRODUCTION

In recent decades, and all over the world, there has been a growing interest in promoting entrepreneurship and innovation as there is evidence that entrepreneurship is crucial to economic recovery and growth, job creation, inclusion and poverty reduction, as well as innovation and competitiveness. Currently the political priority of Europe and European Union (EU) Member States is to take measures to incorporate entrepreneurship in the different society domains [1]. In the education field in the EU the importance of entrepreneurship in education was first published in the European Green Paper on Entrepreneurship In Europe [2], followed by the 2006 Recommendation of the European Parliament and Council related with key competences for lifelong learning, where 'sense of initiative and entrepreneurship' were identified as one of the eight key competences necessary for all members of a knowledge-based society [3]. Other important documents were published to promote initiatives across Europe such as the "Small Business Act for Europe in 2008" [4], the "Communication on Rethinking Education" in 2012 [5] and "Entrepreneurship Action Plan 2020" in 2013 [6]. All these documents promoted the implementation of several actions in Member States to incorporate entrepreneurship as competence in school curricula, vocational training and higher education, and to create frameworks and tools to operationalize in educational contexts. However, and after all these actions, there were no consensus about the components of entrepreneurship as competence. New efforts were developed and in 2015 the EU presented a report related with the development of a European Competence Reference Framework for the key competence "*sense of initiative and entrepreneurship"*[1], where entrepreneurship competences were analysed from several case-studies and resumed in larger themes and groups (*Fig.1*). It was also verified that competences associated with an entrepreneurial subject were related with entrepreneurship definition.

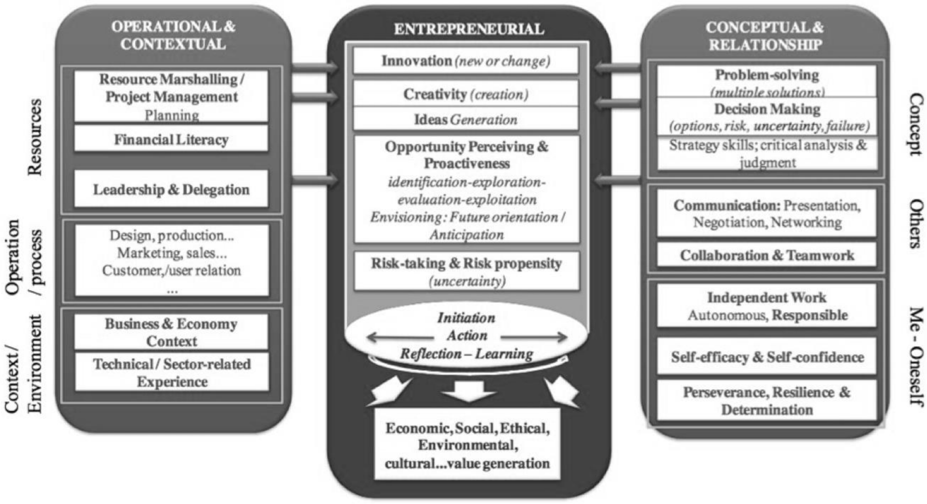

Fig. 1. Entrepreneurship Competences within larger themes and groups [1]

In 2016 The New Skills Agenda was presented to support a shared commitment and to work towards a common vision about the strategic importance of skills for sustaining jobs, growth and competitiveness. This agenda is centred around three main issues: 1) Improving the quality and relevance of skills formation; 2) Making skills and qualifications more visible and comparable; 3) Improving skills intelligence and information for better career choices [7]. The main aim is to promote a set of competences needed for personal development, social inclusion, active citizenship and employment. In this context the Entrepreneurship Competence study (EntreComp) was launched by the Joint Research Centre on behalf of the Directorate Framework to support the development of entrepreneurship competence at European level [8]. This framework consists of three interrelated competence areas: 'Ideas and opportunities', 'Resources' and 'Into action'. Each of the areas have five main competences along an eight-level progression model and proposes a comprehensive framework that can be used as a basis for the development of curricula and learning activities fostering entrepreneurship as a competence.

1 ENTREPRENEURSHIP IN P.PORTO

In the global context of the Academic Entrepreneurship (AE) [9], we have been observing that the Higher Education Institutions (HEIs), particularly Polytechnic Institutes (PI), have been developing, in an integrated way, several activities and initiatives for the development and promotion of innovation, research and entrepreneurship.

Concerning the P.PORTO, we had been participating from 2007 until 2014 on the previously mentioned nationwide initiative – *Poliempreende* – which is an ideas contest with training sessions included on the activities plan. These sessions are oriented for ideation and business plan development. This project emerges as an aggregator and cross-cutting initiative that had reinforced and complemented the different dynamics promoted in the P.PORTO, namely the master programmes and entrepreneurship classes (graduated and master degrees), with the goal to promote the spirit of initiative in students, the entrepreneurial willingness to create their own businesses and generate jobs, exploring the practical and professional character of their training and providing the participants with key skills related to creativity, innovation, planning of a business project, development of a business plan, setting up a business and its administration and management [10], as well as promote P.Porto AE.

The P.PORTO has promoted this contest for seven years continuously, always with very interesting numbers of effective participation of its community. Simultaneously the P.PORTO schools have been creating a formal entrepreneurship offer: curricular units in the several courses of HEIs; and masters, like Master in Entrepreneurship and Internationalization running in ISCAP of Porto. Since 2016 P.PORTO have been promoting the *Programa de Promoção do Empreendedorismo do P. Porto* (PPEPP), which has the same structure and pursues the same goals of *Poliempreende*.

In this context the main objective of this paper is to analyse the P.PORTO student's perception about entrepreneurship competences given by P.PORTO through the graduated courses and entrepreneurship training courses and programmes.

This paper is organized in four sections. The first one is an introduction contextualising the importance of entrepreneurship education in EU, in Portugal and in P.PORTO, and how it can contribute to fostering entrepreneurship, new companies, consequently more jobs and an increase of the economy of the regions and country. The second section presents in detail the methodology used to gather data and analysis. The third section presents the data treatment results and discussion. Finally, the main conclusions and future research developments are in the fourth section.

2 METODOLOGY

The methodology used is a Case Study which includes a literature review on entrepreneurship education and a survey with the development of a questionnaire (Google Forms platform) applied to several schools of P.PORTO: ISEP, ESS, ISCAP and ESTG. The questionnaire was addressed to students of the last year of graduated courses and master's courses and was developed to answer the main question: "What is the Students' perception about Entrepreneurship education and training in Polytechnic of Porto graduated courses?". Data collected was subject to a Statistical Descriptive Analysis and Exploratory Data Analysis with Principal Component Analysis (PCA) and Factor Analysis (FA).

The construct questionnaire is composed by these six major sections, each one with a set of questions. The first one (S1) to collected data from the respondent: School, course, year, gender and age; The second one (S2) about entrepreneurship fostering factors perception by the student; A third (S3) about the perception of competences given by the graduated courses that students attend; A fourth (S4) about competences given by P.PORTO through training courses and entrepreneurship programmes; A fifth (S5) about the students' perception from P.PORTO programmes; and a sixth (S6) concerning to the entrepreneurship internet platform used. The S2, S3 and S4 questions are based on the recommendations identified from literature [1,8], and a 1-5 Likert scale was used to answer (1-totally disagree, 2-disagree, 3-neither agree or disagree, 4-agree and 5-totally agree) (see *Table 1*).

Table 1. Questions in the survey

Section 2-Factors to fostering entrepreneurship
Q7- Have technical and management skills in the project area
Q8- Have own financial capacity
Q9- Plan my project and define the business model and target market
Q10- Have access to funding/incentives from third parties
Q11- Have appropriate partners
Section 3- Entrepreneurship Competences given by the curricula
Q12- Business Plan and Model
Q13- Project Management
Q14- People Management (employees, shareholders) and Relationships (customers, vendors)
Q15- Notions of Finance
Q16- Notions of Organization Management
Q17- Notions of Marketing
Q18- Notions of Leadership and Communication
Q19- Understanding Legal Issues
Q20- Notions of Entrepreneurship and Innovation
Q21- Understanding Industrial Property (patents, trademarks, logos)
Section 4- Entrepreneurship competences to be given by P.PORTO programmes
Q22-Development of the business plan and business model
Q23- Notions of Finance
Q24- Notions of Marketing
Q25- People Management (employees, shareholders) and Relationships (customers, vendors)
Q26- Notions of Entrepreneurship and Innovation
Q27- Understanding Legal Issues
Q28- Understanding Industrial Property (patents, trademarks, logos)
Q29- Project Management
Section 5- P.PORTO entrepreneurship actions students' perception
Q30- Know the training provided by P. PORTO under the Entrepreneurship and innovation framework programme (POLIEMPREENDE/PPEPP)? Yes or No
Q31- Training actions in P. PORTO about entrepreneurship and innovation are suitable in terms of periodicity
Q32- Training actions in P. PORTO about entrepreneurship and Innovation will meet my needs
Q33- Themes that are addressed in the training sessions are interesting and appropriate for the achievement of my project
Q34- I have the necessary conditions to attend to extra-curricular training
Q35- The training courses on Entrepreneurship and Innovation are a complement to the curriculum of my graduated course
Q36- Instruments/tools are given to facilitate my participation in entrepreneurial projects
Q37- These training courses are an additional weight on my individual training, in terms of time and work
Q38- These training courses and graduated activities are adequately in line.
Q39- These training courses should be performed outside the graduated courses period
Q40- The number of sessions is suitable
Q41- Training courses have appropriate disclosure
Q42- These training courses should be made with the joint participation of students from different Schools to promote synergies
Q43- The existence of the *OTIC* (Technology Transfer Office) in P. PORTO contributes to support entrepreneurship and innovation actions
Q44- Internet platforms to support entrepreneurship and innovation are important
Section 6- P.PORTO Entrepreneurship Platform INNOENTRE
Q45- Knowledge of the internet platform "INNOENTRE" Yes or No
Q46- The INNOENTRE internet platform used by P. PORTO to support Entrepreneurship and innovation has useful content
Q47- The INNOENTRE internet platform is easy to use ("user friendly")

2.1 Sample and Data collection

The questionnaire was distributed by email, using Moodle platform, to the students in May 2017, and 148 valid responses were obtained from a total of 262 registered students (a responding rate of 56,5%): 51,4% from ESS% (mainly from Pharmacy and Physiotherapy courses), 30,4% from ISEP (from Industrial and Management Engineering degree and Industrial Management engineering master course),16,9% from ESTG (from Economics Sciences course) and 1,4% from ISCAP (Master course on Entrepreneurship). Concerning the gender, 68,2% of the students are female and 31,8% male. The students' age ranged from 19 to 48 years old, most of them, 70%, between 19-23 years old.

2.2 Statistical Analysis

Statistical analysis was made using IBM SPSS software tool pack, version 24. Descriptive statistical analysis was used for quantitative nature data. Cronbach's alpha was used to measure the internal consistency. For the main questions from S2, S3 and S4, with twenty-three variables respectively, it was used the PCA and FA models. MacCallum *et al*. [12] recommend a minimum sample size of 100 responses and Guadagnoli and Velicer [11] refer a minimum of 100 to 200 observations, which is also recommended by several authors [11, 12, 18]. MacCallum *et al*. [13] define that, as a rule, for the sample size a ratio of valid responses per existing variables should be greater than 5 (6,43 in our case).

PCA and FA are exploratory multivariate analysis techniques that turns a set of correlated variables into a smaller set of independent variables, linear combinations of the original variables, known as components and factors. After performing the Varimax matrix rotation, the PCA becomes FA. If most of the total population variance can be attributed to the first components, then these can replace the original p variables without much loss of information [14]. The principal components are the uncorrelated Zi which are measuring different dimensions of data, ordered by decreasing variances. The variances of the principal components are the eigenvalues Yi of the sample of covariance matrix S, or of the correlation matrix R. When doing PCA, there is always hope that the variance of almost of the indices are negligible [15]. Both techniques are usually seen as data reduction methods but, beyond this goal, one of the main advantages of each one is that they allow to reduce the information of multiple correlated variables into one or more independent linear combinations (components or factors), representing most of the information present in the original variables [16,17]. Although PCA is usually applied to quantitative analysis, SPSS has implemented an optimal scaling procedure that assigns a numerical value to each category of ordinal variables and creates a corresponding quantitative variable with metrics properties, enabling PCA to be performed on categorical variables [16].

3 RESULTS AND DISCUSSION

The Cronbach's alpha for our variables was 0,933>0,8, that is considered very good [18]. Descriptive statistical analysis was used for quantitative nature data. For qualitative data, the PCA method and FA model was used. Concerning that until question Q29, there are 148 valid responses. PCA and FA were done according to section 2.2. Five factors with eigenvalue greater than 1 were retained, as well as the five factors that cumulatively explained a 70,8% variance in the original data. To clear data, the Varimax rotation was made (see *Table2).*

Communalities show that all variables have a strong correlation with extracted factors, since common variance of extracted variables is greater than 50%. F1- entrepreneurship Competences given by curricula (41,4%), explained by Q12 to Q21; F2- entrepreneurship competences to be given by P.PORTO (12,4%), explained by Q22 to Q29; F3- factors to fostering entrepreneurship concerning students' skills (7%), explained by Q7 and Q9; F4- Factors to fostering entrepreneurship concerning students' third financial access and appropriated partners (4,6%), explained by Q10 and Q11; F5- Factors to fostering entrepreneurship concerning students' own financial capacity (5,4%), explained by Q8, the others factors with less than 29,2% of variance explained. Concerning to Q12, Q22 and Q26 the allocation to a single factor is unclear, since the value is high for both factors F2 and F3, being higher in F2, where allocated.

Table 2. Rotating matrix of component

Questions	Component					communalities
	1	2	3	4	5	
Q7			**,463**			,501
Q8					**,903**	,843
Q9			**,793**			,721
Q10				**,728**		,699
Q11				**,816**		,745
Q12	**,632**		,434			,615
Q13	**,747**					,708
Q14	**,796**					,670
Q15	**,771**					,778
Q16	**,796**					,759
Q17	**,747**					,690
Q18	**,742**					,590
Q19	**,733**					,656
Q20	**,751**					,712
Q21	**,743**					,629
Q22		**,689**	,409			,749
Q23		**,805**				,745
Q24	,353	**,718**				,702
Q25		**,716**				,659
Q26		**,716**	,429			,753
Q27		**,842**				,822
Q28		**,824**				,741
Q29		**,822**				,802
% of variance explained	41,4%	12,4%	6,96%	5,4%	4,6%	
eigenvalues	9,51	2,86	1,601	1,242	1,068	

The Bartlett's sphericity test provided a very significant result ($\chi 2 \approx$ 2198,216; df253), featuring a *p*-value less than 0,001, value by which we reject null hypothesis, concluding that all the variables are significantly correlated. The results obtained have granted legitimacy to the use of the PCA method, showing that the matrix contains a significant correlation between the twenty-three variables. We have a 0,888 Kaiser-Meyer-Olkin measurement (KMO), which is considered good when between 0,8-0,9 value [17].

From questions Q30, only 45 students knew the P.PORTO resources dedicated to support and promotion of entrepreneurship and responded to the remaining questions. Hence, only a quantitative analysis was made (see *Table 3*). As the median (50% of the students), the mean and the mode (most frequent value) is higher than 3, from which we can conclude that the students find the P.PORTO entrepreneurship programmes suitable with the degree and useful, although (Q37) near 87% of the students find it as an extra weight to their' tasks and duties.

Table 3. Questions follow yes on Q30, Likert scale from 1-5

	N Valid	Missing	Yes	No	(1-2)	3	(4-5)	Mean	Median	Mode	S.Dev
Q30	148	0	30.4%	69.6%	%	%	%				
Q31	45	103			25,6	28,2	46,2	3,27	3,00	4	1,095
Q32	45	103			17,9	33,3	48,8	3,36	3,00	4	0,981
Q33	45	103			10,3	35,9	53,8	3,60	4,00	4	0,963
Q34	45	103			33,3	28,2	38,5	2,98	3,00	3	1,158
Q35	45	103			15,4	35,9	48,7	3,51	4,00	3	1,036
Q36	45	103			23,1	17,9	59	3,51	4,00	4	1,014
Q37	45	103			11,1	22,2	66,7	3,80	4,00	4	1,014
Q38	45	103			23,1	28,2	48,8	3,24	3,00	4	1,171
Q39	45	103			17,9	20,5	61,5	3,62	4,00	4	1,230
Q40	45	103			20,5	30,8	48,7	3,27	3,00	4	0,986
Q41	45	103			35,9	30,8	33,3	2,89	3,00	3	1,210
Q42	45	103			5,1	15,4	79,5	4,16	4,00	5	0,952
Q43	45	103			5,1	46,2	48,7	3,56	3,00	3	0,841
Q44	45	103			5,1	12,8	82,1	4,22	4,00	5	0,927
Q45	148	0	4%	96%							
Q46	6	142			3	33,3	66,7	3,83	4,00	4	0,753
Q47	6	142			0	16,7	83,3	3,83	4,00	4	0,408

4 CONCLUSIONS

The results of a survey carried on P. PORTO is presented with the main goal to analyse students' perception about Entrepreneurship education in graduated and training courses. Students realized that their graduated curricula gave them some entrepreneurship competences but they found that all the competences listed in the questionnaire should be given by P.PORTO in more detail, through complementary training courses or in the graduated courses. The students found that is important to strengthen competences about business plans and economic viability of projects and marketing. In addition, students stress that beyond all the competences that P.PORTO can offer through the curricula or training courses, as technical skills, to have own money or access to incentives from third parties is the main key to be an entrepreneur. Only 30,4% knew about P.PORTO entrepreneurship initiatives or activities, although students found the P.PORTO entrepreneurship programmes suitable with the degree and useful (Q37), nearly 87% of the students find it as an extra weight to their' tasks and duties. Only 4% knew about the InnoEntre platform, a very low value, despite only it being used since this year in P.PORTO .
The results obtained are in agreement with expected results, showing the importance of promoting formal disclosure of information to promote AE initiatives. As a future work the application of the questionnaire in all P.PORTO courses will be stimulated in a more participative way by all schools in order to obtain a more integrated perception and to promote the comparative analysis between different areas of education of the different schools of the P.PORTO. With regard to engineering courses, it is expected to conduct an exhaustive comparative analysis between the various courses taking into account the specific needs of each course. The results from this research will be presented and discuss with courses coordinators to promote future curricula improvements related with Entrepreneurship.

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Teaching Professional skills in Engineering Programmes: The Academic Perspective

A plan for using Phenomenography to explore academic conceptions of their role in developing professional skills in engineering students

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ABSTRACT

Engineering graduates in today's world face a global industry where professional skills are as important as the intellectual prowess gained by obtaining a degree itself. The importance of these skills is abundant in literature, yet so too is an ongoing barrage from industry that Higher Educational Institutions (HEIs) are not developing sufficient professional skills within students [1].

This occurs against a background of accrediting bodies who have adopted programme outcomes which require employability/professional skills to be integrated into the curriculum. There is also evidence that many educators have attempted to employ innovative strategies, such as Problem Based Learning to expose students to opportunities to practice these skills. Why therefore, is there still a gap between what industry wants and what HEIs provide and whose fault is it? Industry may be demanding more than an academic can deliver, in an already overcrowded curriculum with dwindling funding, particularly in an Irish context [2-3]. To close the gap, academics may need to expose students to professional skills in every module. This paper proposes a research study to explore how academics conceptualise their role in developing professional skills in engineering students.

Conference Key Areas: Skills and Engineering Education, Engineering Education Research, Curriculum Development

Keywords: Professional Skills, Phenomenography, Academic Conceptions of Teaching, Approaches to Teaching Inventory

INTRODUCTION

The author's interest in preparing engineering students for a successful career in industry stems from personal experience of recruiting, mentoring and managing graduates in civil and structural engineering consultancies. The range of skills, abilities and values of each graduate was varied, and it became apparent that academic achievement, whilst important, was not the defining skill for achieving early responsibility or promotion within the company. More often, the graduate who could communicate well and self-direct his/her work was given more responsibility and opportunity.

The intent in this paper is to present a plan for a PhD research study with two aims. The first is to summarise the research plan and proposed methodology. The second is to elicit critique and advice in the design of the study, including the research questions and the methods proposed.

1 BACKGROUND

1.1 Influence of Accreditation Bodies and Industry

Accreditation requirements for engineering programmes serve as a framework for programme design. Several accrediting bodies including Engineers Ireland (EI), and the Accreditation Board for Engineering and Technology (ABET) require degree programmes to include outcomes, which incorporate what may be considered professional skills [4-5]. These skills include; self-directed working, teamwork, multidisciplinary working, ethics, communication with the engineering community and with society at large. The EI programme outcomes have been developed in consultation with employers and should therefore address concerns about professional skills from an employer's perspective. Employers in Ireland however, still report that they are not satisfied with the level of competence of engineering graduates in non-technical skills. [1]. This suggests therefore, that although there are processes in place which should ensure that students have opportunities to develop these skills, there is a disparity between what the accreditation paperwork requires and the skills that students actually develop. One area where this disjoint may occur is in the classroom, and could be influenced by how the academic teaches or how the students learn.

1.2 Academic Conceptions of Teaching

Several studies report that although there is an awareness of the importance of developing non-technical skills within students, academics do not always feel adequately prepared to teach these skills, nor feel compelled to change their teaching pedagogy [6-10]. If we assume that academics are a key driver for change in engineering education, then we need to ascertain what constitutes good teaching or more importantly good learning in relation to developing professional skills. The theory of academic conceptions of teaching provides a lens through which to consider this aspect. When academics enter the classroom, they do so with prior conceptions of what constitutes good learning and teaching in their discipline. Prosser and Trigwell [11] purport that the academic's conception of teaching has a direct influence on how the students learn. Since this theory emerged in 1991, several researchers have produced varying categories of descriptions of the conceptions of teaching [11-14]. Prosser and Trigwell went a step further and created an Approaches to Teaching Inventory (ATI) survey instrument [11]. This can be used to identify which category best describes each survey respondent in a particular teaching context.

At the lowest level, the emphasis is on transmission of information and teacher focussed strategies with the result that students respond by accumulating information and rote learning. The highest category signifies a conceptual change and student focussed approach where teachers focus on their students' own views or conceptions of the subject, rather than their own [11]. In this category, teaching pedagogies would likely include open discussions and debates so that students take ownership of their own views. One could conclude that the ability to critically examine an issue and defend a position requires practice in several of the professional skills that employers are seeking. One aspect of this research study intends to explore if the academic conceptions of teaching bear any relation to how academics feel about teaching **professional skills** in particular.

2 RESEARCH QUESTIONS

The research questions centre around the experience of the academic in the classroom, although we are also interested in factors which may have influenced how the academic contemplates the relative importance of professional skills. This includes how the academic approaches teaching in general (with reference to the ATI) and previous training in different pedagogical approaches. The authors' background has influenced their own views on professional skills and so we want to investigate if academics with an industrial background have different views to those who have a purely academic background. This research study has three interlocking aspects as shown in Fig. 1.

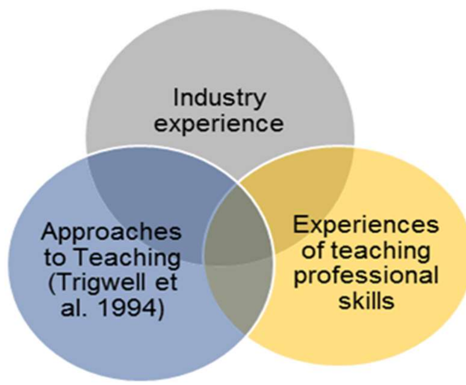

Fig. 1. Interlocking aspects of research study

The overarching research question is;

- What are the qualitatively different ways that academics experience and conceptualise teaching in engineering programmes in Ireland?

Sub-questions focusing on professional skills include;

- What are the qualitatively different ways that academics perceive what is meant by professional skills in engineering? How is the term 'professional skills' understood by engineering academics? What is the variation in academic's conceptions of what 'professional skills' mean?
- How do academics manifest their conceptions of teaching through their actions in teaching professional skills?
- What is the relationship (if any) between conceptions of teaching and academics' background in academia, industry or both?
- What is the relationship (if any) between conceptions of teaching and experiences of teaching professional skills?
- What is the correlation (if any) between conceptions of teaching professional skills and academic's backgrounds in academia, industry or both?

3 METHODOLOGY

3.1 Brief description of Phenomenography

The aim of the study is to build an understanding of academics' conceptions, perceptions and experiences of teaching professional skills. It is not to prove a hypothesis, to look at a particular case study nor a particular group of people. A descriptive method of enquiry was needed. Three research approaches were considered appropriate for the study; phenomenology, phenomenography and grounded theory. We determined that phenomenography would best answer the research questions.

Phenomenographers seek qualitatively different, but logically and hierarchically interconnected descriptions that a group of people experience in relation to a particular context [15]. Ference Marton, the original proposer of the term phenomenography, relates action and experience [16]. It follows that if we want to understand how people **handle** certain situations then we need to investigate how they **experience** those situations. "A capability for **acting** in a certain way reflects a capability **experiencing** something in a certain way. The latter does not cause the former, but they are logically intertwined" [16, p.111].

Phenomenography is proposed as an ideal fit for this research study for two reasons. Firstly, we believe that there are varied ways in which academics perceive, conceptualise and experience teaching professional skills. It is the variation we are interested in, not the commonalities which would be typical of a phenomenological study. The second reason is that a phenomenographic study is usually context bound. It refers to a particular instance that the interviewee is asked to reflect upon. We intend to investigate their experiences in relation to a particular context and not as an idea of teaching professional skills in the abstract.

3.2 Rationale and use of phenomenography in this research

This study aims to effect change in the way students are prepared for industry, particularly in relation to professional skills. This aligns well with the origins of phenomenography which was based in an educational setting. The study, while arguably based in education, focuses not on students but on the experiences and conceptions of academics.

There is merit in this approach as it is argued that previous research studies in science education have sought to develop prescriptive solutions to problems in teaching and learning and that this is not effective, that descriptive results are much more powerful [17]. Phenomenography allows us to look at how academics approach their teaching in a natural setting and how these approaches affect the outcome for students. Research output in a descriptive form will allow academics to reflect critically on their own practice, which can account for their own individual perceptions [17].

Despite initial assertions to the contrary [16,18], phenomenography can be considered a research approach, and the researcher uses whatever research methods most appropriate to the study. In this instance, we will undertake a two-phase approach. Phase One will comprise an online survey, the primary purpose of which is to collect background information on the participants forming the population sample. The survey responses will set the context for the research and will inform the interview questions for the main phenomenographic study, which is undertaken in Phase Two. Fig. 2. outlines the conceptual framework proposed for the research study.

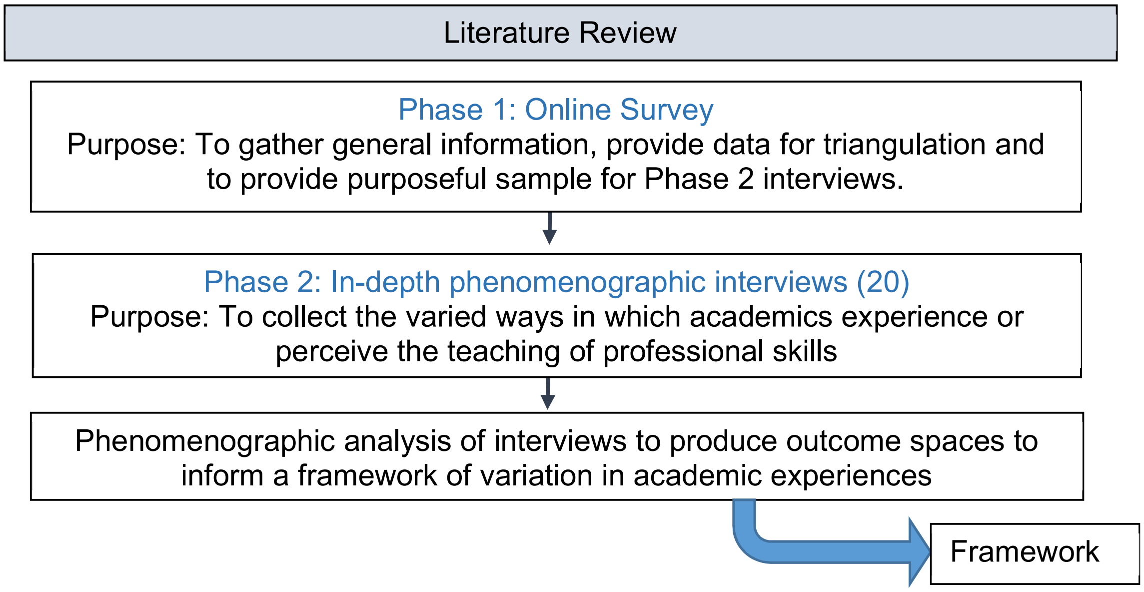

Fig. 2. Conceptual framework of research study showing key milestones

3.3 Data Collection – Phase 1 Online Survey

The primary purpose of the Phase 1 online survey is to enable us to undertake purposive sampling for the Phase 2 (interview phase) of the study. However, it will also be used to assess engineering academics' attitudes towards learning and teaching in general using the Approaches to Teaching Inventory (ATI) [11]. This will allow us to compare and contrast against existing data banks for other disciplines.

3.4 Survey questions

The survey aims to collect information in the following categories:

- Gender
- Professional qualifications (both academic and professional organisations)
- Background career (engineer or other)
- Extent of industrial experience (what level; recruitment or mentoring of graduates)
- Extent of academic experience (what level; responsible for programme design)
- Previous experience of an accreditation event
- Ranking of the skills required to make a **good** engineering graduate.

As the survey will include both closed and open questions, quantitative and qualitative analysis will be possible. In particular, the following aspects may be analysed;

1. What percentage of academics have industry experience and furthermore were responsible for recruiting and/or mentoring graduates in industry?
2. What percentage of academics who teach engineers are engineers?
3. What percentage of academics believe that they only teach technical skills?
4. How does the ATI for engineering academics differ to other disciplines and is there a statistical significance between academics who have an engineering degree compared to others, or academics who have worked in industry compared to those who have not?
5. Is there a statistical difference between ATI for male and female academics?

6. What are the top 10 ranked professional skills for engineering graduates of today?
7. What percentage of academics have undertaken a teaching qualification? Is there a relationship between obtaining a teaching qualification and responses to the ATI?

3.5 Survey Method and Sample

The survey will be distributed electronically to all academics teaching on engineering programmes in all HEIs in Ireland. Only the author's own School will be excluded to avoid ethical issues [19]. A pilot survey will be trialled with respondents selected as meeting the requirements of the sample, but who will not be included in the final survey. They will be asked to give feedback on all aspects of the questionnaire including content, language, length and any ambiguity in the questions. In particular, the terms used in the question on ranking of professional skills will be reviewed in detail and these may have to rephrased in order to extract the type of answers we intended.

3.6 Research Participants

It is important that the interviewees selected for the data collection are appropriate to the purpose of the research, by representing a large cross section of views about the research topic. A purposeful sample (research participants relevant to the central question) and maximisation of sample variation (broad range of views) is preferred [20]. It is important to select interviewees who offer what is described as "the best opportunity of manifesting the full extent of the various ways of experiencing the phenomenon" [21, p.6]. One opinion is that the researcher must not be swayed by being inclusive of gender or other cultural groups, which are in a phenomenographic sense, artificial distinctions. However, other researchers argue the opposite; that emotional responses are important and differ between the genders and "it would be useful for the phenomenographer in considering a purposive sample to include gender as a basis for ensuring adequate variation, to attend to sex differences in the analysis, and to choose to explore areas of learning central to women's as well as men's experiences" [22, p.224]. The sample for Phase 2 interviews will be selected bearing in mind the different facets of the research questions asked.

3.7 Data Collection – Phase 2 Interview Methodology

Whilst some texts suggest 25-30 interviews are required [20], others suggest that saturation can be achieved with 10-20 interviews [23]. It is initially intended to undertake 20 second stage interviews in addition to pilot interviews with two people who will not be included in the sample. The interviews will be undertaken by one researcher "in order to promote consistency in questioning and in the ways in which the responses are prompted and contrasted" [20, p.58].

3.8 Analytical Methods

Phenomenography aligns with a subjective ontology, where the researcher interprets the outcome of interviews with people. It is accepted that the people will construe the world in different ways, as opposed to there being one truth. In fact, in phenomenography, researchers do not make any assumptions about reality, nor do they intend that their research outputs represent the **truth**. The findings of a phenomenographic study are presented in outcome spaces; hierarchically ordered sets of categories of descriptions, identified by qualitatively different variations of experience of the phenomenon. Researchers aim to present outcome spaces that reflect the phenomenon, but researchers can only provide more or less complete outcomes, not right or wrong outcomes [23].

Through uncovering variation, we hope to identify different **categories of description** which show **themes of expanding awareness** of how teaching professional skills is conceptualised by academics. The hope is that the outcome spaces can show academics that there are **more complete ways** of conceptualising how we can teach professional skills and that this will encourage greater adoption by academics, even within technical subject areas.

4 SUMMARY

In this paper, we have provided a brief overview of a proposed PhD research study to elicit feedback from educational researchers in the field. We hope that the research we are about to conduct will contribute to placing increasing importance on teaching of professional skills. We hope that the outcomes will provide a framework for academic staff to reflect upon their own approach towards teaching professional skills in an engineering curriculum.

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4.

Quality Assurance and Accreditation

Revision of the Qualification Framework at the Technical University of Denmark
Part 1: Concepts

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ABSTRACT

When the Technical University of Denmark (DTU) adopted the National Qualification Framework (NQF), it was implemented as an add-on to the existing concept in place for describing educational outcomes, rather than by redesigning the educational outcomes themselves. The system in place does not emphasize the type and extent of knowledge, skills, and competencies adequately to facilitate programme development and evaluations. In this work, an expansion and reorganization of the qualification elements in the NQF at DTU is proposed as a means to facilitate a more detailed design and evaluation of the educational programmes. The top level categories of *knowledge*, *skills,* and *competencies* are reorganized into four categories: *-to know*, *- to be*, *-to interact*, and *–to do*. Knowledge of praxis is a new element in the category *–to know*. The new category, *-to be*, includes mind-set development and self-instruction. The category, *-to interact*, includes competencies in communication and teamwork. The category, *-to do*, includes operative skills and competencies in problem solving. Each of the four main categories contain a number of qualification elements. Suitable taxonomies are suggested for each of the main categories.

Conference Key Areas: Curriculum development, Quality Assurance and Accreditation, Engineering Skills

Keywords: Qualification framework, educational outcomes, constructive alignment

INTRODUCTION

When the Technical University of Denmark (DTU) adopted the Danish National Qualifications Framework [1] (NQF), the new concept of *knowledge*, *skills,* and *competencies* was implemented as an add-on to the existing set of qualifications. Each educational programme constructed a qualification matrix with the existing qualifications listed vertically and the NQF descriptors *knowledge*, *skills,* and *competencies* as the horizontal axis. However, the application of only three descriptors has proven to provide inadequate detail in all aspects of programme design, implementation and evaluation. In this paper, we propose a revision of the *knowledge*, *skills,* and *competencies* categories and present a number of taxonomies aimed at the different types of qualifications. In a companion paper [2], applications are demonstrated for three B. Sc. in Engineering programmes.

1 EXPANSION OF THE QUALIFICATION FRAMEWORK

The NQF organizes qualifications into three descriptors: knowledge, skills, and competencies. UNESCO [3] uses four descriptors: *to know*, *to be*, *to cooperate*, and *to do*. In this section, these approaches are combined to form a revised qualification framework.

1.1 Current framework

The current descriptors of the NQF for programmes at the Bachelor of Science (B. Sc.) level are listed in *Table 1.*

Table 1. Descriptors of the Danish National Qualification Framework [1]

Knowledge	1	Must have knowledge about theories, methods, and praxis within one or more disciplines or professions.
	2	Must be able to understand and reflect on theories, methods, and praxis.
Skills	3	Must be able to apply methods and tools associated with one or more disciplines and be able to apply general skills required by employees in a discipline or profession.
	4	Must be able to interpret theoretical and practical problems and apply relevant methods for analysis and problem-solving.
	5	Must be able to communicate the nature of problems and their solutions to peers as well as to non-specialists.
Competencies	6	Must be able to handle complex entrepreneurial challenges in study and work situations.
	7	Must be able to work independently and to cooperate in groups in a professional manner.
	8	Must be able to identify personal need of learning and to orchestrate self-instruction in different learning contexts.

The NQF contains eight educational levels with Bachelor of Science ranked 6, Master of Science ranked 7 and the Ph. D. as the eight and top level. In an indirect manner, the NQF thus represents a taxonomy for educational outcomes. The NQF does not offer a taxonomy for measuring progression in learning within each such level. This is one reason for developing a qualification framework aimed specifically at the B. Sc. in Engineering programme. Another reason is the absence of a clear distinction between skills and competencies. While descriptor number 3 fits the category of skills very well, descriptors number 4 and 5 are indistinguishable in nature from descriptors 6, 7, and 8. Descriptors number 4 and 6 are both about problem solving and could be merged into one descriptor. Placing descriptor number 5 about communication within the skills category is also questionable. Another accepted opinion is that mastery of languages is a skill, while communication of professional matters is a competency. Finally, the NQF fails to address the development of a personal and professional mind-set.

1.2 Revised framework

Besides rectifying shortcomings in the current NQF mentioned above, a revised framework must also facilitate constructive alignment by defining qualifications that are equally meaningful at the programme level and at the level of individual courses. A third objective of a revised framework is to facilitate a more systematic use of taxonomies as a linkage between programme outcomes and course outcomes.

Table 2 defines the top two levels of the revised qualification framework. The three major categories based on knowledge, skills, and competencies have been abandoned in favour of four categories similar to UNESCO's *Four pillars of learning* [3]. The first category, - *To know*, is essentially identical to the knowledge category in the NQF. The second category, - *To be*, is a new addition, emphasising development of a personal and professional mind-set. This category, by some referred to as the *Disciplinary future self* [4], includes the notion of *Life long learning*, which here has been renamed *Self-instruction* in order to strengthen its relevance in the minds of young students. The third category, - *To interact*, includes communication as well as teamwork, and is therefore similar to the notion "Learning to live together" in UNESCO's *Four pillars of learning*. The fourth category, -*To do*, is the combination of operative skills and problem solving. The most noticeable change in the organization of the revised qualification framework is the significant narrowing of the definition of skills and its closer association with problem solving. This closer association is motivated by the taxonomy for problem solving presented in the next section.

Table 2. Components of a revised qualification framework

1st level	2nd level descriptors	Description
1: - To know	Knowledge of theories	Acquire and apply terminology and facts, theories, laws of nature, methods, and procedures.
	Knowledge of praxis	Apply knowledge about praxis-induced boundary conditions and their influence on the applicability of theories and methods.
2: - To be	Mind-set	Develop a personal and professional mind-set.
	Self-instruction	Identify need for new knowledge, gather resources, execute, and evaluate learning outcomes.
3: - To interact	Teamwork	Conduct, coordinate, lead, monitor, and develop teamwork.
	Communication	Master language and tools, structure content, choose between narrative styles, edit for logic and clarity, and define communication objectives and receiver competencies.
4: - To do	Operative skills	Advance degree of training, from novice to expert, in executing manual and cognitive tasks.
	Problem solving	Interpret problem information, identify objective, diagnose problem, choose strategy, execute and evaluate solution, interpret impact of solution.

2 QUALIFICATION CATEGORIES AND THEIR TAXONOMIES

A qualification framework serves not only to define educational outcomes but also to construct an alignment between outcomes at the programme level and at the level of individual courses. A qualification framework must also take into consideration the learning processes facilitated by the courses and it becomes necessary to distinguish between learning objectives and learning processes. The complexity of learning objectives and the complexity of learning processes cannot be described by a single taxonomy.

2.1 Object and process complexity

Academic complexity follows the scholarly advancement semester-by-semester from introductory courses to more advanced courses in the final year of a programme. We will refer to this dimension of complexity as *object complexity*. The complexity of the processes engaged in acquisition and use of knowledge is here referred to as *process complexity*. Bloom's taxonomy (*Figure 1*) for the cognitive domain [5] is one of the most used taxonomies for measuring process complexity.

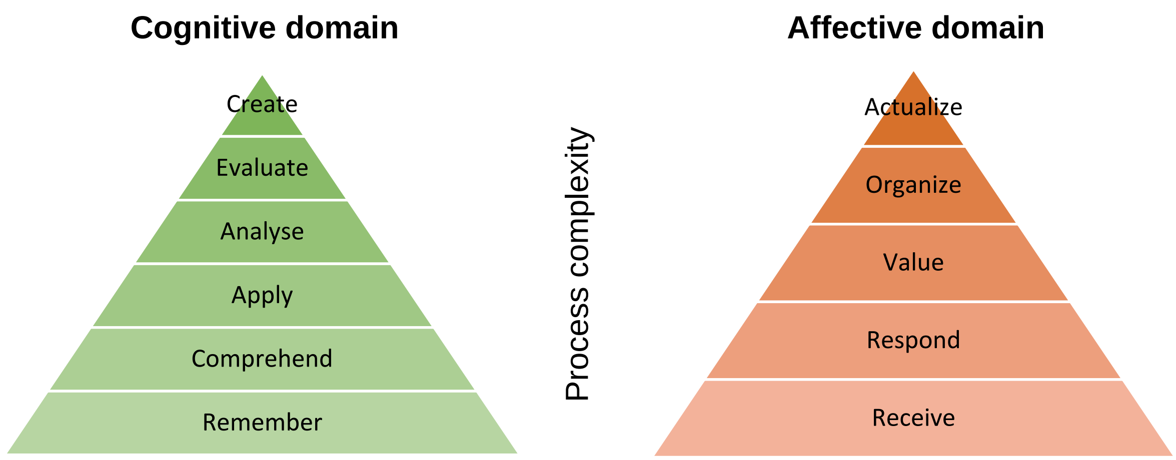

Figure 1. Bloom's taxonomies for the cognitive [5] and affective domains [6]

Bloom's taxonomy for the cognitive domain only describes the process complexity in acquiring and using knowledge. This taxonomy is thus not suitable for defining the topic complexity of the individual courses within a program. To document progression in topic complexity from the beginning to the end of a programme, a course hierarchy scale is needed (see *Table 3*).

Table 3. Course level hierarchy

Course levels	Description	Characteristics
4. Capstone	Projects, capstone design, internships, and thesis work	Non-taught programme activity.
3. Discipline specialization	Intermediate level studies in sub discipline.	Elective course aimed at a subpopulation of students within a programme. Has *Discipline core* courses as its prerequisites.
2. Discipline core	Discipline specific foundation courses.	Unique to a specific programme. Has *Generic foundation* courses as its prerequisites.
1. Generic foundation	Discipline independent courses.	Shared between many programmes.

Courses at the *Generic foundation* level are introductory courses, often with no prerequisite courses, typically first-year courses in natural science. *Discipline core* courses are first level engineering courses, which only have introductory natural science courses as their prerequisites. Such courses typically have little or no inter-dependencies. At the *Discipline specialization* level we place second level engineering courses, where each course may have several first level engineering courses as their prerequisites. A course in instrumentation typically embraces both analogue and digital electronics as well as programming and a course in biomaterials embraces cell biology and materials science. At the top of the course ranking, *Capstone courses* are project courses, capstone design courses, internships and thesis work.

2.2 –To know

The qualifications in the category, *–to know*, is founded on Krathwohl's elements of knowledge [5], but extended with *knowledge of praxis* (*Table 4*).

Table 4. Qualification elements of knowledge

Knowledge elements	Description
1.5 Metacognitive knowledge	Knowledge of cognition in general and awareness of one's own cognition.
1.4 Knowledge of praxis	Knowledge of praxis or regulatory induced limitations to application of theories, methods, and materials within relevant disciplines.
1.3 Procedural knowledge	Knowledge of procedures and methods and the criteria for their use.
1.2 Concepts	The interrelationships among the basic elements within a larger structure that enable them to function together.
1.1 Facts and terminology	The basic elements required to be acquainted with a discipline or to solve problems in it.

The elements of knowledge in *Table 4* are organized from low to high level of complexity and should be considered to have cumulative dependencies. They form one axis in a *knowledge-qualification matrix* and the levels of Bloom's taxonomy for the cognitive domain forms the other axis. Thus, with respect to acquisition and use of knowledge, course instructors should not only aim high on Bloom's taxonomy for the cognitive domain but also aim high on the scale of knowledge elements (*Table 4*). Both scales in the *knowledge-qualification matrix* are independent of topic complexity, hence first semester courses should aim just as high as last semester courses.

2.3 –To be

The elements of mind-set development are divided into two major categories, personal mind-set and professional mind-set (*Table 5*).

Table 5. Qualification elements of mind-set

Mind-set	Components	Description
Professional mind-set	6. Product-oriented	Embedded value set founded on safety, reliability, sustainability, usability, serviceability, aesthetics and ethics.
	5. Process-oriented	Hypothesis and needs driven curiosity, evidence based creativity, logical and critical thinking.
Personal mind-set	4. Self-instruction	Curiosity, self-reflection, need-awareness, resourcefulness, competence-oriented, metacognition.
	3. Self-governance	Vision, self-consciousness, receptiveness, competence-oriented learner, priority-setting.
	2. Social attitude	Empathy, tolerance, reliability, moral and ethics.
	1. Self-efficacy	Initiative, decision-making and responsibility.

The elements have been enumerated by the chronological order in which these components typically enter the mind-set of an engineering student, and represent increasing levels of *qualification element complexity.* The *process complexity* of mind-set development is measured by Bloom's taxonomy for the affective domain (*Figure 1*). Tacit, but strategic enforcement and monitoring is required to obtain a satisfactory development in all students. The top three mind-set levels (Self-instruction, Process-oriented and Product-oriented) must be integrated into courses in an explicit manner.

2.4 –To interact

The third category, - *To interact*, includes communication and teamwork. *Table 6* describes elements of oral and written communication in order of increasing element complexity.

Table 6. Qualification elements of communication

Element complexity	Element description
5. Context analysis	Define communication objectives and analyse receiver competency.
4. Narrative style	Choose between multiple narrative styles in accord with context.
3. Quality control	Edit grammar, style, logic, clarity and sources.
2. Structure of content	Structure content according to standards.
1. Language and tool skills	Master language and information technology tools.

Table 7 describes elements of teamwork in order of increasing complexity.

Table 7. Qualification elements of teamwork

Element complexity	Element description
5. Development	Develop team processes as well as personal growth in the team members.
4. Monitoring	Monitor team processes and team members' adherence to defined codes.
3. Definition	Design time schedules and define codes of behaviour, efforts, ethics, and accountability.
2. Coordination	Coordinate tasks and resources.
1. Execution	Work in teams with individual tasks and adopt codes of behaviour, language, effort, deadlines, and accountability.

In order to embrace the qualification elements of communication and teamwork, engineering programmes must include courses with considerable time allocated to student-centred learning activities. At DTU, such programme elements are mandatory at the first, fourth, and sixth semester in the B. Sc. programme.

2.5 –To do

The qualification category, -*To do*, includes operative skills and problem solving. *Table 8* describes a taxonomy for operative skills based on work by Dave [7]. Dave's taxonomy is used here to express levels of training, from novice to expert, in both manual and cognitive tasks. When operative skills are not a prioritized teaching objective, some students will remain novices throughout their study. Glaser's method of *Shaping* [8] can be used to train operative skills.

Table 8. Qualification elements of operative skills

Taxonomy levels	Level description
5. Naturalization	The expert can discriminate between situations and visualize solutions while diagnosing the task.
4. Articulate	Learners see the goal and adapt procedures.
3. Precision	Learners choose when and how to apply rules.
2. Manipulate	Understanding the context, the learner starts to recognize additional aspects and alternatives.
1. Imitate	Learners rely strongly on guidance and rules they have been instructed to follow.

Table 9 describes elements of problem solving in order of increasing *element complexity* based on work by Plant et al. [9]. The lowest level of complexity is the step-by-step execution of procedures following outlines. Operative skills are the main prerequisite for this level. It is for this reason we have chosen to combine operative skills and problem solving into one qualification category, *-to do*.

Table 9. Qualification elements of problem solving

Element complexity [9]	Element description [9]	Learning activity
5. Create	Design of procedures that are new to the problem solver.	Projects, capstone design, thesis work
4. Interpretation	Interpretation of problem description, identification of objective, translation of the real problem to an idealised problem, evaluation of validity of solution to idealized problem, prediction of impact of solution on problem sphere.	Case studies Course embedded mini projects
3. Strategy	The task of choosing the best suitable procedure among several valid procedures.	Case studies Course embedded mini projects
2. Diagnosis	The task of choosing between correct and incorrect procedures for a specific problem.	Textbook problems
1. Procedure	Operations to be done step-by-step by following a procedural outline. Ability relies on possession of operative skills.	Textbook problems

The elements of *Strategy* and *Interpretation* are rarely met in problem solving activities based solely on textbook problems, regardless of the level of the textbook. Case studies and mini projects embedded in courses are better options. Inclusion of these two elements in the qualification framework will help close the gap between problem solving at the introductory level and at the final level of an engineering programme.

3 SUMMARY

A proposal has been presented (*Table 2*) for a revised qualification framework at DTU. The set of qualifications are organized into logical categories: *-to know*, *-to be*, *-to interact*, *-to do*, and the elements in the qualification framework are easily integrated into outcome statements for individual courses. A number of taxonomies have been associated with different categories of qualifications to facilitate instructional planning and execution in alignment with programme objectives. The proposed framework strengthens the focus on knowledge dimensions, on mind-set development and on operative skills. Finally, it embraces a method for designing problem solving activities to progressive levels of complexity.

In a companion paper [2], the elements of the proposed qualification framework are put into use to write Programme-Qualification Matrices for three different B. Sc. in Engineering programmes.

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RTU Approach to pursuing excellence: sustainable integration of internal quality system in the strategy development. Pilot project review

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ABSTRACT

The aim of this article is to explore the pilot project dedicated to integration of internal quality system in the Strategy Development of Riga Technical University (RTU). Recent development of RTU has been mainly achieved due to the adopted RTU Development Strategy 2014 – 2020 and introduction of the European Foundation for Quality Management (EFQM) management model. RTU Strategy focuses on three pillars – high quality study process, research excellence and sustainable innovation and commercialization. RTU has introduced the EFQM management system as the basis for operations to support implementation of the strategy and to ensure process efficiency and quality. During this research, quantitative and qualitative analysis was performed. More than 150 experts and stakeholders participated in this research in order to evaluate the implemented pilot project. The proposed model and actions to introduce sustainable integrated concept are based on the Planning Stage, Approach, Implementation, Assessment and Refinement. The method how to define action plan priorities has been adopted to suit the needs of RTU. Results showed that this was

Conference Key Areas: Education Excellence for Sustainability, Sustainability and Engineering Education, Quality Assurance and Accreditation.

Keywords: strategy, EFQM model, sustainability, internal quality assurance

INTRODUCTION

In the current volatile and demanding business environment, managers are eager to demonstrate that their organizations are excellent, which can mainly be achieved through continuous performance improvement. Based on the assessment of organizations, the EFQM Excellence Model is the most frequently applied and suitable tool that shows how successful they are in ensuring organizational excellence. [1]

In the recent period, RTU has grown to become the biggest university in Latvia by the number of students. In Times Higher Education ranking RTU was ranked among top 500 universities in the world, and collaboration with industry was marked as the strongest pillar. RTU has established Design Factory which is part of global Design Factory Network aiming towards more entrepreneurship focused university. It is clear that organizations must have an appropriate management system to succeed in this path. [2] Basu states that quality can be explored considering three dimensions (Design Quality, Process Quality and Organization Quality). [3] The researcher reflects on the lack of attention dedicated to Organization Quality. Main challenges associated with introduction of quality systems at the institutions of higher education are connected with lack of motivation, unwillingness of staff and lack of qualified personnel [4]. Human resources are "the living resource" of organizations, and as such are present in the evaluation criteria of all excellence models [5]. Therefore, administration of RTU created a two level strategy – general university strategy and action plan as well as the strategy of each faculty. This article focuses on the EFQM model and the ways how it can be effectively integrated into the strategy to enhance sustainable education, research and valorization.

1 STRATEGY AND QUALITY SYSTEM DEVELOPMENT

1.1 Development of the university strategy

Strategy defines a path for organizational development. The major goals are included in the core strategy document, but wider range of indicators can be defined in the action plan [6]. Careful and planned approach to execution is important for successful strategy implementation, and that is the factor on which organizations fail the most [7]. Research conducted by Rapert, Velliquette, and Garretson [8] shows that reaching internal consensus allows organizations to achieve better financial results and increases efficiency. Additionally, many authors maintain that management is responsible for developing and sharing the vision, encouraging innovativeness, supporting employee efforts and involving employees in the decision-making process [9]. To define general strategic goals a university must have a clear understanding of what it needs to deliver and perform gap analysis to understand its current position [10]. Along with general strategic goals, the management should define horizontal priorities – groups of tasks, which will allow a university to reach the aims of the core priorities. Horizontal priorities can be grouped in sections (no more than 3-6) and they should be incorporated in the core processes as shown in Fig.1.

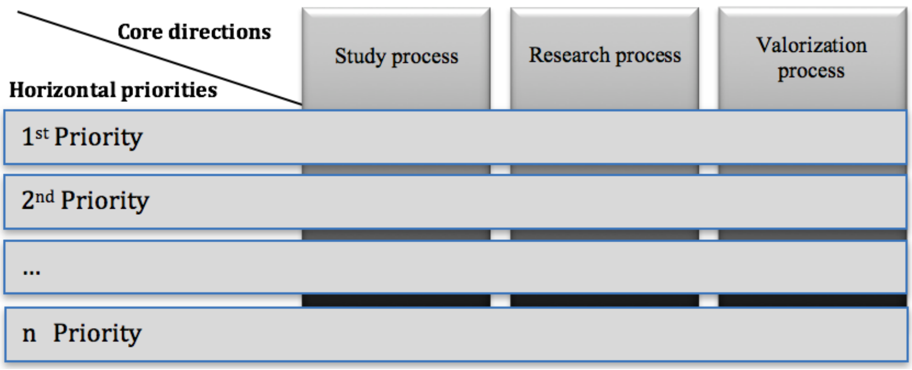

Fig. 1. Incorporation of horizontal priorities in the strategy.

1.2 Setting strategy KPI

Formulating its core action areas and defining general settings, a university sets the framework for all further actions and policies included in the strategy document. Academic and scientific personnel play an important role by setting the aims according to the existing tendencies and trends. When the requirements for reaching the desired strategic goals are set, the university should develop an action plan. These stages are integral elements of the process of university strategy development (Fig. 2).

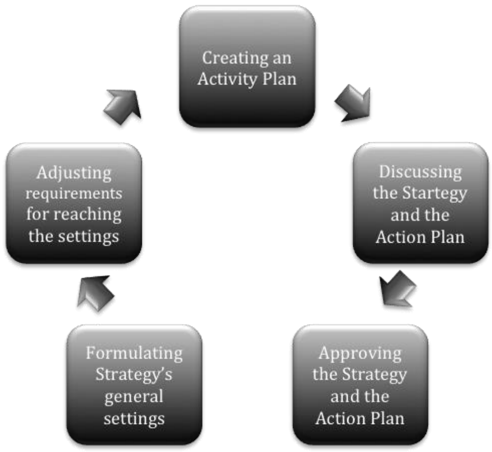

Fig. 2. Development of the Strategy and Action Plan.

To ensure the university's strategy is implemented effectively it is recommended to develop an action plan setting detailed strategic targets – KPI (Key Performance Indicators), based on which the university is able to plan clear tasks, select measurable indicators, appoint responsible units and set deadlines.

1.3 Strategy development at Riga Technical University

RTU has developed the strategy for the period of 2014-2020 (approved in October 2013) and has drawn up an action plan that sets the core priorities and detailed key performance indicators that allow monitoring strategy implementation. At first, management work group performed benchmarking and SWOT analysis. Based on the information obtained through benchmarking and SWOT analysis, the management work group together with the Rector worked on the mission that would reflect three core objectives of RTU – high quality study process, research and innovation, and commercialization. The work group introduced horizontal priorities, which include internationalization, interdisciplinarity, organizational efficiency, financial efficiency and infrastructure efficiency, and these priorities should have been incorporated in all three objectives as seen in Fig. 3.

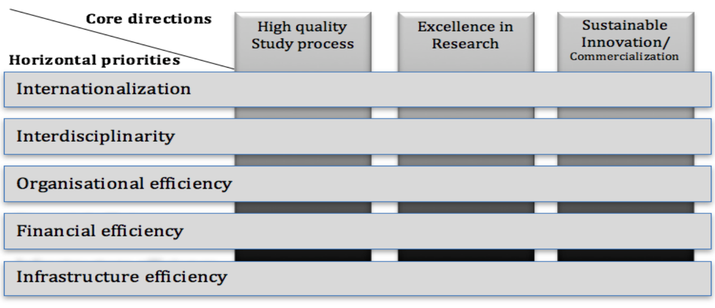

Fig. 3. Horizontal priorities of the Strategy of Riga Technical University.

1.4 Quality system concept in RTU

According to Calvo-Mora, Navarro-García & Periañez-Cristobal, organizations need to establish an appropriate management system to achieve success, irrespective of the sector, size or structure. [11] There are two ways in which firms in Western countries are addressing quality management issues. On the one hand, implementation and certification of quality management systems according to ISO 9000 standard are undoubtedly the most popular methodology. On the other hand, evaluations based on the EFQM are gaining ground in improvement processes. [12] As Escrig & de Menezes point out, the EFQM was launched in 1991 as a non-prescriptive framework based on nine criteria. [13] The present version of the model and respective weights are shown in Fig. 4. Each criterion encompasses several sub-criteria, thus leading to a total of 32 sub-criteria. RTU Quality System is based on the EFQM Excellence Model.

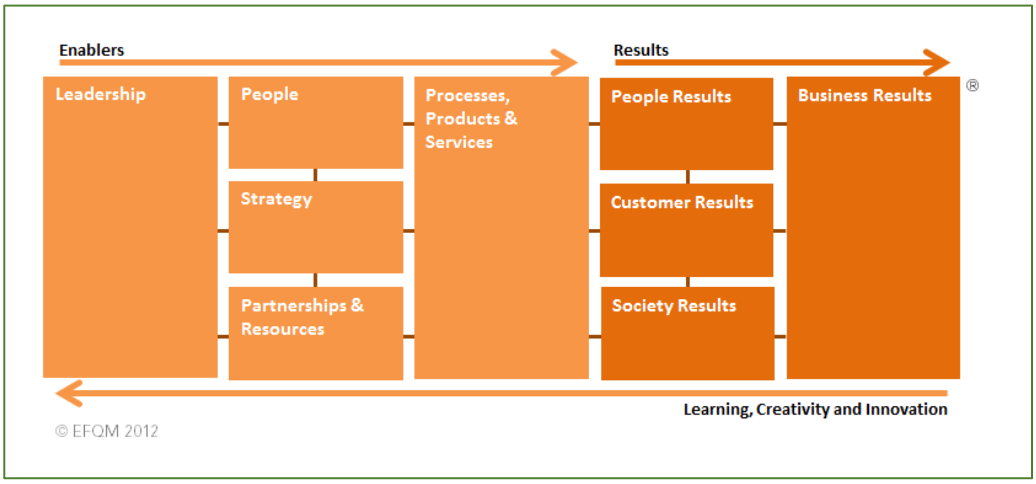

Fig. 4. EFQM Excellence Model. Source: EFQM (2015).

EFQM 2013 states that each of the nine criteria has a definition, which explains the weight and implication of each criterion. Every criterion comprises a number of elements formulated as statements that describe examples of what can typically be seen in excellent organizations and what should be considered part of self-evaluation, which, in its turn, is part of the quality system. The model is based on eight fundamental concepts of excellence (adding value for customers; creating a sustainable future; developing organizational capability; harnessing creativity & innovation; leading with vision, inspiration & integrity; managing with agility; succeeding through the talent of people; sustaining outstanding results). [14]

2. PILOT PROJECT OF INTEGRATION OF THE EFQM CRITERIA WITH KPI

In order to synchronize processes of university strategy development and monitoring and quality system pilot project was launched to combine these platforms. Objectives of process synchronization was to make both platforms more integrated and systemic, that would lead to increased efficiency, reduce duplication of data management and quality indicators play more significant role in determining universities strategy. Method to evaluate process was quantitative and qualitative analysis. As for quantitative analysis surveys were sent out. Qualitative analysis was conducted through individual meetings and interviews. In this article, the authors consider integration of RTU KPI in RTU EFQM quality system model. In case of RTU, all KPI can be classified as EFQM result criteria, see Fig. 4. More than 150 experts and stakeholders participated in the research to evaluate correspondence of each of RTU 32 strategy KPI with the EFQM criteria and corresponding sub-criteria. Afterwards, interviews with some RTU staff members, students, project managers and other stakeholder were carried out. Completing the questionnaires, respondents, based on their opinion, had to evaluate which KPI fits best a with certain EFQM sub-criteria. In some cases, results were equally divided between two or more criteria, then this indicator was represented in more than one slot. Table 1 shows integration of strategy indicators in the EFQM result criteria, more detailed sub-criteria relations were not included in this paper. This analysis was very useful to set a framework for EFQM quality system that later was used to draw up a fact-based self-evaluation report.

Table 1. Integration of RTU Strategy indicators in the EFQM result criteria

No.	Indicator	EFQM Result Criteria			
		Customer Results	People Results	Society Results	Business Results
	Study indicators				
1.	Total number of students	X			X
2.	Number of graduates			X	X
3.	Student drop-out rate	X			
4.	Number of foreign students	X			X
5.	Number of study programs	X			
6.	Average age of academic personnel		X		
7.	Number of study programs in English	X			
8.	Number of study programs implemented jointly with other universities	X			
9.	Number of study subjects implemented in English	X			
10.	Average rate of faculty evaluation done by students	X			
11.	Relative number of academic personnel with Doctor's degree		X		
12.	Number of foreign guest professors		X		
	Scientific research process indicators				
13.	Number of scientific research staff		X		
14.	Number of scientific research staff (FTE)		X		
15.	Average age of research personnel		X		
16.	Relative number of research personnel younger than 35 years		X		
17.	Implemented scientific projects financed by external funding				X
18.	Attracted external research funding ('000 EUR)/ Number of scientific research staff (FTE)		X		
19.	Publications and citations				X
20.	Number of organized seminars and conferences			X	
21.	Effectiveness of doctoral promotion – number of defended doctoral theses/ number of enrolled doctoral students	X			
22.	Number of scientific journals cited in SCOPUS				X
23.	Number of foreign scientific research staff		X		
	Innovation and commercialization process indicators				
24.	Number of patent applications		X	X	
25.	Number of granted patents				X
26.	Number of signed intellectual property licensing agreements			X	
27.	Earned income from signed intellectual property licensing agreements				X
28.	Number of prepared commercialization offers		X		
29.	Number of signed agreements with companies			X	
30.	Earned income from signed agreements with companies				X
31.	Number of created new spin-offs			X	
32.	Number of created new spin-offs active for at least 2 years			X	

RTU Approach to Pursuing Excellence defines the following steps to achieve sustainable development of RTU: stating and planning required results, Approach, Implementation, Assessment and refinement, as it can be seen in Fig 5.

Fig. 5. Stages of RTU Approach to Pursuing Excellence. Source: RTU Approach to Pursuing Excellence (2017).

Fig. 5 presents the process cycle of ensuring excellence. Initially, RTU Mission, Vision and Values are set by RTU Senate and administration. They are mainly focused on setting achievable goals, developing and reinforcing more competitive national economy through creation of additional value for perspective graduates and existing students. Keeping this in mind, RTU has set its goals that are implemented within RTU Strategy, which focuses on high quality study process, excellence in research and sustainable valorization. Once all strategic objectives are set, action plan is drawn up listing concrete activities how to improve university performance and to help achieve the targets set previously. Implementation phase begins with systematic process oriented review of the real time data. Analyzed data is used to further enhance the process or make conclusions on the set targets. This is conducted by RTU Quality Management Unit. Once a year, the university prepares a self-evaluation report to analyze the processes and consider possible improvements in the future in terms of Action Plan and Strategy implementation process. After self-evaluation and analysis of performance data, proposals for administration to introduce further changes for continuous improvement are made.

3. DEFINING ACTION PLAN PRIORITIES

Creation of the Action Plan means defining clear tasks, and that allows setting detailed key performance indicators, appointing responsible units and setting deadlines. This year, the pilot project dedicated to the introduction of new methodology how to develop an Action Plan at RTU has been launched. Various stakeholders were involved as participants in creating Strategy Action Plan, which is managed by administration of the university. Challenge is to have the mechanism on how to select ideas that should be included in the strategy. In case of RTU, this becomes even more challenging as the current process allows collecting proposals and ideas from a variety of sources. Focus group reviews indicate that more input sources lead to more proposals and pool of action ideas. This makes development of the strategy action plan more effective. It helps to include employees, mid-level managers, and other stakeholders in the decision-making process, increases awareness of the strategy, quality of action plan and helps to implement the strategy in general. Certainly, it is not possible to implement all actions included the Strategy due to numerous reasons but mainly due to lack of resources. Ideas should be prioritized and RTU has created the methodology to do so. In case of RTU, the Action Plan is reviewed annually. Input for the Action Plan is generated from the review of the previous Action Plan results; senior management input; self-evaluation group input; quality management unit input; employee surveys, and the input from internal and external auditors. All Action Plan proposals are evaluated with action coefficient Eq. (1) where based obtained results list is prioritized list is generated. Pool of ideas is rated as shown in Table 2 at strategy review meetings, usually led by Vice-Rector in each of strategy field (Fig.1) with representatives from all faculties and some central units. The bigger A_c, the more actions should be included in the Strategy.

Table 2. Action prioritizing

Action (A_c)	*Importance (I)*	*Urgency (U)*	*Needed resources (R)*	*Impact on strategy implementation (S)*	*Priority group*
1st action	1 to 10	1 to 10	1 to 0,1	1 to 10	1 to …n
2nd action	1 to 10	1 to 10	1 to 0,1	1 to 10	1 to …n
n action	1 to 10	1 to 10	1 to 0,1	1 to 10	1 to …n

The maximum score for A_c is 1,000 if the action has high importance and urgency, it does not require a lot of resources and has significant contribution to implementing the general strategy. After all actions are scored and A_c is calculated according to Eq. (1), results priority group is given as shown in Table 2. It is decided by the senior management on how to prioritize the list.

$$Ac = I * U * R * S \quad (1).$$

This leaves the window for senior management to decide what action should be listed in the lower priority group. The final decision on the priority groups to be included in the Strategy is made by the Rector. Research showed that introducing periodic reviews of the Action Plan has changed organizational culture as more people feel involved. For example, respondents indicated that since their inclusion in the process, they more actively support the overall strategy implementation and that the quality of their work has been influenced.

4. SUMMARY AND CONCLUSIONS

The pilot project to integrate Strategy development with the EFQM system can be considered successful at RTU to combine strategy and quality system platforms. Complete cycle of stating and planning required results, Approach, Implementation, Assessment and refinement has been developed. The research showed which Strategy KPI’s should be included in the EFQM criteria and analyzed in the self-evaluation report. Employees have better understanding of which outcomes of their work are expected and will be evaluated. Overall support to strategy implementation has increased. Action Plan tasks are prioritized by evaluating and scoring their importance, urgency, required resources and impact on strategy implementation. Research findings confirmed that the EFQM Model integration in strategy development has had a positive effect on achieving key performance indicators. More comprehensive action plan development process has been introduced, which is based on input from various stakeholders. Further analysis should be conducted to evaluate the impact of EFQM enabler criteria on KPI. Because of pilot project both platforms of strategy and quality monitoring were combined, making strategy development aligned with quality system and quality system more supporting of strategy KPI. Pilot process showed, that if people working on both processes work together then it leads to increased efficiency and better governance of data. This helps both units to use the date for analysis and better understand each other. This also eliminates waste in working hours as it reduces duplication of data management. Employees connected with both processes confirmed that data analysis is quicker than if both units do it separately. Another conclusion with closer integration is that quality indicators play more significant role on processes to support strategies KPI. This has led to more increased KPI influence on process outcomes.

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Accreditation of Flemish Civil Engineers programmes (2016): an experience of cross-border Quality Assurance

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ABSTRACT

In the Yerevan Communiqué (2015) ministers in charge of higher education in the EHEA promoted the transnational aspects of quality assurance (QA). However, the internationalisation of the QA activities is far from having reached the objectives assigned by the ministers. The main hindrance comes from the national regulations, which do not allow or strongly restrain home institutions to call for accreditation by foreign agencies.

Although experiences of transnational accreditations of programmes are not unusual, and calls to international experts in national accreditation teams tends to be a standard, the delegation to a foreign agency of the quality assessment of the whole national engineering education, is a rather unique experience.

This paper deals with the accreditation of all the Flemish civil engineer's programmes in Belgium by the French agency CTI. It describes shortly the origin and the building of the project, and gives the analyses of the experience from the respective point of views of the accreditors (CTI) and of a senior representative from an accredited institution (KU Leuven).

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INTRODUCTION

From the origin of the European Higher Education Area (EHEA), the Conferences of ministers in charge of Higher Education, emphasize the international dimension of QA (Quality Assurance); in the Bucharest communiqué [1], they set as a priority to "allow (..) registered quality assurance agencies to perform their activities across EHEA, while complying with national requirements".
Despite the noted advances of the Bologna process, the internationalisation of the QA activities is far from having reached the objectives assigned by the ministers. The main hindrance comes from the national regulations, which -apart in some countries as for example Germany or Switzerland- do not allow or strongly restrain home institutions to call for accreditation by foreign agencies. To this must be added the language barrier and the widespread feeling that the foreign experts team may not perceive and understand the national specificities.

If experiences of transnational accreditations are reported, very few deal with a complete field of higher education. This paper deals with the accreditation of all the Flemish civil engineering programmes in Belgium by the French CTI agency, which is a rather unique experience as quality assessment of a whole national field of education, delegated to a foreign agency. It will be described in the following sections; respectively, the origin and the building of the project (sect. 1); the analysis of the experience from the accreditors (CTI) point of view (sect. 2), and the view from a senior representative of an accredited institution (KU Leuven) (sect. 3).

1 THE ORIGIN AND THE BUILDING OF THE PROJECT

1.1 The "Commission des Titres d'ingénieur" (CTI)

In France, the "Commission des titres d'ingénieur" (CTI) is an accreditation body established 80 years ago (1934) by the French law, responsible for setting the standards for the "titre d'ingénieur diplômé" (master degree of engineering science) and for the programme accreditation in higher education institutions willing to deliver it. CTI is an autonomous institution equally composed on the one hand of representatives of employers and professional engineers, and on the other hand of academia [2]. CTI contributed to the Bologna process in the French engineering domain; it is member of ENQA (European Network for Quality Assurance), registered in EQAR (European Quality Assurance Register) and a founding member of ENAEE (European Network for Accreditation of the Engineering Education).

In addition to its national QA activities (more than 200 Higher Education Institutions delivering engineering degrees to about 35 000 graduates per year), CTI has set standards and procedures for transnational accreditation [3] and has a well-established international experience (about 130 programmes accredited in Belgium, Bulgaria, Burkina Faso, China, Switzerland, Viet Nam; others in process in Tunisia, Morocco, etc.). Transnational accreditation is part of CTI's mission from its beginning; its founding law states that the graduates of foreign accredited programmes are entitled

to hold the" titre d'ingénieur diplômé" and have the same professional recognition in France as graduates of national institutions (procedure of "Admission par l'Etat").
CTI is authorized by ENAEE [4] to award the EUR-ACE® label to the programmes which fulfil the Framework Standards and Guidelines (EAFSG) [5].

1.2 The three Flemish Universities and the national context

The three Flemish civil engineer's programmes involved in the procedure described in this paper are organized by the Vrije Universiteit Brussel (Brussels), KU Leuven University (Leuven) and Ghent University (Ghent).
Since the 1990's, visitations (and later accreditations) of higher education institutions are mandatory in Flanders. This is organized, together with The Netherlands by the NVAO (Nederlands-Vlaamse Acreditatie Organisatie). Visitations were planned by programme, and took place every 8 years. Nearly every year some programmes were visited. For the universities, this was a large burden. A long, separate Self Evaluation Report had to be written for every visitation. The commissions that came for the visitations, often had several non-engineer members, giving sometimes rise to comments that were not perceived by the faculties and their teaching staff as to the point, but rather out of scope.
Replacing this system by a visitation by CTI was a great opportunity for several reasons. First, it is an accreditation by engineers. The supposition was that the comments would be more tailored towards the engineering field. Second, CTI looks at the 5-year programme (3 years of Bachelor, and 2 years of Master) as a whole. As the specific competences that are crucial for an engineer are introduced in the Bachelor, and further developed in the Master programmes, only accrediting the Bachelor, or only accrediting the Master, makes less sense. Third, the CTI approach visits the whole faculty in one movement. This allowed all programmes of each faculty to join forces in quality assurance. It was an opportunity to sharpen their vision and objectives, and to write texts at the level of the Faculty, which was not done before in a systematic way. Last but not least, the texts required by CTI were perceived as much more to the point than the texts that used to be asked by the NVAO. They were less extensive, much more focused. A 50-page Self Evaluation Report had to be written for the faculty and each programme had to write a specific report of 4 pages. This allowed the faculty to concentrate on the essentials.

1.3 The project building

The first contacts with CTI were informally taken in 2010 and then at the SEFI conference in Leuven in 2013. Under the aegis of the Flemish Interuniversity Council (VLIR), CTI and the Flemish faculties set a procedure, based on agreed Terms of Reference (TOR, January 2014).
Before the starting of the accreditation procedures, a change occurred in the legal context. On June 2015, the Flemish Parliament approved a revision to the system of quality assurance and accreditation in higher education, with an evolution towards full institutional accreditation in 2020 and a suspension of the previous programme accreditation system. Consequently, NVAO and VLIR were released from their commitments in the agreed process.
However, even though they were no longer legally required to do so, the three faculties decided to go on and to ask CTI alone the accreditation of their engineering programmes. A latest version of the Terms of Reference (TOR September 2015) was worked out, where the three faculties "seek accreditation by CTI through the procedure of "admission par l'Etat" with the possibility to "request the EUR-ACE label".
The degree programmes concerned by the assessment process comprise:

- Bachelor programmes (180 ECTS): Bachelor of Engineering and Bachelor of Engineering Architecture. These programmes have no professional objectives, almost all their graduates immediately enter a master degree programme in line with the options they selected during their Bachelor studies; as such these programmes are neither eligible for the procedure of “admission par l’Etat”, nor for the EUR-ACE label; however, their quality was assessed and a review report published with recommendations.
- Master programmes (120 ECTS): most of these programmes are taught in English; to be compliant with the Flemish regulation they are also offered in Dutch; as the two tracks share the same learning outcomes, they were considered as a single degree programme. When Master degree programmes were jointly prepared by two (Flemish) universities, one faculty was selected to present the application on behalf of the two. Some Masters programmes presented by Vrije Universiteit Brussel (VUB) are joint programmes with the French-speaking “Université Libre de Bruxelles” (BRUFACE project). All these Master programmes are eligible for “Admission par l’Etat” and for the EUR-ACE label.

At least, the Flemish faculties were successful in their application to the European project Erasmus; consequently, several master programmes asking for accreditation are prepared by a consortium of European universities; they were presented by the Flemish university of the consortium, although it was not always clear that all the members were equally informed of the accreditation process and that they equally share the same learning objectives.

2 THE ACCREDITOR’S VIEW

Beyond the needs of human resources and the organisation constraints, the accreditation campaign was a very rich and demanding experience for CTI and for the persons who contributed to it.

The objective of this section is not to present a comprehensive report on the accreditation results (which are available on the CTI website [6]), but to present the insights which can be extracted from such an experience and to contribute to the enhancement of international collaborations in Quality Assurance [7].

2.1 The favourable key factors

The accreditation campaign was not the result from a top-down decision of the University directions or from legal requirements, but from a collective initiative of the deans and of the programme managers. This has resulted in a remarkable implication of all faculty staffs, an outstanding quality of the self-evaluation reports and a very active participation to all the audit meetings. The operations -notwithstanding their complexity- were made easier too by the culture of Quality Assurance obviously implemented in the faculties and shared by the academic and administrative staff, which does not imply a total agreement on the objectives of the process (see below).

The three universities involved have clearly their own personality owing to their history and cultural backgrounds; however, the engineering studies are regulated at the national level by stringent regulations – sometimes considered by the experts as too stringent-; this homogeneity saved experts’ time and efforts, as they could rapidly focus on each faculty specificities.

2.2 Specific issues

CTI national language is French, Dutch is the national language of the Flanders; it was decided that the working language would be English and that the main documents, including the self-evaluation report (SER), must be written in English. Most masters

are taught in English and the Flemish students and teachers speak fluent English; however, a very sizeable amount of student works and of teaching documents were written in Dutch; the participation of Dutch speaking experts was very helpful although the scientific contents of the documents allowed the experts to grab their topic and level. Besides the need to translate from Dutch to English some key documents and to translate to French the experts' report for the CTI plenary session, the language issues have not raised important difficulties.
The three universities are research-driven and roughly built on the so-called "von Humboldt" model with a strong emphasis on the scientific excellence and on the academic freedom of professors in their research and lectures [8]; this feature clearly favours the individual initiatives and the bottom-up approach to the collective decisions; it may however contradict with the Quality Assurance culture in general which assigns collective objectives and collective assessment methods.
At several occasions, such ongoing misalignments showed up in the interviews or in the documents when individuals or teams seemed reluctant to apply the policy globally approved at the faculty or at the university levels.

In Flanders, the employment of the civil engineers is very good, with a high demand for graduates. The employers report their difficulties to hire skilled employees in this domain. Clearly the less than 1 000 civil engineers graduating per year in Flanders are far from fulfilling the national (and international) job market needs, taking also into account that many engage in Doctorate studies. This excellent employment situation does not induce the engineering faculties to develop the employability of their graduates; the experts regretted the lack of statistics on the engineers' job market, the average time for job search for each programme, the professional trajectories of the graduates, etc., that one expects from pre-professional curricula.

2.3 The case of the "international" curricula

A difficulty arose for the "international" curricula and especially the Erasmus Mundus programmes (or their successors when the Erasmus contract is ended). They are high level and highly selective programmes, the scientific quality of which is not arguable. However, engineering programmes -particularly according to the CTI and ENAEE's criteria- are pre-professional degrees, the accreditation of which must guarantee that every graduate acquired the skills and competences expected from an engineer and specified in the outcome profile published by the faculty.
In the pool of universities which support the transnational degree, it was sometimes difficult to assess that all partners are aware of and that all implement at the same level the pedagogical objectives and methods, which are subject to assessment in the visited university (here Flemish). There were sometimes evidences of the contrary: the curriculum which is designed in Flanders as an engineer degree with all its all-about, is presented as a pure research degree in a partner university. Furthermore, owing to the Erasmus rules, students may obtain the degree from a university where they spent a small part (if not no part at all) of their studies; if this is not arguable from a purely academic point of view, it raises very important issues for the entry into the profession and for the relation with the employers.

3 THE VIEW OF THE LEUVEN FACULTY

KU Leuven is a comprehensive university, with over 55.000 students. It is a typical research-oriented university, member of LERU (League of European Research Universities). It is well ranked internationally, especially for innovation.
The Faculty of Engineering Science (FES) counts over 3.500 students. It offers 2 Bachelor's programmes (a general Bachelor of Engineering, and a Bachelor of

Engineering: Architecture), 12 Master programmes and 6 advanced Master programmes. In the departments over the FES, more than 1.000 PhD students are doing research. The largest part of research funding is acquired through competitive calls.

3.1 Approach taken

Quality assurance is the task of all people involved in education. The FES has a small support team that gives assistance for quality assurance where needed in the Faculty. This team was strengthened by one extra person for 2.5 years.

First, for each of the Bachelor's and Master's programmes, a detailed set of learning outcomes was identified and formulated in the ACQA framework (Academic Competences and Quality Assurance [9]). This was followed by a comprehensive curriculum mapping, linking courses to outcomes. This effort has led to valuable insights into the structure, strengths and weaknesses of each programme.

Second, all course descriptions (so called ECTS files in Leuven) were revisited. Special attention was given to the correct formulation of the goals of each course, and of a detailed description of evaluation criteria and organization.

Third, several questionnaires were launched. One aiming students finishing their degree. The questions pertained the whole of the curriculum, and covered all classical areas of quality assurance. The answers complemented the regular questionnaires organized by the university for each course at least every 3 years. A different questionnaire was sent to the alumni of the faculty, focusing on the more recent alumni of the last 5 years.

Fourth, several industrial advisory boards (IAB) were installed as not every programme had the tradition of meeting regularly with representatives of industry.

The curriculum mappings, the output of the questionnaires, and the comments of the IABs, were used to discuss in length, both at the level of the faculty as at the level of each individual programme, an extensive SWOT analysis. These SWOT analyses resulted in actions plans, again both at the level of the faculty as at the level of each programme.

The writing of the faculty SER was started about 18 months before the deadline. The good table of contents of CTI allowed the FES to describe its vision, strategy and processes in a structured and comprehensive manner. The SER was complemented with several annexes, giving more details about topics such as programme outcomes and the extensive problem solving and design pathway. The SER of the faculty was extensively discussed at all levels of the faculty (including the students) and with the Senate (specifically the vision and strategy aspects).

3.2 Research-oriented nature of the KU Leuven

The fact that the KU Leuven is a typical research-oriented university has its influence on several aspects. First, the education is given by top researchers in their field. The students are involved in the research (through several projects and their master thesis), and special attention is given to research skills. As professors are keen on hiring top PhD students, they pay a lot of attention to education. Furthermore, often the top researchers are also the best lecturers! Researchers have an innovation mindset, and are ready to innovate in their education – as long as the university and faculty do not ask to change everything every 6 months!

However, education is not always the main focus of top researchers. They often are more concerned with their own contributions to the programme (contributions that are focused on their research), than with the programme as a whole. This led CTI to qualify the programs as content-driven, and less as output-driven.

3.3 Outcome of CTI for KU Leuven

The exercise of self-evaluation, and all the activities described above to prepare the visitation by CTI boosted the quality assurance mind set, and gave rise to a global enthusiasm towards quality of education, and this both at the faculty level as at the level of each individual programme. The texts that were produced were written in a way that they could be re-used on websites, in brochures, in university-wide actions.
The visitation itself, and the report by CTI, although interesting, brought less new insights. At the level of the faculty there was a short but sharp analysis. The strong points included the first rated scientific environment, the research-driven focus and the high level of acquired scientific competences by the students, initiatives such as ACQA [9] and the programme solving pathway, and the quality of the provided documents. Some of the weak points are a result of the research-driven focus, such as lacking a comprehensive view and proper management of non-scientific learning outcomes, and the reluctance to some extent of involving all external stakeholders in the formal supervision of programme content and outcomes.
The level of feedback for each individual programme varied strongly. The feedback was never extensive.
It is clear that the main benefit of the whole process lies in the strong groundwork that was done. The preparation and the writing of the SER gave the faculty and its programmes a mirror. The process of CTI, including the table of contents of the SER, guided this reflection. For the faculty, this was a strong momentum.

3.4 The future

The legal landscape in Flanders has changed. In the meantime, visitations and accreditations of individual programmes have been put on hold by the Flemish government. A system of institutional reviews has been set up, where each institution for higher education in Flanders is visited as a whole, including its quality assurance system.
The new quality assurance system of the KU Leuven, called COBRA, is based on regular reflection meetings of primary actors (students, lecturers, other education staff). The problems that come up in these reflection meetings are either solved locally or are pushed to a higher level (first faculty level, than university level). Each 4 years external peers, the working environment and alumni are involved in the reflection.
The FES, as a faculty of the KU Leuven, will implement the COBRA system. The question is if they will continue the accreditation process with CTI. Having to conform to two separate systems of quality assurance is of course extra work. The EUR-ACE label that can be acquired through CTI is certainly an incentive for continuing with CTI.

4 CONCLUDING REMARKS

This paper addresses most questions raised in the report on “cross-border quality assurance” [7] published by EQAR and the E4 group. It draws up the benefits and problems for both the agency and the institution points of view.
The main difficulty concerned the “international” curricula (i.e. supported by a pool of international universities); they enter in the category of “joint degrees” which are strongly promoted within the EHEA. Specific guiding principles [7] were not anticipated and then not met during the process, e.g. a) “the external quality assurance procedure should be based on a SER jointly submitted by the cooperating institutions, or b) the site visit should therefore include discussions with representatives of all cooperating institutions. For these programmes, notwithstanding their scientific excellence, the assessment could not be conclusive.

There is a strong ongoing debate on the pros and cons of programme accreditation vs. institutional accreditation; the programme accreditation performed by CTI in Flanders comprises an important institutional component, since all the degrees of each faculty were concerned in a single round.
Such a procedure is more efficient and allows to involve all the faculty staff for a self-assessment. However, as one can only expect to have one or two experts per domain, each professor has less chance to discuss in detail his/her teachings with a peer colleague; some may feel some frustration when they are eager to demonstrate the high scientific level of their teachings.
But the assessment could focus more on the general objectives and outcomes, and on the quality of pedagogical processes; more time was dedicated to the interviews of the governing bodies of the faculties and to the stakeholders (as the employers and alumni). A whole faculty assessment is then more coherent with the quality assurance fundaments which aim to assess the quality of the internal processes and not to certify the detailed contents of the curricula [10].

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Construction and exploration of the engineering education accreditation system with Chinese characteristics

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ABSTRACT

In recent years, China’s engineering education has trained a large number of qualified talents for the development of China's economy and society, and has made due contributions to the global economy. Based on a brief introduction of the current development situation of China's engineering education, this research, firstly, systematically reviews the development process of China's engineering education accreditation system (CEEAS) from its start in 1992 to 2016; secondly, focuses on analysing institutional framework, accreditation standard and accreditation procedure of CEEAS; thirdly, emphasizes comparing the differences of engineering education accreditation system between China and the main contracting countries of the Washington Accord in order to analyse the existing problems of CEEAS; finally, reflects the problems existing in the construction of CEEAS.

Conference Key Areas: Quality Assurance and Accreditation; Sustainability and Engineering Education; Engineering Education Research

Keywords: Engineering education; Accreditation system; System construction; International mutual recognition; Washington Accord

INTRODUCTION

Since the founding of the People’s Republic of China in 1949, engineering education has trained more than 20,000,000 engineering talents for China's industrialization and social economic development. As of 2015, 1,650 colleges and universities have

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set up engineering specialties, and the number of specialties reaches to 16,284. Engineering undergraduates have up to 5,247,000, accounting for about 33.3% of the total number of students at school. The rapid development of industrialization determines that China has a strong demand for engineering talents, and the number of graduates in colleges and universities in China is rapidly increasing. In terms of scale, China has a huge number of students in engineering education and has ranked the first in the world.

With the rapid expansion of scale and the higher standard of training quality of engineering talents, the existing engineering education quality assurance system is facing a severe test. On the other hand, with the development of economic globalization, the internationalization trend of engineering education is becoming clearer, and the transnational flow of engineering talents is also becoming more frequent. In this process, the educational and industrial sectors in China have recognized that it is necessary to establish China's engineering education accreditation system (CEEAS) with international substantial equivalence.

1 REVIEWING DEVELOPMENT HISTORY OF CEEAS

CEEAS launched a pilot project of the architectural accreditation in 1992, which has 15 years' development history. The former Ministry of Construction started a pilot scheme of 6 majors' accreditation in Tsinghua University, Tongji University, Tianjin University and Southeast University from 1992, and began to explore the practice of CEEAS(Fang 2013)..

In 2005, the State Council approved the establishment of the China Engineers System Reform and Coordination Group (CESRCG). The Ministry of Human Resources and Social Security is the head of the unit, and Chinese Academy of Engineering, Chinese Association for Science and Technology (CAST), the Ministry of Education is the deputy head of the unit. Three deputy heads of the unit are respectively responsible for the classification and design of the engineers system, external contact of accreditation and engineers, engineering education accreditation.

In 2007, after the approval of CESRCG, the Ministry of Education set up Experts Committee of China Engineering Education Accreditation (ECCEEA). With referring to the current international and domestic practice, ECCEEA formulated a set of guidance documents for CEEAS, including accreditation standard, accreditation procedure, accreditation policy etc. The ECCEEA worked until December 31, 2011, and the newly established China Engineering Education Accreditation Association (CEEAA) took over the accreditation work in 2012. In October 2015, CEEAA formally established, which was a national, non-profit, membership-based organization organized by more than 30 organizations and individuals. Under the leadership of the CAST, it is the only legal institution authorized by the Ministry of Education to carry out engineering education accreditation in China.

At the end of January 2013, China was accepted as a probationary member of the Washington Accord. In June 2016, China became the eighteenth formal member of the Washington Accord, which indicated that the quality standard of China's engineering education has basically achieved the international substantive equivalence and has been gradually recognized by international community.

2 THE CONSTRUCTION OF CEEAS

2.1 Institutional framework

CEEAA is responsible for the organization, implementation and management of China's engineering education accreditation. The association currently has 33 group members and some individual members. The group members cover the major trade and professional associations in engineering fields, and the individual members include the leaders and experts from government, universities, industry organizations and enterprises.

There is board of supervisors, council and secretariat under CEEAA. The council is the executive body of the association. The board of supervisors is responsible for overseeing the work of the council and the secretariat. The council includes Specialty Accreditation Committee (SAC), the Accreditation Conclusion and Review Committee (ACRC) and the Academic Committee (AC) (Figure 1). The SAC is the branch of CEEAA, which is established in accordance with the relevant professional fields.As of 2016, CEEAA has a total of 14 SAC, including mechanical, computer, chemical and pharmaceutical etc. The AC is responsible for formulating and revising accreditation standard and other accreditation documents, providing academic support for engineering education accreditation, and accrediting qualification for experts. The ACRC is responsible for considering accreditation report and accreditation conclusion made by the SAC and submitting the results to the council for approval.

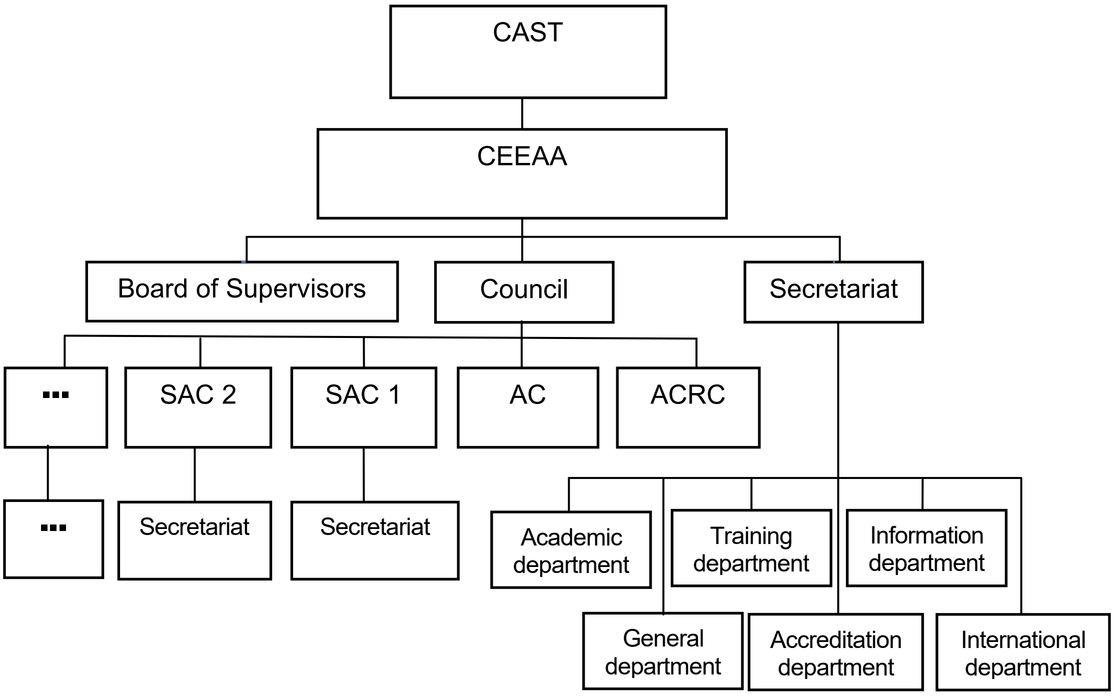

Fig. 1. The framework of CEEAA

2.2 Accreditation standard

The accreditation standard is composed of two parts: general standard and supplementary standard. The general standard is consisted of seven elements: student, training objective, graduation requirements, continuous improvement, curriculum system, teachers and support condition. The supplementary standard specifies the special professional requirements and supplements of one or more areas (Table 1).It needs to be emphasized that: (1) The certification standard only contains 7 indicators, and 21 investigation points are just as the reference; (2) The supplementary standard is not a single index, but the content supplement that is not included in the general standard; (3) The training objective covers internationally accepted 11 capability requirements of graduates and accords with result-oriented characteristic of the Washington Accord (ABET 2007).

Table 1. Accreditation standard and connotation interpretation

Type	Index	Investigation point
General standard	Training objective	Target evaluation and revision
		Graduate ability
	Curriculum system	Curriculum
		Practice link
		Thesis
	Teachers	Number and structure of teachers
		Teacher development
	Support condition	Teaching funds
		teaching facilities
		Teaching management and service
		Books
		Industry-university-research cooperation
	Students	Recruit students
		Student training and guidance
		Student employment
	Continuous improvement	Quality control of teaching process
		Graduates feedback
	Graduation requirements	Theoretical knowledge
		practical ability
		Professional ethics
		Lifelong learning
Supplementary standard	Special requirements for each specialty	

2.3 Accreditation procedure

The process of accreditation is basically the same as that of most members of the Washington Accord, including 6 links: application and acceptance, school self-assessment, review of self-assessment report, on-the-spot investigation, accreditation conclusion, accreditation status’s maintenance and improvement. Therefore, this study will no longer carry out specific discourse.

3 COMPARISON THE DIFFERENCES OF ACCREDITATION SYSTEMS

The core content of the Washington Accord is that the accreditation standard and procedure of each member are basically the same (Patil & Codner 2007). In order to achieve the objectives of the agreement, the institutional framework, accreditation standard and accreditation procedure developed by each member have shown great similarities. However, viewing the current practice, there are many differences between China and the main contracting countries of the Washington Accord. This study mainly analyses the differences from the cognition level, organization level, system level and practice level.

3.1 Cognition level

In the construction of engineering education accreditation system, the government, universities, industry and professional associations in the most contracting countries of the Washington Accord have a high degree of acceptance. Taking the design of accreditation standard as an example, Accreditation Board for Engineering and Technology of the United States (ABET) adopted the Engineering Criterion 2000 (EC 2000) in 1997, which realized the innovation of quality evaluation standard. In the design process of EC2000, the government, universities, industry and professional associations participate actively and play different functions. In the premise of full participation by all parties, accreditation system has a high acceptance and authority.

The design concept of CEEAS draws lessons from EC2000 and has maintained a high consistency with the Washington Accord (Han & Zhang 2015). However, the design of CEEAS is dominated by the government and the universities, and the industrial sectors are not effectively involved. Secondly, the phenomenon that emphasizes on the theoretical education and neglects the practical education in the process of students training in universities still exists, which leads that students' engineering practice ability is still not strong enough. The training of engineering talents in universities cannot fully meet the requirements of the industrial sectors (Zhu 2015), indirectly causing that the enthusiasm of the industry to participate in accreditation is not high. Overall, the acceptance of industrial sectors to CEEAS needs to be improved.

3.2 Organization level

Accreditation institutions in various countries have different development history, and the form is also unique. However, the development of accreditation institutions is closely linked with the social and economic development at that time. At the end of 1980s, with the needs to guarantee the quality of engineering education and the acceleration of economic globalization, accreditation has become an important function of engineering education organizations in various countries, and the emergence of international mutual recognition agreement on engineering education has also become inevitable. The Washington Accord was born under such a background.

Accreditation organizations of the main contracting countries of the Washington Accord are generally unofficial and independent institutions. For example, the ABET, established in 1932, is a non-governmental organization. As an organization of membership, ABET has a sound management mechanism and organizational structure with a high degree of independence and professionalism, and the authority of it is admitted by both the official and unofficial (Bi 2005). In contrast, China's accreditation organization has a big difference with ABET. The government plays a leading role in current accreditation organization, and it is involved in the work of the accreditation organization with the direct administrative means. Although the establishment of CEEAA promotes the independence and professionalism of accreditation organization, the official dominant colour still exists.

3.3 System level

The ultimate goal of the Washington Accord is to ensure that the graduates has professional qualifications in the field of their work after a certain period of time and continues to maintain and improve their vocational ability. Therefore, the effective convergence of accreditation system and engineer accreditation registration system is very important. At present, the accreditation institutions of the Washington Accord (such as Australia, Canada, Hong Kong, Ireland, New Zealand, Singapore, South Africa, Britain, Malaysia, Sri Lanka etc.) are comprehensive accreditation agencies, which are not only responsible for the accreditation of engineering education degree, but also the professional qualifications of engineers.

At present, excepting architecture or related majors, CEEAS is in a relatively isolated position, and failed to achieve effective convergence with engineer registration system. According to a survey, the enthusiasm of schools and students for accreditation begins to decrease, and many students think that their employment does not matter much with accreditation system. In addition, the industry is not very concerned about whether the school's specialty has passed the accreditation or not in the recruitment. This is largely due to lacking of effective convergence between accreditation system and engineer registration system.

3.4 Practice level

Compared with the main contracting countries of the Washington Accord, China has a large number of specialties that need to be certified and the scale of accreditation is growing too fast. Since 2006, the scale of China's accreditation has increased year by year, from 8 specialties in 2006 to 375 specialties in 2016, with an average annual growth rate of 46.9% (Figure 2). As of the end of 2016, China has certified 996 specialties, accounting for 6.1% of the total. Therefore, the future workload of accreditation is very large, which needs a huge and experienced team of experts.

Most members of the Washington Accord have a wealth of practical experience, encompassing a large number of experts with reasonable structure and high quality. Viewing the current practice, there are many problems in the quantity, structure and quality of China's accreditation team. At present, China's accreditation team only has about 600 people, which causing it is difficult to guarantee the accreditation quality in such a large workload. At the same time, the experts are mainly from the university's teachers and administrative staffs. They generally become a probationary expert through a simple training and become a formal expert through participation in an accreditation work. Therefore, a considerable number of experts lack accreditation experience and cannot have a good grasp of the concept, principle and standard of accreditation.

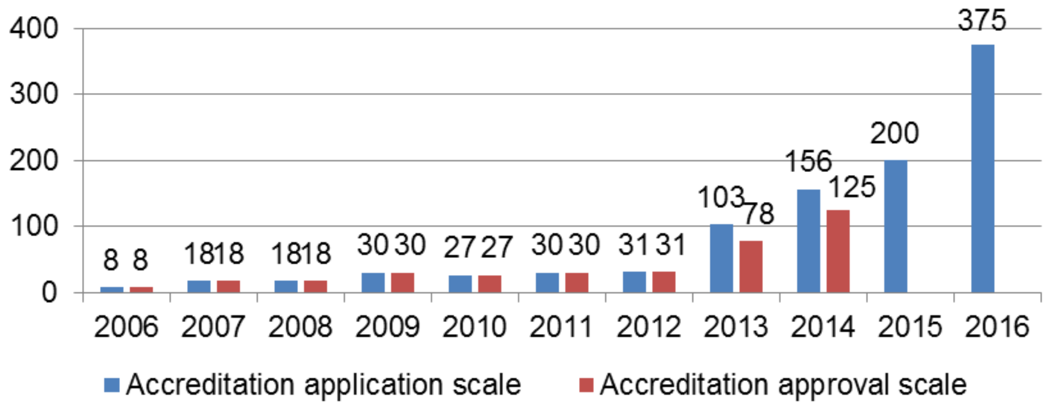

Fig. 2. Accreditation application scale and approval scale

4 REFLECTING THE PROBLEMS EXISTING IN CEEAS

4.1 Enhancing the acceptance of the industry

In the main contracting countries of the Washington Accord, the industry is actively involved in all aspects of accreditation and has a high degree of acceptance to its accreditation system. Therefore, China should strive to strengthen the contact with the industry and promote the industry to participate in the whole process of the CEEAS in order to effectively enhance the acceptance of the industry. Viewing the construction of accreditation bodies, China must formulate detailed working rules as soon as possible in order to clearly define the functions of the industry and gradually form a sound internal operational mechanism of the association. Viewing the improvement of accreditation standard and practice, China should let engineers that have rich practical experience in industry fully participate in the accreditation work, and listen to their opinions and views, so as to enhance the industry acceptance to accreditation conclusion and even the whole accreditation system.

4.2 Building the completely independent and fair accreditation body

The prerequisite for the effective implementation of the accreditation system is the establishment of a fair, professional and standardized accreditation body. The organization responsible for accreditation is generally unofficial institution, such as the America’s ABET, the United Kingdom’s ECUK (Engineering Council UK), and the Japan’s JABEE (Japan Accreditation Board for Engineering Education) etc. At present, CEEAS is still at the preliminary stage of practice and engineering education in China is very large and complex. If China completely imitates the western countries to use unofficial institutions for accreditation, it may not be able to ensure the effective management of accreditation and organizational work. In consideration of China's specific national conditions, China will gradually transform into a fully independent, fair accreditation body in a more mature stage. At the same time, in the process of constructing accreditation body, it is necessary to strengthen the mutual cooperation and make clear the division of functions among the government, universities and the industry, so as to improve the efficiency and quality of the accreditation work.

4.3 Promoting effective convergence between accreditation system and engineer registration system

Accreditation system and engineer registration system are interconnected and interactive. The main contracting countries of the Washington Accord have different practices in the implementation of the two jobs, but most of them have had a mature experience. Therefore, it is necessary for us to make further analysis and research on their experience, so as to provide reference for the reform of China's accreditation system and engineer registration system. From the view of future, Chinese effective way may be divided into two points. Firstly, China should set up the classification standard of engineering education and the qualification standard for engineers recognized by both the education and industry, in order to lay a good foundation for effective convergence between accreditation system and engineer registration system. Secondly, China should integrate the accreditation bodies and the engineer registration agencies into a system in order to simplify the organization, reduce operating costs, and effectively improve their work efficiency.

4.4 Building a large number of experts with reasonable structure and high quality

The effective implementation of accreditation work requires a high level of experts as a backup. In terms of the quantity, there are only about 600 people engaging in accreditation work in China. With respect to more than 16,000 specialties needed to be certified, the number of experts seems very lack. Therefore, it is necessary to appropriately increase the number of experts to meet the growing demand for accreditation. In terms of the structure, China's accreditation team is mainly composed by experts from universities. For example, when CEEAA organizes a field investigation, the experts group generally has 5 people, but only 1 people are from the industry. Therefore, China should improve the proportion of experts from the industry in order to truly evaluate the quality of engineering education from the perspective of users. In terms of the quality, China should strengthen the training of experts in the accreditation concept, standard and procedure etc. At the same time, it is necessary to strengthen the professional ethics training of experts, so as to improve the impartiality of accreditation.

5 CONCLUSION

After 15 years of development, CEEAS has established a sound accreditation body, accreditation standard and accreditation procedure under the guidance of the Washington Agreement. However compared with the major signatory countries of the Washington Agreement, CEEAS still have some problems and challenges at the cognition level, organization level, system level and practice level. Therefore in the future development of CEEAS, it is necessary to strengthen ties with the industrial sectors and strive to enhance the acceptance of the industry; reduce the direct intervention of government and gradually build a completely independent, fair accreditation body; promote effective convergence between accreditation system and engineer registration system; build a large number of experts with reasonable structure and high quality etc. At the same time, for the actual development of China's engineering education, the number of universities is large, the level of running school is not uniform, and the demand for engineering talents from industries is also different. Therefore, under the premise of maintaining the certification standards and quality standards required by the Washington Agreement, it is necessary for us to think deeply and continue to practice how to maintain the local characteristics of CEEAS.

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Revision of the Qualification Framework at the Technical University of Denmark

Part 2: Applications

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ABSTRACT

Using a revised Qualification Framework (QF) with four main categories: *-to know*, *- to be*, *-to interact*, and *–to do*, this paper demonstrates how to use the elements of the QF to construct Programme-Qualification Matrices. A general Programme-Qualification Matrix defines the qualifications and their respective conceptual understanding common to all engineering programmes. This is complemented by programme-specific qualification matrices with added emphasis on content and context. Redesigned educational outcomes for three bachelor programmes are presented to demonstrate the versatility of the concept.

Conference Key Areas: Curriculum development, Quality Assurance and Accreditation, Engineering Skills

Keywords: Programme-qualification matrix, educational outcomes, constructive alignment

INTRODUCTION

In a companion paper [1], revisions to the Danish National Qualification Framework (NQF) were proposed in order to facilitate more detailed design and evaluation of engineering programmes at the Technical University of Denmark (DTU). The organization of the proposed qualification framework is repeated here for the reader's convenience.

Table 1. Components of a revised qualification framework [1]

1st level	2nd level descriptors	Description
1: - To know	Knowledge of theories	Acquire and apply terminology and facts, theories, laws of nature, methods, and procedures.
	Knowledge of praxis	Apply knowledge about praxis-induced boundary conditions and their influence on the applicability of theories and methods.
2: - To be	Mind-set	Develop a personal and professional mind-set.
	Self-instruction	Identify need for new knowledge, gather resources, execute, and evaluate learning outcomes.
3: - To interact	Teamwork	Conduct, coordinate, lead, monitor, and develop teamwork.
	Communication	Master language and tools, structure content, choose between narrative styles, edit for logic and clarity, and define communication objectives and receiver competencies.
4: - To do	Operative skills	Advance degree of training, from novice to expert, in executing manual and cognitive tasks.
	Problem solving	Interpret problem information, identify objective, diagnose problem, choose strategy, execute and evaluate solution, interpret impact of solution.

In this paper, the revised framework is used to define educational outcomes for three programmes in B.Sc. in Engineering.

1 PROGRAMME QUALIFACTION MATRICES

1.1 Common qualification elements

The proposed Qualification Framework for programmes at the Bachelor of Science (B. Sc.) level can be divided into elements common to all programmes and elements that are specific to the individual programmes. In this section, the common elements are presented in a *Programme-Qualification Matrix* with Programme-Outcomes listed along the vertical axis and Course levels listed along the horizontal axis.

Table 2 describes the elements of the qualification framework, which are common to all engineering programmes. Levels of *process and element complexity* are indicated by italicised keywords defined in a companion paper [1]. In the four columns to the right, course numbers are to be entered, ordered from left to right by a ranking of object/subject complexity [1]. Multiple course numbers can be entered into each cell. Here fictive course numbers have been used. *Generic foundation* courses (Gen.) are 100-level (courses with no prerequisites), *Discipline core* courses (Cor.) are 200-level (first-level engineering courses) and *Discipline specialization* courses (Spe.) are 300-level (second-level engineering courses). *Capstone* courses (Cap.) relate here to project courses, hands-on courses, internships, and thesis work. Learning activities in the *Capstone* category are annotated in the rightmost column using the following abbreviations: First semester project (1SP), fourth semester project (4SP), hands-on course (HO), B. Sc. Project (BSc).

Table 2. Programme-Qualification Matrix. Common elements. Fictive course numbers

		Object complexity→			
	-To know	Gen.	Cor.	Spe.	Cap.
XXX.K1	**Knowledge of natural science:** Can *classify*, *explain,* and *interpret* facts, terminology, principles, generalisations, theories, models, methods, and procedures within mathematics, physics, chemistry, statistics, and biology, and can *apply* this knowledge to *analyse, evaluate,* and *solve* technical problems.	101 102 103 104 105	201 202 203		1SP 4SP
XXX.K2	**Knowledge of information technology:** Can *use* a programming language and independently *design*, *implement*, test, and document software for technical problem solving. Can, in addition, *explain theories and algorithms underlying* general and specialised software for data acquisition, visualisation, analysis, design, and simulation.	106			1SP 4SP
XXX.K3	**Knowledge of science:** Can *understand* and *assess* the relationship between scientific knowledge and practical experience in creating new technologies, types of knowledge and competences, building the foundation of engineering and the work involved in technological solutions, and the qualities of technologies, and its historic dependency and importance in the development of society.			307	4SP BSc
	-To be				
XXX.B1	**Personal and professional mind-set:** Embodies *self-efficacy*, positive *social attitude,* and *self-governance*. Is *process-oriented* with a hypothesis- and need-driven curiosity, and evidence-based creativity. Thinks logically and critically. Actualize *product-oriented* entrepreneurship founded on safety, reliability, sustainability, usability, serviceability, aesthetics, and ethics.	111 121	211 221 241	321	1SP 4SP BSc
XXX.B2	**Self-instruction:** Is *self-reflective*, *need-aware*, and *metacognitive.* Can orchestrate resources, execute and evaluate learning. Is familiar with and can sort critically between sources of information within the discipline.	121	221 251	321	4SP BSc
	-To interact				
XXX.I1	**Communication:** Master oral and written *language and communication tools* expertly, *structure content* to norms, perform *editorial editing*, can use a variety of *narrative styles* in accord with the standards of the context. Can, through *context analysis*, define the objective of the communication and take into account the competencies of the receiver.	111 121	211 241	321	1SP 4SP BSc
XXX.I2	**Team work:** Can *execute tasks* in teams while observing codes of behaviour, effort, ethics and accountability. Can take responsibility for *coordination*, *leadership*, process *monitoring*, and team and individual *development.*	121	221 251	321	1SP 4SP BSc

	…continued	Gen.	Cor.	Spe.	Cap.
	-To do				
XXX.D1	**Skills – general:** Can execute complex cognitive and manual procedures effectively and with *precision* and use advanced tools correctly and independently. Can *see the goal of the task*, *adapt procedures* and *visualize solutions*.	111 121	211 221 231 241 251	311 321 341	1SP 4SP BSc
XXX.D2	**Problem solving - general:** Can solve complex closed and open problems in *procedural* steps with complex, incomplete and imprecise problem descriptions. Can *reduce* a complex problem to an idealized problem and evaluate the consequences thereof. Can *diagnose* a problem*, identify* the objective, *sort* between valid and invalid solution methods, and argue a *strategy* for choosing between valid methods. Can *judge* the validity, strengths, and weaknesses of solutions. Can *interpret* the impact of the solution to the problem sphere.	111 121	211 221 231 241 251	311 321 341	1SP 4SP BSc

1.2 Programme specific elements – Biomedical Engineering

The common elements of the Programme-Qualification Matrix must be complemented by a set of programme-specific qualification elements. In *Table 3*, programme-specific qualifications are listed for the B. Sc. programme in Biomedical Engineering. This programme started in 2003, enrolls 60 students annually, and offers courses in biosignals, biomedical imaging, biosystems, bioinstrumentation, biomechanics, biomaterials, biotransport, and cellular signalling. As for the common elements in *Table 2*, the depth of learning is indicated by italicized descriptors. In the common qualifications (*Table 2*), focus is on defining the level of conceptual understanding. In the programme-specific qualifications (*Table 3*), the descriptions complement with content and context. Course numbers are real, but with department prefix removed. Course level is not indicated by the first digit, only by its placement in the four rightmost columns.

Table 3. Programme-Qualification Matrix. Biomedical Engineering

		Object complexity→			
	-To know	Gen.	Cor.	Spe.	Cap.
BME.K1	**Knowledge of health science:** Can *classify* cellular structures, anatomy and physiology of organ systems, and *explain* form and function with correct use of terminology. Can *analyse* and *interpret* histochemical preparations, *apply* biophysical principles, and *analyse* and *interpret* results of experiments. Can *define* diseases and *explain* pathogenesis and aetiology. Can *account* for symptoms and methods for diagnosis and treatment.	K02	K03 K11		1SP 4SP BSc
BME.K2	**Knowledge of health-care praxis:** Can *describe* and *explain* the rationale for technology applied in diagnosis and treatment. Can *explain* and *analyse* how technical factors influence the quality of clinical examinations. Can *describe* methods for evaluating accuracy and reproducibility of clinical procedures.			K04 K06	HO BSc

	…continued	Gen.	Cor.	Spe.	Cap.
BME.K3	**Knowledge of biomedical engineering:** Can *classify*, *explain,* and *interpret* facts, terminology, principles, theories, models, methods, and procedures within electrical circuits, biomedical instrumentation, signal processing, biomedical imaging, material science, biomechanics, biofluids, biotransport, and biosystems modelling. Can *apply* this knowledge to *analyse* and *solve* biomedical engineering problems.	501 502	K10 512 520 540 605 650	K05 511 522	1SP 4SP BSc
BME.K4	**Knowledge of biomedical engineering praxis:** Can *list* the major biomedical engineering companies, *describe* their product lines and *list* the main qualifications required in these companies. Can for specific disciplines *account* for praxis and regulatory induced limitations to the applications of theories, methods, and materials.	502	512 520 540 650		BSc
	-To do				
BME.D1	**Clinical skills:** Can *apply* general codes of hygiene and conduct in health-care environments. Can *assist* clinical staff in measurements, data analysis, and trouble shooting. Can *instruct* clinical staff about correct use of biomedical equipment, and their strengths and limitations.			K04 K06	4SP BSc
BME.D2	**Technical skills:** Can *setup* and *operate* systems for test and measurement and acquire data in a reproducible manner. Can *design* and *implement* software for analysis and visualisation of data. Can *perform* systems check and calibration, and make corrections and simple repair to medical equipment.	501 502	K10 540	598	HO BSc
BME.D3	**Problem solving – Investigative:** Can assist in hypothesis-driven research within cell biology and organ physiology, within signal and image processing with implementation of problem specific software, within biomechanics, biofluid mechanics and biotransport with model development, mathematical analysis, computer simulations, experiments, and data analysis.	501 502	K10 520 605	K05 522 561	4SP HO BSc
BME.D4	**Problem solving – Creative:** Can assist in need-driven development of programmable products by design and construction of analog electronics and with software development for systems control and data analysis, and of mechanical products with computer-aided design, finite element analysis, and selection of materials.	501 502	512 540 650	511 561 598	HO BSc

1.3 Programme specific elements – Quantitative Biology and Disease Modelling

The B. Sc. in Quantitative Biology and Disease Modelling is a new education started in 2016 where computational and mathematical engineering skills are taught in parallel with biology, pathology, and pharmacology. The goal of the education is for the students to be able to develop quantitative mathematical models of biological and pathological processes. The programme-specific qualifications for the B. Sc. programme in Quantitative Biology and Disease Modelling (QBDM) are listed in *Table 4*.

Table 4. Programme-Qualification matrix, QBDM

		Object complexity→			
	-To know	Gen.	Cor.	Spe.	Cap.
QBDM.K1	**Knowledge of biology, physiology and health science:** Can *classify* cellular structures, anatomy and physiology of organ systems and *explain* form and function with correct use of terminology. Can *analyse* and *interpret* histochemical preparations, *apply* biophysical and bioinformatic principles, and *analyse* and *interpret* results of biochemical experiments.	K02 002	K03 K11 022 023	088 089	1SP 4SP BSc
QBDM.K2	**Knowledge of pathology, pharmacology and mechanisms of disease:** Can *define* diseases and *explain* pathogenesis and aetiology. Can *account* for symptoms and *describe* diagnosis and treatment. Can *explain* fundamental pharmacology and bioavailability of drugs.		K03 004	087	1SP BSc
QBDM.K3	**Knowledge of quantitative biology:** Can use mathematical modelling to *analyse* and *describe* physiological processes and disease dynamics within cells, organ systems, and populations. Can use experimental and clinical data to *calculate* and *evaluate* selected parameters of pharmacodynamics and pharmacokinetics.	K02 002 050	K03 004 633 087	088 089	1SP 4SP HO BSc
	-To do				
QBDM.D1	**Experimental skills:** Can *design* and *perform* quantitative biochemical, molecular biological and pharmaceutical experiments and *collect* data with understanding of technical error. Can *design* and *implement* computational software for analysis and visualisation of quantitative data.	002	023 087	088 089	1SP HO BSc
QBDM.D2	**Mathematical modelling skills:** Can *perform* mathematical modelling of physiological and pathophysiological systems and *apply* this to *analyse* and *predict* the quantitative effect on changes in biological input. Can *perform* simple PK/PD modelling of drug bioavailability.	002 632	004 050 087 601	088 089	1SP BSc
QBDM.D3	**Problem solving – Investigative:** Can assist in hypothesis-driven research within cell biology, organ physiology, and disease mechanisms with identification of contributing biological factors model development, mathematical analysis, computer simulations, experiments, and data analysis.	K02 002 050 402	004 023 K11 087	088 089 015	4SP BSc
QBDM.D4	**Problem solving – Creative:** Can assist in need-driven development of mathematical models for identification of knowledge gaps, new molecular disease targets, and bioprocessing of pharmaceutics.	002 050	004 K11	088 089 015	4SP BSc

1.4 Programme specific elements – General Engineering

The General Engineering programme is a new international education started in 2016 with approximately half of the students and lecturers having an international background. The education focuses on general engineering competencies and combining these in a cross-disciplinary manner. Further, the programme has great emphasis on Design-Build already from first semester. The students are introduced to the programme's four focus areas—Living Systems, Cyber Systems, Cyber Materials, and Future Energy—and in the following semesters, they will specialize in one of these areas. The four cross-disciplinary specializations makes the programme specific elements very diverse. However, the qualification elements can still be organized according to the principles suggested in Table 1.

Table 5. Programme-Qualification matrix, General Engineering

		Object complexity→			
	-To know	Gen.	Cor.	Spe.	Cap.
GE.K1	**Knowledge of living systems:** Can *describe* basic principles in biochemistry, molecular and cell biology, and ecology. Can *account* for cell and microbiology and organisms and *explain* fermentation technology, microbial communities or species interactions.	008 030 701	000 022 023 026 105 201 400	025 034	1SP 4SP BSc
GE.K2	**Knowledge of cyber systems:** Can *examine, select,* and *apply* algorithms and data structures in a general engineering context.	016 135 240	203 157	105 270	1SP 2SP BSc
GE.K3	**Knowledge of cyber materials:** Can *explain* the fundamental concepts of materials science and manufacturing technology. Can *apply* and *explain* fundamental materials modelling and materials visualization.	018 030 240 680	203 580	502	2SP 3SP BSc
GE.K4	**Knowledge of future energy:** Can *explain* the fundamentals of renewable and sustainable energy resources (e.g. wind energy, solar, fuel/electrolyzer cells, batteries). Can *explain* the fundamentals of energy conversion and storage.	018 030 041 202	260 501 735	201 205	2SP 3SP BSc
	-To do				
GE.D1	**Experimental skills:** Can *setup* and *operate* basic laboratory techniques in either molecular biology or process chemistry or ecology. Can *setup* and *operate* complementary characterization methods for materials properties and internal structure. Can *design, perform,* and *implement* methods for analysis of large amounts and diverse types of data. Can *apply* the fundamental organization of a computer system in a cyber-physical context. Can *design, perform,* and *implement* characterization methods for energy conversion.	016 135 402 680	023 157 203 240 685	027 141 160 205 270	1SP 2SP 3SP 4SP BSc
GE.D2	**Mathematical modelling skills:** Can *implement* and *apply* machine learning algorithms to classify and retrieve patterns in data. Can *apply* techniques from discrete mathematics in computer science and engineering.	135 601	019	105 141 160	1SP 2SP 3SP 4SP BSc
GE.D3	**Problem solving – Investigative:** Can *assist* in hypothesis-driven research within computer-based tools to manage, analyze, and evaluate biological or chemical data. Can *analyze* and *validate* computer science models based on discrete mathematics, automatons, and semantics. Can *assist* in hypothesis-driven research within methods and models for engineering materials' performance. Can *examine* the properties of a component for a range of renewable and sustainable energy technologies. Can *analyze* simple engineering problems in relation to various renewable and sustainable energy resources and technologies. Can discuss fundamental challenges of implementing sustainable energy solutions into today's society and future approaches. Can compare efficiency of current and future energy technologies.	006 016 135 202 240 402 601 631 680	019 023 157 203 260 501	027 141 160 205 270 526 611	1SP 2SP 3SP 4SP BSc

	… continued	Gen.	Cor.	Spe.	Cap.
GE.D4	**Problem solving – Creative:** Can demonstrate a fundamental understanding of living systems to *solve* engineering problems. Can *assist* in need-driven development of living systems in the context of the environment and its resources and engineered systems. Can *assist* in need-driven development of appropriate programming paradigm concept to solve a specific engineering problem. Can *design* and *construct* small and medium sized programmes. Can *assist* in need-driven development within prediction of materials properties and performance. Can select materials and *engineer* them for technical applications. Can *assist* in need-driven development within materials modelling in relation to material science and engineering. Can *select* a design of a sustainable energy system to *solve* a simple engineering problem.	016 022 135 240	023 026 105 157 201 203 260 400 684	000 008 034 141 160 205 270 526	1SP 2SP 3SP 4SP BSc

2 SUMMARY

Inspired by UNESCO's Four pillars of learning [2], the elements of the National Qualification Framework used at DTU were reorganized in a companion paper [1] into four main categories of qualifications: *-to know*, *-to be*, *-to interact*, *-to do*. In the present paper, the revised framework is used to define the educational outcomes in three B. Sc. in Engineering programmes. A set of educational outcomes common to all engineering programmes at DTU is presented, focusing on common knowledge and in particular on competencies characteristic for all engineering programmes (e.g. personal and professional mind-set, self-instruction, communication and teamwork). The common Programme-Qualification Matrix is complemented by programme-specific qualification matrices, where programme content is integrated into the outcome statements. Examples are given here for B. Sc. programmes in Biomedical Engineering, in Quantitative Biology and Disease Modelling, and in General Engineering. The proposed framework aim to facilitate both university-wide uniformity as well as programme-specific focus points. The three qualification matrices presented here, introduce four new elements of educational outcomes (knowledge dimensions, mind-set development, operative skills, and problem solving complexity) none of which previously have been considered in educational programmes at DTU, and which may be implemented while revising the programmes.

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Quality assurance of Master’s theses at a large engineering faculty.

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ABSTRACT

The Faculty of Engineering Science at KU Leuven is responsible for 29 Master’s programmes (incl. 5 Advanced Master’s), educating over 5000 students. In this context, quality assurance faces many challenges, not only because of its numerous programmes, but also due to varying student characteristics and student numbers per programme. In the paper presented, the quality assurance of the Master’s thesis will be highlighted.

A Master’s thesis is an essential part of an academically oriented programme, since it integrates knowledge and skills connected to a certain discipline. It is a research project in which students show whether they have acquired the appropriate academic competences to contribute independently to scientific research.

The core of the Master’s thesis quality assurance is the “Faculty committee of Master’s theses” who formulates its policy regarding organisation and quality assurance of the thesis. Over the last years, efforts have been made, especially in terms of learning outcomes, of a learning pathway regarding reporting skills, evaluation and mentoring students. The latter resulted in an elaborated educational support programme for supervising teaching assistants (TAs).

This paper will give an overview on how the Faculty’s policy was formulated and subsequent actions that have been taken regarding quality assurance of the Master’s thesis, without compromising every Master’s programme own habits and traditions. Specific attention will be given to the educational support programme for supervising TAs. Finally, future plans will be discussed.

Conference Key Areas: Engineering Skills, Quality assurance, Curriculum development

Keywords: Master's thesis, Quality Assurance, Coaching TAs, Reporting skills

INTRODUCTION

At the Faculty of Engineering Science the Master’s thesis is an essential part of the Master programmes. Each Master’s student has to complete a Master’s thesis of 24 credits during the final master’s stage. Since one academic year typically corresponds to 60 credits, a Master’s thesis forms a major part of the programme. Since a Master’s thesis has a considerable research component, most Master’s theses are therefore conducted in the research labs of the Faculty. Besides, a fair number of Master’s thesis are performed in collaboration with industry, or a Master’s thesis can also be carried out abroad as part of an Erasmus+ exchange. A major concern of the Faculty is to assure the quality of these Master’s theses, taking into account varying student characteristics and student numbers as well as each programme own habits and traditions.

1 FACULTY COMMITTEE RESPONSIBLE FOR THE MASTER’S THESIS

The core of the Master’s thesis quality assurance is the Faculty committee responsible for the Master’s thesis (FCMT) who formulates its policy regarding organisation and quality assurance of the thesis. This committee reports to the Faculty Educational Committee (FEC) that consist of all programme directors and is headed by the vice-dean Education. The committee itself is composed out of representatives of each programme, the TA’s and the students. It is chaired by the vice-dean Education, and the secretariat is taken care of by the educational development unit of the Faculty.

The committee started out as a rather administrative and practical consultative but as quality assurance became more prominent on the Faculty’s agenda, it’s mandate became more policy-focused. Over the last years, efforts have been made, in terms of refining admission procedures, formulating learning outcomes, developing a learning pathway regarding reporting skills, evaluation and mentoring students. The latter resulted in an elaborated educational support programme for supervising teaching assistants.

1.1 Admission procedures

Each Master’s programme has its own procedure to assign Master’s thesis topics to students. However, to ensure uniformity, some elements are shared by all Master’s programmes organised by the Faculty. During the spring semester of the first Master’s stage, a list of possible topics for Master’s theses is announced to the students through an online platform. In most programmes students can propose their own topic, if they find a professor who is associated with the programme and willing to act as advisor. Students are encouraged to contact researchers and professors to make an informed choice about the thesis topic they would like to pursue. For example, in some programmes this can be done during a theses fair, where coaches and supervisors are present. The topics are assigned to the students before the end of June, taking into account the preferences of the students and a fair distribution of the theses over the Faculty staff.

1.2 Learning outcomes

At the Faculty, every course is described in an ECTS course description. This file is available on the programme website. It contains a full course description, including the goals and learning outcomes of the course, the content, teaching and evaluation methods. Concerning quality assurance, well defined learning outcomes are crucial. Therefore, the committee refined the learning outcomes of the Master's thesis, in close cooperation with all stakeholders: professors, teaching assistants, students and industrial partners. This exercise resulted in learning outcomes acceptable and recognisable for all programmes:

After completion of the Master's thesis, the student:

- has set up an original research (original in the sense that the student has generated (partly) new knowledge);
- has state-of-the-art knowledge regarding the topic of his research;
- formulates the research question clearly and correctly;
- follows the developments in the field independently and can assess their relevance for answering the research question(s);
- designs a research plan, using the most appropriate and achievable techniques (based on the information found in the scientific literature) and executes it;
- analyses and interprets the obtained results;
- has a critical attitude towards (own) research results;
- considers optimization (context and (suboptimal) prerequisites) and always keeps track of uncertainties to define boundary conditions;
- can report about his research in a coherent way, where adequate attention is given to: correctness of the displayed information (state-of-the-art), understandable and clear within the discipline, scientific language, correct Dutch or English, the layout of the text, references, tables and figures that meet the specified formal requirements, etc.;
- has an academic correct attitude in relation to references;
- creates a decision-making process where the obtained results are framed in relation to the state-of-the-art (also demonstrating what the student has imparted to the state-of-the-art);
- can report orally about his research, in which due consideration is given to: situating the research within the discipline, presenting in an attractive way, the structure and coherence of the presentation, the scientific language, respecting the time constraints;
- can answer in scientifically correct language to questions from both fellow students and researchers from the discipline;
- has demonstrated a critical self-reflective attitude, an active commitment, a large autonomy and to be able to work in a team (if applicable).

1.3 Supervision and mentoring

During their Master's thesis, students are provided with qualitative guidance. All Master's students have a Master's thesis advisor, usually a professor associated with their Master's programme. Besides, students are guided by a teaching assistant, who is more closely connected to the Master's thesis and acts as a mentor for the student.

There is regular contact between the student and his mentor, usually (but not always) on a weekly or biweekly basis. The mentor tracks the progress of the student and acts as a first access point for advice and other resources. However, all initiatives on reports and progress meetings must come from the student. Besides regular meetings with the mentor, students meet their advisor at least once or twice per semester. Thus, the mentor has a close understanding of the Master's thesis progress and informs the advisor regularly.
In some cases the coaching can also be performed by the advisor himself. When the Master's thesis is done in close collaboration with a company or other organisation, the student will be coached both by an employee of the company, as well as by a faculty member of Engineering Science. During the academic year, the students are asked to formally report on the progress of the Master's thesis. Depending on the programme this can be done once or twice during the year. Furthermore, depending on the programme, the students are asked to keep track of the work they have done, e.g. through a time sheet or a blog.

As the teaching assistants play an important role in the guidance of the Master's thesis student, the Faculty provides qualitative educational training sessions, described in detail in paragraph 2. Furthermore a memorandum describing the Faculty's vision of qualitative mentoring was written. Specific attention was given to the different roles and responsibilities of mentors as well as promotors.

1.4 Reporting skills

The main deliverable of the Master's thesis is the Master's thesis text, which can include appendices with descriptions of code or experimental data. In some programmes, also a paper is required, or a paper/poster in a style appropriate for a non-specialist audience. The Master's thesis can be submitted at three moments of the academic year: June 6th, August 21st, and January 15th. In some programmes intermediate deliverables, such as a literature review, are required.

To enhance the quality of these reports, The Educational Development Unit of the Faculty, in co-operation with the University Library, organises Master's Thesis workshops about information literacy, intellectual integrity and plagiarism and academic writing. These workshops aim to support the writing process of the Master's thesis:

- Workshop to recapitulate on literature search in the library and its extensive e-collections (Information Literacy);
- Workshop to refresh the principles on academic writing (Academic Writing);
- Workshop on integrity

1.5 Evaluation

The evaluation of the Master's thesis applies both to the process and the product and is done by a commission that consists of the advisor, the mentor and two additional assessors with sufficient expertise.
Each student has to give a final presentation of at least 15 minutes, and answer to the questions of the jury during an oral defence.
To ensure the quality and consistency of the evaluation of the Master's theses, the Faculty developed an evaluation sheet (table 1) and an assessment Scale (table 2). Table 2 is not a grading matrix, but contains criteria that have to help the assessors situate the master's thesis within the different aspects. The final obtained mark is a

weighted average of these different aspects. The evaluation sheet of table 1 needs to help jury members weigh the various aspects of the thesis in order to reach a final score.

Table 2. Evaluation sheet

	Insufficient	Poor	OK	Good	Very good	Excellent
Global evaluation						
1 Research aspect						
1.1 Content, i.e. *Research question* *Review of literature* *Approach and methodology* *Interpretation of the results obtained* *Conclusions*						
1.2 Final report i.e. *Accuracy* *Intelligibility* *Depth* *Style* *Language* *Lay-out* *Tables and figures* *References*						
1.3 Presentation i.e. *State of the art* *Presentation* *Explanation* *Language* *Time management* And the defence i.e. *Answers to the questions* *Defensibility* *Clarification*						
2 Additional assignment						
3 Method i.e. *Dedication* *Planning* *Autonomy* *Half-term report* *Teamwork*						

Table 1: Assessment scale

Score	Research quality, personal contribution and originality	Insight into the subject matter	Methodology	Quality of text and presentation	Histogr.*
19- 20	Master's thesis of high research quality that exceeds expectations. The personal contribution is high **and** the work is characterized by a high level of originality from the student.	The student has insight and can discus with experts within the domain.	A correct methodology was used, characteristic of the discipline.	Text and presentation of excellent quality.	0.9%
18-18.9					3.9%
17-17.9	Master's thesis of good research quality. The personal contribution is high **and/or** the work is characterized by a high level of originality from the student.	The student has insight and can carry on a meaningful discussion with the members of the jury.	A correct methodology was used, characteristic of the discipline.	Text and presentation of very good quality.	11.1%
16-16.9					12.3%
15-15.9	The quality of the master's thesis meets the expectations. The personal contribution and/or the work is characterized by a good degree of originality from the student.	The student has insight and can have a discussion, albeit limited.	A correct methodology was used, characteristic of the discipline.	Text and presentation of good quality.	19.2%
14-14.9					17.2%
13-13.9	The quality of the master's thesis meets the expectations. The degree of personal contribution is limited and the work is characterized by a rather limited degree of originality from the student.	The student has mastered the topic, but has no insight into the wider domain.	A correct methodology was used, characteristic of the discipline.	Text and/or presentation of moderate quality.	12.9%
12-12.9					8.4%
11-11.9	The quality of the master's thesis only just meets the expectations. No personal contribution has been made and the work is characterized by a very low degree of originality from the student.	The student has mastered the topic, but has no insight into the wider domain.	Small methodological mistakes that do not influence the conclusions of the work.	Text and/or presentation are poor.	6.6%
10-10.9					5.1%
9-9.9	Poor, but remediable in the short term. The amount of work and/or the reasoning does not meet the expectations.	The student has only mastered the subject to a limited extent.	The conclusions of the work are questionable.	Text and/or presentation of insufficient quality.	0.9%
8-8.9					0.5%
<8	Poor, not remediable in the short term. The amount of work and/or the reasoning does not meet the expectations.	The student has not mastered the subject.	The conclusions of the work are questionable.	Text and/or presentation of insufficient quality.	0.9% **2012-'15*

2 EDUCATIONAL SUPPORT PROGRAMME FOR SUPERVISING TEACHING ASSISTANTS

2.1 Training?

Every academic year, about 200 new PhD students start their research at The Faculty of Engineering Science. Most of them will teach students and coach Master's theses. Therefore, the Faculty provides an educational training programme for these teaching assistants (TAs). In September 2014, the new training programme SWEET² or 'Starters Week of Engineering and Education: Training for TAs' was introduced. Besides enhancing the TAs' teaching skills, the improvement of the quality of education is aspired. The guiding principle in developing this TA training is the 'teach as you preach' principle.

SWEET² consists of a number of thematic training modules organised during the first week of each semester. Every training module consists of two 2-hour sessions and two corresponding preparatory assignments. These sessions focus on dealing with frequently occurring problems, activating students, providing feedback, and the implementation of modern technology in the teaching practice. The first session strives for providing TAs advice before they start their teaching assignment. During the second session, the emphasis is reflection on their teaching experience and feedback. In order to enable more interaction between the TAs and to facilitate peer learning during the TA training, we introduced blended learning by asking the TAs to make a preparatory assignment before each session.

According to the 'teach as you preach' principle, each module departs from one specific teaching format that corresponds to the teaching practice of the TAs, such as supervising exercise sessions or coaching Problem-based Learning. During the sessions the SWEET²-coaches utilise teaching methods that are considered desirable to be put into practice by the TAs during their own teaching assignment.

2.2 Specific training module 'Guiding a Master's thesis'

Within the training module Guiding a Master's thesis, the importance of clear agreements is highlighted and the TAs receive tips and tricks on guiding a student. In accordance with the 'teach as you preach' principle, the teaching formats refer to the one-to-one relationship of the TA with the student. During a roleplay for example, cases are given and the participants should react as a TA or a student. Besides, the structure of the module corresponds to the different steps in the Master's thesis process throughout the academic year, like defining the subject, getting started and giving feedback.

2.3 Evaluation of the module 'Guiding a Master's thesis'

The module 'Guiding a Master's thesis' was implemented in its current format in September 2015. To ensure the quality of the sessions and to further optimize them, the instructors asked the participants to write down three positive aspects and three points that need improvement, after each session organised during the SWEET²-weeks of September 2015, February 2016 and September 2016.

Overall, the feedback of the participants was positive, as shown in tables 3. 74% of the participants gave 3 positive remarks, whereas almost 51% gave less than 2 negative remarks. The interactive format was thoroughly appreciated (62%) out of 193 participants. The 'teach as you preach' principle, was recognised and mentioned explicitly as positive by 5% of the respondents. The materials used during the sessions turned out to be helpful, as 34% of the respondents mentioned them. In particular a testimonial video where professors explain their view on guiding Master's theses was inspiring for 19% of the respondents. 6% of the respondents would even like to see more of these videos. The concept of student archetypes,

developed to help identify different types of students and how to adapt your communication style accordingly was appreciated by 20% of the respondents. Another positive aspect was the use of hands-on guidelines and tips (18%). However 18% of the respondents would wish to discuss more examples of real-life cases.
In September 2015 13% of the respondents acknowledged that the relevance of some of the exercises was not always clear to them. In order to improve this, efforts were be made to make the relevance of the exercises and the cohesion of the session more clear to the participants. This resulted in a more positive evaluation of that aspect in February and September 2016, respectively 23% and 22% of the participants mentioned the cohesion and relevance of the exercises as a positive aspect.

Table 3: Number of remarks 'Guiding a Master's thesis'

	3 remarks	2 remarks	1 remark	0 remarks
Sessions *(# 193)*				
Positive	74,09%	23,32%	2,59%	0,00%
Negative	23,83%	25,39%	41,97%	8,81%

3 DISCUSSION AND CONCLUSIONS

All efforts in terms of refining admission procedures, formulating learning outcomes, developing a learning pathway regarding reporting skills, evaluation and mentoring students resulted in a supported and coherent framework. This framework allows the faculty to continuously monitor and develop the quality of the master's theses without compromising each programme own habits and traditions.

Maintaining and continuing this framework is one of the challenges for the Faculty in the future. In this perspective, the FCMT is the key actor in coordinating all the different aspects and stakeholders involved. It is important to allow the committee to establish an efficient quality developing process while keeping a balance between bottom-up and top-down concerns. In the future, a relapse to the original more administrative and practical mandate can be considered as a thread and should be avoided. Therefore, close attention will be paid to keep the FMCT's mandate content-focused.

In this paper specific attention was given to the development and evaluation of the educational support programme for TAs mentoring theses. The implementation was successful and the participants evaluated the training module positively. As discussed above, the possibility to interact during the sessions was highly appreciated by the TAs: working in group, sharing experiences and discussing problems that occur during their teaching assignment were mentioned as positive aspects. Furthermore, the respondents gave positive comments about the content, teaching formats and materials used during the sessions.
Efforts were made to make the rationale and cohesion of the session explicit, which was successfully proven by the subsequent evaluations. In the nearby future, more elaborated use of real-life cases is a suggestion that will be taken into account by SWEET^2-coaches to further improve the module.

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Pedagogy, Practice and Procedure (*The P [3] Project*) - Educating Engineering Managers: A Model for the Future

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ABSTRACT

Over the past two decades there has been much discussion about how to best educate Engineering Managers. Indeed, traditional Management Education within Business School Settings has been subjected to considerable criticism, with, some suggesting that traditional MBA programmes lack engineering context and application and thus fail to meet the needs of both employers and students. Conversely, others postulate that Business Schools provide graduate students with <u>generic</u> skills and <u>transferable</u> competencies and are thus exactly engineering managers *should* be educated. Looking critically at Engineering Management Education within an Engineering School, this paper suggests that graduate level Engineering Management Education needs to be led by Engineers who have experience in industry and who also are qualified in management. It introduces a model of organisational change developed specifically for an Engineering Education setting and considers how that model may be best applied to an Engineering Management Education setting.

Key words: RVS, Graduate Students, Engineering Management Education

1) INTRODUCTION

Set within a global workplace where professional engineers need to be multi-skilled practitioners able to work in multi-disciplinary teams , the matter of how to best educate those individuals who find themselves with managerial responsibility for major engineering projects is of great importance. Yet the question of how and where management training should be included within an engineer's career path is rarely discussed; with many professional engineers looking outside their employers' vocational offerings and beyond traditional university engineering education to access management training from graduate level Business Schools. Such business-centric education has been subjected to considerable criticism, with some suggesting that traditional MBA programmes lack engineering context and application and thus fail to meet the needs of both employers and students [1]. On the other hand some literature suggests that Business Schools provide graduate students with generic management skills and transferable competencies and are therefore exactly what engineering managers *should* be accessing as an opportunity to broaden their thinking [2]. In looking at both sides of the argument, what is clear is that engineers who take on management responsibilities should be trained; and because most engineers do, at some time in their career, find themselves working at a management level, this training needs to be appropriate to an engineering context. Despite this, the question of how and when management training should be accessed by engineers, or what it should comprise in terms of practice, focus and theory, remains largely unanswered.

In seeking to explore this issue, this paper looks at engineering students' experiences and perceptions of a management module that is embedded into graduate level engineering education. The module, which provides students with key Project Management knowledge, theory and skills, has been carefully constructed around an approach to engineering education developed by the paper authors [3]. Termed the RVS Model of Engineering Education, the approach comprises three key concepts, Relationships, Variety and Synergy and is built around the concept of 'Synergetic Configuration'. The study upon which this paper is based critically discusses students' perceptions of the Project Management module that has been synergistically configured so as to encapsulate key engineering, managerial and educational requirements. The paper builds on previous studies to show how the RVS approach to engineering education can be a catalyst for educational change. In this case it is in teaching engineers about management, thus adding to key discussions in the area of management education for engineers.

2) BACKGROUND

In a pre-Brexit UK Government Report, Member of Parliament Vince Cable, who was at the time Secretary of State for Business, Innovation and Skills commented "*A strong British engineering sector is vital to the long term sustainability of our economic recovery, and increasing the supply of engineers is at the heart of this*" [4]. Indeed, both before and after Brexit, the importance of engineering to a thriving UK economy is frequently featured in the British press with arguments that 'engineering skills shortages' comprise a present and future threat to the success and security of the country being a favoured topic [5,6]. From a more global perspective, it is evident that much of the world acknowledges the important role that Professional Engineers play in both solving transnational problems and challenges including issues around: Sustainability and Sustainable Development: Political unrest, terrorism and war: Global warming and pollution: An aging infrastructure, and, as we move into the 21st Century: International cyber security and artificial intelligence [7].

Set against this challenging environment, the need for those managing engineering projects to be able to understand science and maths and to be in a position to solve engineering problems, whilst adopting sound managerial practices, has become increasingly important, with much debate focusing on the need to promote leadership and management skills within the engineering workforce [8,9]. Yet in many areas, engineering projects are managed by non-engineers who, whilst being 'professional managers' have little or no understanding of the underpinning engineering or scientific theories. At best this can result in financial and project mismanagement, whilst at its worst technical errors could result in loss of life and a damage to the environment. Hence the need to educate engineers with managerial skills is increasingly important. In seeking to address this, business and management modules have been introduced into many graduate level engineering programmes. The P^3 Project looked at one such module. It examines the issues around applying the RVS approach to management training for engineers so as to 'Synergistically Configure' the curriculum and in doing so promote pedagogy and practice within graduate engineering education.

- **Introducing Synergetic Configuration: An Approach to Engineering Education developed by Engineering Educators *for* Engineering Education.**

Synergetic Configuration is defined as "*the requirement that university level Engineering Education should equip students with the technical capabilities required by industry, whilst providing them with a sound theoretical knowledge base, within a supportive curriculum in which 'softer skills' are embedded alongside technical competencies and independent learning is the norm*". Grounded in the findings of previous studies and published work by the paper authors, Synergetic Configuration has emerged out of a new model of Engineering Education developed by the paper authors, the RVS Approach to Engineering Education [3]. Synergistically synthesizing three distinctive concepts, Relationships, Variety and Synergy, and developed with the intention of promoting Scholarship in Engineering Education, the model has been specifically developed so as to overcome the linguistic and conceptual barriers many engineering educators encounter when trying to engage with pedagogic theory. As such it has helped to facilitate change in an environment that typically struggles to adopt new ideas quickly and holistically [10].

In considering how to promote Scholarship in Engineering Education the paper authors turned to the work of Boyer [11] who argued that there are four separate, but overlapping, areas of Scholarship (Discovery, Integration, Application and Teaching). Each of these four areas was considered in the development of the RVS Approach from an Engineering Education perspective. Synthesized with the three different concepts that make up the RVS approach, the foundational use of Scholarship as an educational ideology resulted in a theoretically grounded and academically relevant pedagogy specifically aimed at those working in Engineering Education.

From an Engineering Education perspective, the first area of Scholarship, that of Discovery, is encapsulated by the pursuance of knowledge which underpins engineering pedagogy and research. Following on from this the Scholarship of Integration is evident within an Engineering Education context when considering the inter-connectivity across different engineering disciplines, particularly when taking account of the vital role engineers play in society. Within the RVS approach the Scholarship of Integration encourages learners and teachers to seek answers beyond traditional disciplinary boundaries in a manner that is *imaginative*, *interdisciplinary, interpretive* (and) *integrative* (Boyer, p 21). The third area of Scholarship, Application, represents the fundamental basis of much engineering education, indicative of the fact that engineering is an applied discipline and as such requires the acquisition *and* application of knowledge, competencies, skills and contextual insight. The final area of Scholarship, Teaching, represents the fundamental purpose of the model, which is to provide an easily adaptable, scholarly approach to engineering education. In bringing together three distinctive concepts of Relationships, Variety and Synergy the paper authors have produced a useful and useable model which has been tested over a number of years. The P^3 Project aimed to take this testing one stage further and set out to critique how proactive synergetic configuration of pedagogy, practice and procedure within different elements of a graduate level engineering management programme can act to promote a positive learning experience at graduate level.

3) THE P ^{3} PROJECT METHODOLOGY

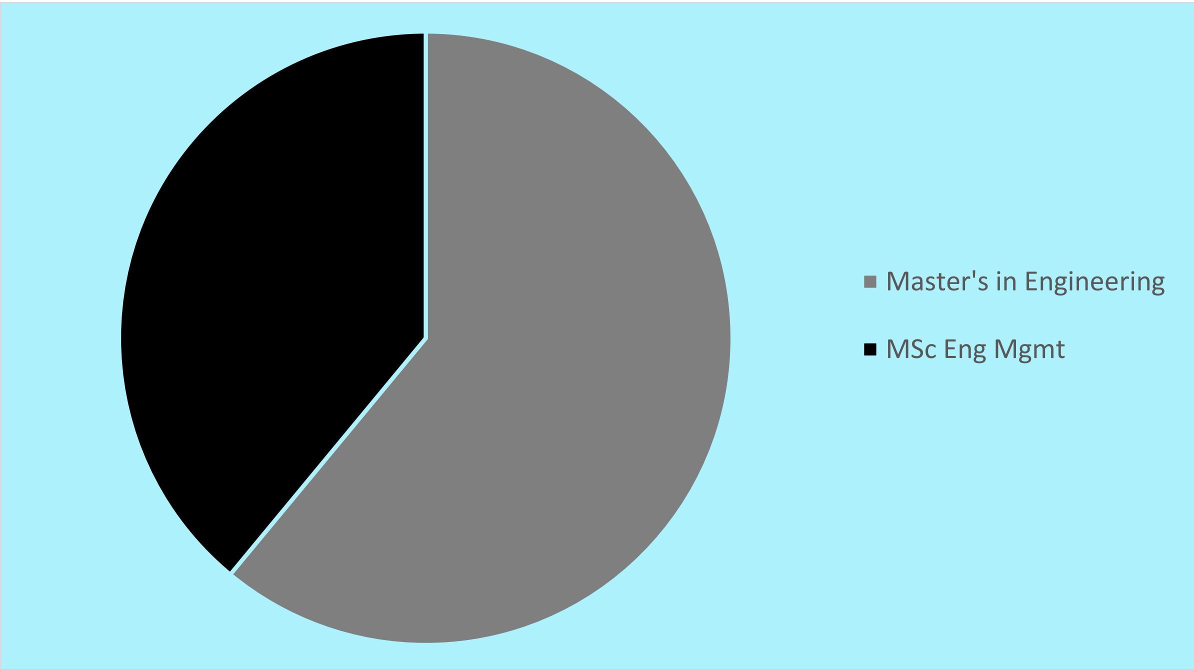
To achieve this aim, an Action Research Approach [12] was adopted in which the project leaders set out to answer the question *"How can pedagogy, practice and procedure be improved through the application of the RVS model of engineering education at graduate level?"* A small exploratory study was conducted focusing on pedagogy and practice within an Engineering School based in the UK. A survey tool was developed and administered to a cohort of 80 engineering students studying Engineering Project Management. The response rate was 75% (61 students). The survey itself was divided into three main themes, each one relating to the key concepts of the RVS approach to engineering education: Relationships, Variety & Synergy. Each of the concepts aligns with one of the three areas upon which the P^3 study was focused: Practice (Relationships): Pedagogy (Variety): Procedure (Synergy).

This paper uses descriptive statistics only at this stage in an attempt to gain some insight into students' background and experiences. The reasons for this is reflective both of the small sample size, and of the fact that the study aims to directly impact practice. The next stage of the work will be to conduct in-depth interviews with students studying engineering management.

- **P^3 Project Sample**

The sampling field comprised a cohort of 80 students studying either an MSc in Engineering Management or an MSc / MEng in a range of different engineering subjects, including Chemical Engineering, Design Engineering, Mechanical Engineering and Computing Science amongst others. The respondents were divided into two main groups as shown below in Figure 1. Just under two-thirds of the cohort were enrolled on a technical MSc / MEng Programme, with the rest, all graduate engineers, studying for an MSc in an Engineering Management related discipline.

Figure 1: Programme of Study: Percentage of Sample (*N* = *61*)



In looking closely at the demographic makeup of the respondents it was noted that just under a quarter of the sample were female; this is typical of the School of Engineering in which the study was conducted

Figure 2: Demographic Breakdown of Sample: Gender

Gender	*N*	%
Male	47	77
Female	14	23
Total	61	100

In considering the issues around engineers in management, one of the key variables which emerged out of the literature related to individual work experiences, particularly when considering graduate engineers. Figure 3 shows that the majority of the sample had undertaken a period of paid internship as part of their undergraduate training. This figure, which for the UK is quite high, is indicative of the School of Engineering & Applied Science in which the study occurred, whereby all undergraduates are strongly encouraged to participate in a year-long formal work experience. This is usually paid and is, where possible, at graduate level.

Figure 3: Sample work experience

Work Experience	%
Undergraduate internship	54
Part-time work whilst studying	9
Engineering management role	8
Engineer	5
Consultant Engineer	2
Other	7
None	15
Total	**100**

4) THE STUDY FINDINGS

This section focuses on the study findings. It is divided into three sections, each one looking at a different area explored in the P^3 Study.

- **Exploring relational issues in engineering management education**

The first part of the study focused upon the importance of developing a practice-based approach to teaching that encourages positive work-study relationships amongst the cohorts. The importance of relationships in education is discussed elsewhere [3] and is viewed as particularly important for engineers who, upon graduating, may soon find themselves responsible for managing teams of people from a wide-range of backgrounds and disciplines with different levels of knowledge and understanding.
The Project Management module was carefully constructed so as to encapsulate the main theoretical and practical issues around Project Management. Human relations is key to this, and thus the assessment requires high levels of cross-cohort collaboration and communication. The student-focused approach adopted by the module lecturer represents an important part of learning as the students are encouraged to view the lecturer’s interactions with them as a role model in terms of how to manage disparate groups and situations. In total, seven relational-practice focused question-statements were asked. Whilst a five point Likert scale was used in all of the questions, the

differentiation between the levels of agreement and disagreement was not valid; hence the 'agree and strongly agree' data (denoted as A) and 'disagree and strongly disagree' data (denoted as DA) are merged together. This provides a clearer picture of the students' perspectives. The numbers of those students who either agreed or disagreed with the statements is given below.

Figure 4: Relational (Practice focused) Questions

In thinking about the Project Management module the following applies…	**A**	**DA**
The group work in this module has enabled me to build some close friendships	**47**	**11**
The group work has provided the opportunity for me to develop my communication skills	**53**	**4**
The fieldtrip has provided the opportunity for me to get to know my classmates better	**48**	**10**
I have found the module lecturer approachable throughout	**54**	**2**
I found it difficult to work in a group	**20**	**39**
The opportunity to gain feedback in stages has helped me develop my understanding of PM	**49**	**6**
The class visit by a Project Manager helped me appreciate the real world PM context	**55**	**1**

- **The Importance of Variety in Pedagogy**

Having examined the issues around relationships in teaching and learning practice, the survey then turned to the question of variety in pedagogy. In seeking to expose students' to a range of different scenarios and situations the module leader aimed to provide an interesting and relevant learning experience. One of the key aspects of the Project Management module is the manner in which management of engineering projects has changed over time. This is contextualised by a fieldtrip to a heritage site in which students are encouraged to look at the different socio-economic, engineering and political issues associated with project management from the end of the 18th Century through to modern-day practice. The location used for the field trip is part of a UNESCO World Heritage Site. The site is Cromford Mill and it is considered to be the first factory established anywhere in the world [13]. The questions asked in this section therefore focused both on classroom activities but also included a look at students' perceptions of the value of the fieldtrip. Figure 5 presents the 7 question statements asked and the data is again disaggregated into 'Agree' (A) and 'Disagree' (DA).

Figure 5: Variety in Pedagogy Questions

In thinking about the Project Management module the following applies…	**A**	**DA**
The different learning and teaching approaches used in the module made the lectures more interesting	**57**	**0**
The different learning and teaching approaches used in the module made the content more understandable	**56**	**1**
The use of case-studies has helped me appreciate the range of practical project management issues	**55**	**2**
The class discussions have been valuable in helping me understand the main issues	**50**	**6**
The lectures provided the foundational knowledge necessary to study the subject independently	**57**	**4**
The visit to Cromford Mill was interesting in helping me understand the concept of industrial heritage.	**50**	**6**
The presentation at Cromford Mill was useful in helping me comprehend some of the practical issues associated with PM	**60**	**1**

- **The importance of Synergy in Pedagogic Practice**

The final area explored by the survey related to the manner in which the module leader had purposefully and synergistically aligned all aspects of learning and teaching. Figure 6 provides an overview of the disaggregated data relating to the 10 questions posed.

Figure 6: Synergy in Pedagogic Practice Questions

In thinking about the Project Management module the following applies…	A	DA
The module content is relevant to modern day engineering	60	1
The module content is applicable to the coursework	60	1
The group work in the module is good preparation for work	57	4
The real life case-studies helped me understand the theory	53	8
The visit to Cromford Mill helped me gain a wider perspective on PM	46	9
The visit to Cromford Mill has given me an insight into the importance of heritage within contemporary society	51	7
The visit to Cromford Mill brought PM to life	51	10
The module learning outcomes have been achieved	60	1
The assessment is appropriate for developing my PM skills	58	3
The module content is relevant for a career in industry	59	2

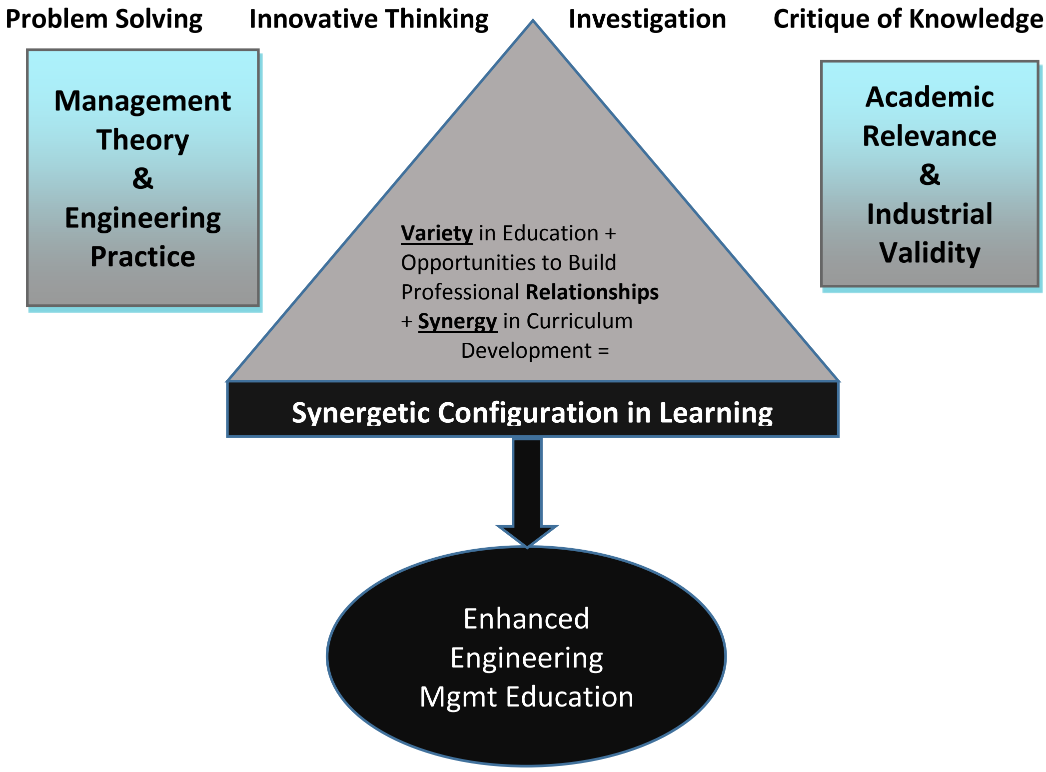
5) DISCUSSION

Based upon the emergent research findings, a conceptual framework was developed. Depicted overleaf in Figure 7, the framework highlights the centrality of the main three concepts of the RVS formula [3]. In further developing this approach, the paper authors drew upon a meta-analysis of the findings of *a priori* educational research studies they were directly responsible for leading; the largest one of which examined the experiences of around 1,000 undergraduate students and found that the most important driver of student success is a 'sense of belonging' [14,15].

An important facet of belonging, learning and professional *Relationships* represent a key part of student success. Whilst some colleagues appear to believe that students' professional relationships have little or nothing to do with engineering education, the fact is that following graduation, personal and professional networks are often key to success in engineering and management roles. Thus, in educating engineering managers, there is a clear need to identify mechanisms by which 'networking' and 'communicating' may be taught and assessed.

The second component of the RVS formula, *Variety* applies directly to innovative engineering education **and** practice. In engineering management education, the concept of *variety* requires educators to take account of students' individual learning preferences and styles, whilst factoring in their differing demographic, professional and educational backgrounds [16,17,18]. Additionally, it is also important that educators consider the future different disciplinary settings that the students, once they are employed as engineering managers, will be working in.

Figure 7: Emergent Conceptual Framework: Synergetic Configuration in Engineering Management Education



The final component of the RVS formula, *Synergy* needs to be applied at all levels of learning. In an engineering management module this means purposefully constructing learning experiences that synthesize and synergize engineering contexts and problems with real-life management tools and approaches. In applying a formulaic approach, the application of the RVS approach results in Synergetic Configuration and leads to enhanced student experiences, retention and success. The link between the quality of learning and teaching and student success is reflected in the literature [19,20], with much of the contemporary academic debate built upon the concept of Scholarship proposed by Boyer [11,21]. In educating engineering managers the application of the RVS approach to pedagogic practice means that each distinctive strand of scholarship is considered to be central to student success.

6) CONCLUSIONS

As engineering teachers, we are confronted with the challenge of engaging a diverse student body in a discipline that is multi-faceted with the aim of preparing them for future employment. Often, when speaking to alumni, the role they fulfil after graduation is more reliant on the life skills they have developed during their university education rather than the technical content of the programmes they have been studying. This is reflected in the literature and often discussed as skills development [22].

Courses such as the one described here, expose students to authentic settings with real problems and issues that need addressing. Whilst engaging with the learning context as an interested and knowledgeable observer, students quickly begin to appreciate the multiplicity of opportunities a career in engineering can offer.

In conclusion, too often, the need for accreditation, study of discipline content and traditional pedagogy frame the learning environment. Certainly innovation in learning and teaching through active approaches and industry engagement are welcome, but perhaps now is the time to move the debate forward and start to consider our students as taking an 'engineering role' rather than being an 'engineer' on graduation [23]. Clearly more work needs to be done in analysing this data and exploring the subject further, but now is certainly the time to challenge the status quo.

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"Is it the mission of an accreditation and quality agency dedicated to engineering education to introduce criteria related to society?"

The experience of "Focuses" at Commission des Titres d'Ingénieur

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ABSTRACT

The role of quality agencies changes because quality of institutions increases thanks to the regular intervention of those agencies since a couple of years. We can observe that periodic evaluation has really upgraded quality of HEIs; but this quality increase can also be attributed to interventions of international organizations such as ENQA (European Network for Quality Assurance) or ENAEE (European Network for Accreditation of Engineering Education with EUR-Ace label) that work on the standards of quality assurance at the European level.

So new criteria arise, suggested by stakeholders or by members when members come from a socio-economic college for example. It is a new concept because in some cases we are far from considerations concerning the teaching of science and technology.

In this paper we will see how this phenomenon take place as well in generalist agencies as in an engineering education dedicated agency but very often, much more in those; the learning outcomes approach has also a strong role in this evolution.

Then we will present the devices that CTI (Commission des Titres d'Ingénieur: French Accreditation Agency for Engineering Education) has put in place in this frame in three specific domains: innovation, sustainable development and health and safety at work.

Conference Key Areas: Quality Assurance and Accreditation, Sustainability and Engineering Education, Ethics and Engineering Education

Keywords: accreditation agency, sustainable development, innovation, health and safety at work

INTRODUCTION

Even in the academic world, the definition of engineering is changing; in the last Global Engineering Dean Council forum, engineering was defined as a mean to increase the quality of life of people: it is not surprising that accreditation changes too.

Previously, experts of accreditation agencies were much more seen as « Constables » coming in the institutions to verify if everything was right, now they are very often considered either as prescriptions makers or counsellors on specific points, this shows that in the minds of the deans as well as in those of the members of those agencies things are changing. But this is not evident for all the deans because a few of them are always thinking that accreditation agencies should stay on fundamentals such as mathematics or physics and not go through all these “peripheral” matters.

The “Commission des Titres d’Ingénieur” is particularly concerned by this evolution because it includes both academic and socioeconomic members and those are directly concerned by economy and so by society. As we exist since 1934, and have defined periodic institution since 1997 (which is a rather long period of time) some questions are arising about simplification and evolution of the process and criteria of our audits; but the evolution of these criteria also appears as driven by quality considerations including ENQA’s and ENAEE’s (since 2007 when we decided to become member of ENQA and to conform our processes to its requirements).

These criteria linked to society can be of very different kinds according to the continents and even the countries, in this paper we will focus only on some of them.

1 THE FACTORS LINKED WITH THE KIND OF AGENCY

Depending on the country, engineering is evaluated by generalist agencies or engineering devoted, or both. It is interesting to compare the importance of societal criteria in both systems.

1.1 Generalist agencies

The number of quality agencies increases singularly since 10 years. In our country there are 2 agencies belonging to ENQA, one of them (HCERES) is generalist and the other one (CTI) dedicated to engineering education. Some of the engineering institutions are evaluated by both agencies.

If we compare the criteria of the two agencies, we see that, for example, for the moment, criteria such as Sustainable Development (SD) are not really taken into account in the generalist agency criteria.

There are several reasons for this:

-Sustainability is in fact taken into account by a law in France: “loi de Grenelle” that make mandatory the fact that universities deal with it, so the criteria of the generalist agency do not deal with mandatory things, even if this law is not really applied!

-There are many labels concerning SD that have been developed by private associations concerning either Universities or “Grandes Ecoles” or both and the fact that the HCERES deals as well of medicine, art, or engineering makes it not easy defining the good criteria linked to society concerning all fields of education.

It is the same for other criteria for example “health and security at work”, however “innovation” which is a great consideration of French government and for which money is given to institutions to develop a device called PEPITE, is considered by HCERES. This shows however that those links between society and accreditation depend on the factors linking specifically politics of education and economy (money given for the PEPITE device for example).

HCERES considers more the research and education strategy of the institution and the opportunity of success that this strategy will have, than details: if a University thinks that sustainable development or health and security at work is a strong differentiation point of its strategy, it can describe it in its Self-Evaluation Report.

If we have a glance on ESG proposed as reference by ENQA (generalist agency), we find that “according to the European desire to constitute a society based on knowledge, higher education is a basic point of the socio economic and cultural development”. So, in ESG 1.9, we find the criterion:
“Institutions follow and evaluate periodically their programs so as to insure that they reach the aims they defined and that they answer to the needs of students and society. With the following guidelines:” The follow up, evaluation and periodic revision of programs aim to guarantee that the offer stays appropriate and to create an apprenticeship surrounding efficient for the students”; among the devices suggested to realize this criteria: “Taking account of the needs in constant evolution of the society”.
Those guidelines let to the institution a very large opportunity to take into account the needs of society but, as they are guidelines and not criteria, it does not really make things mandatory for institutions.

1.2 Agencies dedicated to Engineering Education

If we have a look now on the agencies dealing with engineering education, we can compare for example EUR ACE criteria and other specific agency like CTI or ABET for example.

This comparison is very interesting: it shows that factors linked to society appear in both agencies but not at the same compulsory level.

ABET has among its criteria the following one: “a knowledge of contemporary issues”, this can be applied to many fields [2].

EUR-ACE has defined criteria and guidelines: criteria are mandatory, guidelines can either be considered as explanations of criteria or possible ways to answer to the criteria, they are not mandatory. In EUR-Ace we find the criteria linked to society in the guidelines. ENAEE is a European agency and the state of development of society in not the same in every country, so ENAEE cannot oblige all European countries to have the same criteria linked to society and development. We can again notice that politic factors (for example human rights considerations and policy for sustainability) also intervene in this field.

2 THE FACTORS THAT CAN ALSO PLAY A PART IN THIS KIND OF POLICY

2.1 Accreditation agencies are not always seen as acting in good directions for the future of society

The paper recently published by MIT [1] about universities of the future shows that there is a tension between what engineering science professors want to teach engineers to do, so that they can become young scientists and PhD students and the needs of the government and society, which is to create engineers to contribute to economic development and growth.

The role of quality and accreditation agencies can be either to make this tension progress or resolve it in the future decades. At the same time people think that in countries like China, India, Brazil or Canada, the accreditation agencies leave little room for new ideas and experimentations, this means that it appears that accreditation agencies should better act in favour of needs of societies if we want that things change.

It is a very important question for the agencies, what is their precise role: we can answer that it depends on their statute: are they academy driven or government driven? The good answer is in between and the necessity of independence given by ENQA could perhaps insure this good equilibrium.

However, for example, on questions linked to new pedagogies, things are not so evident because teacher's habits are strong, but money is often given by government and very often those new pedagogies are in relation with this policy (introduction of SD for example).

2.2 Basic accreditation or follow up?

Very often when an agency visits an institution for the first time, it concentrates on program contents in their technical aspect or in their pedagogy: number of hours of science teachings, good quality of staff…There are so many important criteria in engineering education today such as new pedagogies, internationalisation of students, numerical aspects of engineering and for some of them, we are quite in societal problematics (use of "Big Data" in society is a problem of ethics).

It is during following up visits that the agency begins to have a look everywhere and especially on criteria more specifically linked to society. It is completely normal that an institution that does not fulfil basic requirements concerning engineering education, even if criteria linked to society are fulfilled is not accredited because the agency is there at first to verify the quality of the institution.

However, the trend is now to have simplifications in the follow up audits: this is a danger that agencies that are taking into account society preoccupation do not take them into account them anymore.

2.3 Role of the socio economic member or experts

They are necessary

More and more quality agencies have socio economic members or experts in their audit panels because it is necessary to understand precise things about employability of the institution for example and that those people coming from society are qualified to deal with this part of the criteria. Either they are in their working position facing those debates or their company has realised studies on them [3].

But not sufficient

Employment of "socio economic" members can hide a great diversity among those people and some of them can be less conscious of a specific societal problem that sociology teachers for example. However, very often sociology teachers are not member of agencies! So this is not the unique solution: if people have no occasion to discuss together between academic and socioeconomic people, as well during CTI 's meetings (such as expert formation) as well as during audits, it is a pity so, it is a very important thing to have exchanges between different categories of members.

Very often, the agency employ specific experts on a specific field, for example in CTI we have experts in innovation, in SD and in health and security at work that help CTI in its demarches such as analysing the "focuses" that will be explained later on.

3 THE IMPORTANCE OF THE LEARNING OUTCOMES APPROACH

For some years, companies (such as Boeing in the early 90's [3]) and now many agencies ask the institutions to describe their programs in terms of learning outcomes, this is particularly specified in EAFGS [4] and in R&O [5] but also in CEAB [6].
A good comparison on those subjects by GEDC can be found in [7]. This presentation in terms of skills really allows preoccupations of the society to be taken into account.

3.1 It allows to take into account the needs of society as criteria

The learning outcome descriptions allows the introduction of specific skills expected from the graduates. For example, in CTI's learning outcomes (among 14 at the total), the second chapter concerns the adaptation of graduates to the constraints of companies and society:

1. The ability to take into account the issues of the companies
2. The ability to take into account the issues of relations at work, ethics, responsibility, safety and health at work
3. The ability to take into account environmental issues
4. The ability to take into account issues and needs of society

These demands are very clear and precise; they constitute a specific paragraph that completes two other ones: the first one concerns the acquisition of technical and scientific knowledge and the mastery of their implementation and the last one is about organizational, personal and cultural dimension of engineering education

3.2 This can be also done through guidelines

For criteria of agencies common to a set of countries, reasons may occur that make things not completely explicit. For example, the first look at learning outcomes in EAFSG shows nothing about preoccupations of society, we have very common basic engineering requirements:

Knowledge and understanding; Engineering Analysis; Engineering Design; Engineering Practice; Investigations; Making Judgments; Ability to engage in Lifelong Learning.

We discover that inside the detailed items (guidelines) that define a criterion, we can find societal preoccupations; we must carefully look to be sure of the content of those criteria in front of those of CTI [4].

Inside "Investigations" we find: "Ability to consult and apply codes of practice and safety regulations"

Inside "Engineering Practice" we find: "Critical awareness of economic organizational and managerial issues"

And Inside "Engineering Analysis": "Ability to identify formulate and solve complex problems"

It is clear that the problems of society are considered by EUR-Ace but not at the same intensity (only guidelines) as by CTI.

4 AS AN EXAMPLE: THE CASE OF CTI

4.1 The partner's context of CTI

ENQA asks all its members to make their requirements evolve through concertation with stakeholders. In the network of close partners of CTI, 3 organisms exist that have particular missions and preoccupations on some precise subjects linked to society:

CGE (Conférence des Grandes Ecoles) is an association of Schools of Management and Engineering. It has for many years created a commission on Sustainable development and Social responsibility, CTI members had meetings with this commission, in 2010 we first defined common principles that were not at this moment part of our criteria but only recommendations to schools. Then in 2014 they began part of the criteria.

INRS (Institut National sur les Risques et la Sécurité) is an organism linked with the French Public Welfare System, its role is to study risks in all professions. From about 10 years it intervenes in Engineering Education Institutions to explain risks, professional diseases (one of them being burn out), and their prevention. CTI has realized an enquiry on fresh graduates together with them. In 2016 criteria linked to Health and security at work were part of CTI's criteria.

The interest for innovation and entrepreneurship has been awaken in CTI through many influences: first the researchers in academic part, then the socioeconomic members but also the French Government with the PEPITE device. Some HEIs had a strong interest for it since a long time but the creation of PEPITE made things evolve massively.

These three points were considered by members of CTI as common strong and necessary points for education of engineers in link with evolution of society. So, in 2016 CTI decided they should become part of its criteria.

4.2 The criteria associated

CTI has evolved a lot in taking account society needs between 2006 and 2016: a recent comparison in [13] show a change of paradigm in the description of its criteria. In the learning outcomes approach main criteria are specified (they are developed in 2.1) but it is not sufficient. It is also necessary to insure that the management of institution is in conformity with the learning outcomes expected from graduates. This is very important because institution should be considered as a model by its students.

In February 2014, CTI, considering that teaching social responsibility to engineers was a critical aspect for society and a duty for engineering institutions, decided to include immediately SD not only in the intended learning outcomes but also in the description of the global policy of the institution: this was an important evolution of the accreditation criteria.

The strategic guidance document of the institution being evaluated must include the orientation chosen by the institution regarding SD and particularly the Green Plan that describes the institution's strategy and its implementation and evaluation. The strategic guidance document is an important part of the self-assessment report because the institution's administrative council votes it, and when this institution is part of a group of faculties the university council votes it too.

CTI wishes strongly that institutions really integrate SD through curricula in the education of engineers but also apply the principles of SD in their own management, working in an exemplary way.

When an institution is accredited or reaccredited, the implementation of Green Plan has to be explained within the quality process of the institution.

CTI has quoted 8 axes of operational actions to be verified during the evaluation process: strategy and governance, social management and local integration, environmental management, research, curricula, documentation, industrial rooting, quality management and continuous improvement

CTI also stresses that a specific innovative active pedagogy has to be put in place for SD: the pedagogy of action puts the engineering student in the situation of finding and building solutions to "real world" matters. CTI specifies that the recruitment of students must guarantee diversity according to a policy concerning chance equity [7].

4.3 The focuses

It is not easy to introduce new criteria in an old system of reference and to be sure that they will be taken into account.

We decided to create "focus", that is to say that in the self-evaluation report, the institution has to present in four pages one of these new specific points. In this way it is easier to convince those (members or institutions) reluctant to change and it will be also easy to publish a document showing the state on a subject inside institutions and giving ideas to institution that don't have: a best practice catalogue. So, this year CTI asked more information on those 3 points that seem important for society at this moment:

- Sustainable development and social responsibility
- Health and Safety at work
- Innovation and Entrepreneurship

Among the institutions that were concerned by periodic evaluation (about 30 this year) one third were submitted to the redaction of each focus. That is to say that we collected the view of 10 institutions on each subject. In February 2017 each of the focus was analyzed and the conclusion presented to all deans.

Institutions and CTI members found this exercise very interesting, a debate was hold at February 2017 conference and results published, then the members of CTI decided, on the same themes, to go on with these focuses to get a more important panel (there are 206 institutions for Engineering education in France).

So we think that those points can now really be considered as part of a quality system: accreditation system can help institution to progress on society subjects.

5 CONCLUSION

The point of introducing criteria linked to society is important but not so easy: it was possible in France because periodic evaluation took place already 3 times before (3 periods of 6 years since 1997) and quality of institution had increased; but now, we are trying to simplify accreditation procedure so "details" will be suppressed: it show the importance that these factors be considered inside criteria and not in guidelines.

Is it possible to define priorities into criteria? We observe that very often in many countries doors of the accreditation criteria are opening to society problems: the importance given now to soft skills and transversal skills is a good attempt.

However, we think that it strongly depends on the law of the country and on the political situation (emphasizing or not such or such problem), however, in this case, the public opinion has a role to play in the criteria chosen for education realising pressure on the agencies.

We can conclude saying that consideration of engineer's education preoccupations linked to society has much evolved since 10 years, because both of society and companies but this has still to progress in some countries. These preoccupations must be taken in consideration either in law or in another place, but accreditation agencies when existing stay a place very convenient for this.

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5.

Continuing Engineering Education and Lifelong Learning

Part-time Engineering Master Programmes: Implementing Real-life Engineering Problems as a Means of Learning.

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For more than two decades, University Aalborg has enrolled learners into their part-time engineering Master's programmes. These programmes are designed for employed learners who work full-time in the industry and who want to keep their job while they study on a Master's programme. Aalborg University's pedagogical approach is solely based on problem-based learning, which means that learners are, to a large extent, implementing real-life engineering problems as a means of learning. This paper will investigate what types of problem formations the learners are able to identify from their working-life, which is also aligned with the requirements of the part-time master's study programme.

Conference Key Areas: continuing engineering education and lifelong learning

Keywords: continuing engineering education, problem based learning, problem formations

INTRODUCTION

For more than two decades, University Aalborg have enrolled students into its part-time engineering master's programmes. These programmes are designed for employed learners who work full-time in the industry and who wish to keep their job while they study on a Master's program. Consequently, the courses and seminars are mainly given in the evening and during weekends.

The part-time Master's should not be mistaken for the traditional Master's of Science (MSc) programmes, which according to Bologna is two years of study (120 ECTS) following a Bachelor's degree. The part-time Master's programmes are specially prepared to meet the needs of employed learners who lack knowledge, skills and competence within exact identified areas (subjects). The curriculums are carefully designed to be attractive and exciting for the engineers and they provide an opportunity to work with authentic problems from the learner's professional life. Thus, the Master's programmes are 60 ECTS, of which at least 30 ECTS of the programme content is project-work and the 30 ECTS are subject courses or seminars. The extensive amount of resources dedicated to project work allows the learners to identify, analyse and solve real-life engineering problems in-depth.

This paper will investigate what types of problem formation the learners are able to identify from their working life, which also is aligned with the requirements of the part-time Master's study programme.

1 THE MASTER'S PROGRAMMES

The Master's programmes at Aalborg University, to a large extent, implement real-life engineering problems as means of learning. This concept of 'posing problems' as a means of learning began in the 1960s when Paulo Freire described '*the banking concept of education'*, which is still prevalent as '*education becomes an act of depositing, in which the students [learners] are the depositories and the teacher is the depositor'* (Freire, 2009 p. 72). This educational approach, with the teacher as narrator of a subject and learners listening to memorize the narrated content, is something that we are all, to some extent, familiar with. But, as Freire (2009) argues, this teacher-centred approach must be rejected: '*they must abandon the educational goal of the deposit-making and replace it with the posing of the problems of human beings in their relations with the world'* (Freire, 2009 p. 79). Abandoning the banking concept and implementing the posing of problems is one of the backbones of problem based learning (PBL) and, hence, the problem-orientation and problem formations. Another pioneer in the field of 'posing of problems' was Howard Barrows, who in the late 1960s was involved in the early stages of the development of PBL at McMaster University in Canada. Barrow defined the concept in terms of specific characteristics as being student-centred, taking place in small groups with the teacher acting as a facilitator, and being organised around problems (de Graaff et. Kolmos, 2003, p. 657). In Denmark, the PBL model was developed based on ideas from, among others, Illeris, *'who formulated the principles of PBL as problem-oriented, project work, inter disciplinarily, participant directed learning and the exemplary principle and team work'* (Kolmos et al., 2004, p. 10).

At Aalborg University, all of the students and academic staff act out the basic principles of PBL, which is a general characteristic of all of the studies at the university. The principles, which are acknowledged by Aalborg University, are:

- Problem-orientation: Problems/wonderings appropriate to the study program serve as the basis for the learning process.
- Project organization: The project stands as both the means through which the students address the problem and the primary means by which students achieve the articulated educational objectives. The project is a multi-faceted and often extended sequence of tasks culminating in a final work product.
- Integration of theory and practice: The curriculum, instructional faculty members and project supervisors facilitate the process of connecting the specifics of project work to broader theoretical knowledge for the students. The students are able to see how theories and empirical/ practical knowledge interrelate.
- Participant direction: Students define the problem and make key decisions relevant to the successful completion of their project work.
- Team-based approach: A majority of the students' problem/project work is conducted in groups of three or more students.

- Collaboration and feedback: The students use peer and supervisor critique to improve their work. The skills of collaboration, feedback and reflection are an important outcome of the PBL model.

(Barge, 2010)

On the part-time Master's of Building Physics programme, which has been selected for this study, the PBL principles are well integrated into the study. The Master's of Building Physics is a research-based education programme that enrols researchers and leading experts in the field, and which applies current scientific theories and methods to practical building-related issues.

This Master's is an accredited, qualifying continuing education programme, which is aimed at all professional groups with a long or intermediate higher education in the field of construction, such as:

- Civil, diploma and academics engineers;
- Building engineers; and,
- Architects.

In addition to a relevant higher education, it is required that the learner should have at least two years of practical experience at a high level of construction. This practical experience enables the learners to bring real-life problems with them into the Master's programme, which will be exemplified in Section 3.3.

2 RESEARCH APPROACH

The research approach in this study is basically a literature review of PBL, with a particular focus on problem formation, and a review of the Master's of Building Physics programme that has been selected as the subject context for this investigation. The literature review is expanded by empirical data that consists of problem formations, which are compiled among the Building Physics learners, demonstrating their ability to identify authentic problem formations within their everyday professional work and applying it as means for learning through their project work.

This paper will begin with a theoretical definition of problem formation in a PBL environment. It will then describe the Master's of Building Physics programme (curricula and semester description). Next, some examples of the student's problem formations will be given (i.e. research questions). This paper will then conclude with a discussion of the learners' opportunity and ability to draw real-life problems as a means for learning within the subject context of their study programme.

3 PROBLEM FORMATIONS IN PART-TIME MASTER'S PROGRAMMES

Aalborg University's pedagogical approach is solely based on the educational concept of PBL, which means that all of the students and staff enact the basic principles of PBL, including the part-time engineering Master's programmes. They are designed according to the Aalborg PBL principles; that is, they are problem-based and project-organised. The learner's collaborate in teams, applying theory and practice to solve real-life engineering problems.

The use of problem formations as means for learning and problem-orientation is one of the pillars of the Aalborg PBL model. In relation to the Master's programmes, problem-orientation becomes even more applicable since the learner's are professionals with a working-life and practice, from where problems can be identified. From a learning perspective, the context of the problem has to be as authentic as possible. If the context is the learner's workplace, then the criteria for relevance must be met. Another observation that speaks for problem-orientation in continuing engineering education is the fact that '*53–88% of the participants in continuing educations are adults who are work-related motivated'* (Lorentsen et al. 2010). The learner's are work-motivated and this may support problem-orientation; hence, the learner experiences work-related qualifications and benefits.

3.1 Problem formations from a theoretical perspective

There have been many academic discussions about 'what is a problem'. Overall Kolmos (2004) argues that definitions of problems are diverse in different professional areas. Quist (2004) has, from a literature review of diverse problem formulations, located a variety of understandings. Basically, there is consensus that a problem can be initiated by a w*ondering, a problematic situation* (Quist, 2004; Guerra & Bøgelund, 2014) or an *un-explored potential* (Guerra & Bøgelund, 2014 with reference to Borrows & Tamblyn, 1980; Quist 2004; Jonassen, 2011).

- A wondering: This indicates an observed phenomenon creating (qualified) curiosity (Quist, 2004), which can include situations, events, persons or a thing (Guerra & Bøgelund, 2014), something that happened or happens, something heard and seen (Quist, 2004), an uncovered need or wish (Guerra & Bøgelund, 2014; Quist, 2004).
- A problematic situation: This can, according to Quist (2004), be 'something you find a scandal', 'a lack of knowledge' or 'a lack of function' and it can be caused by contrasts; that is, between a wish and reality, conflicts, contradictions (Guerra & Bøgelund, 2014; Quist, 2004). In the definition of a problem, Guerra and Bøgelund (2014) explain the understanding of a problematic situation as also including the student's sorrow and/or indignation, frustration or stress, which makes them act to change this problematic situation.
- An un-explored potential. This idea is also a possible starting point for the problem formulation, such as the potential of a mobile phone not only as a device for communication but also to take photographs and video, agendas, e-mails, GPS applications and so forth.

Furthermore, consistent with the Aalborg PBL model, problem formations can be defined as theoretical, practical, social, technical, symbolic-cultural and/or scientific (Barge, 2010, p. 7). Depending on the type of problem and its starting point (a w*ondering, a problematic situation* or an *un-explored potential)* there is also a distinction between 'retrospective' or 'prospective' problem formulations (Holgaard et.al. 2015, p. 37), which can be characterised by:

- Retro-spective problem formations want to find justifications and explanations for something already happened;
- Pro-spective problem formations are designed to solve practical problems and to produce concrete solutions

In summary, problem-orientation, or problem formations, as one of the basic principles of PBL, cannot be described and categorised as one and only type of problem. Problem-orientation is a concept that relates to various different types of problem formations with different points of departure, implementing distinctive theory and methods that are the means for solving the problem and which are documented by the learners in their project work.

3.2 The part-time Master's of Building Physics programme

The Master's of Building Physics programme has a background in two urgent challenges of social significance:

- More than a third of the total Danish energy consumption goes to the heating of buildings. To realise the goals set by the EU and the Danish government to reduce CO2 emissions, it is imperative to significantly reduce the energy consumption of buildings.
- More than half of all building damage is caused by damp, such as in relation to energy efficiency and post-insulation. Many of the damages arise due to lack of knowledge or errors in design or execution. This results in an increased risk of damp accumulation, which may cause mould and poor indoor climate, and—in the longer term—degradation of materials and constructions.

Large energy savings in the construction industry can be difficult to achieve—both in building engineering, economic and cultural terms—and the damp-sensitive consequences result in additional complexity. In view of these challenges, there is a need for a competency lift among several professional groups in the building and property sector.

Building Physics Curriculum

Title: Master's dissertation of Building Physics
Module descriptions for the 4th semester

The Master's project is written within the building area and contains a presentation of previous research in the field and the Master's project relation to this.

Learning ou tcomes

Knowledge
The student must have obtained:

· In-depth knowledge of one or more selected subject elements.
· Wider insight into the field as regards theories and methods, as well as their mutual context, possibly in connection with a renovation or new-building project.

Skills
The student must have the following skills:

· Independently, systematically and critically identify, formulate and analyse the current problem formation.
· Relevantly relate the problem formation to the subject, including explaining and justifying the choices made in the delimitation of the problem formation.
· Relate the subject of the project to a historical context.

Competences

The student must have obtained the following competencies:

· Independently take and justify the choice of scientific, theoretical and/or experimental methods.

· Independently and critically evaluate the chosen theories and methods, as well as the project analyses, results and conclusions.

· Communicate relevant academic and professional aspects of project work in a clear and systematic way.

These are the goals for the learners and they should be followed throughout their Master's dissertation to demonstrate that they have achieved the defined learning outcomes, which is ranked in knowledge, skills and competences and which will be the basis for the assessment.

3.3 Cases

With a background in the two urgent challenges that have been identified (i.e. the need for energy savings and damp-sensitivity in construction), the learners have identified the following problem formations for their Master's dissertations.

Case 1: In-door damp insulation of an older brick-build basement: a case study and theoretical analysis of mineral insulation panels
How do the different types of insulation plates react to each other and does it matter what type of surface treatment is used?

Case 2: Bathrooms instead of back stairs: the conditions for establishing bathrooms in an existing back staircase
What are the damp conditions in a shared bathroom in a basement, bedroom with shower cabinet and existing back stairs?

Case 3: The thermal and atmospheric indoor climate in offices
What is the relationship between the measured and experienced thermal and atmospheric indoor climate in a number of offices in the City of Rødovre and the City of Copenhagen?

Case 4: Calculated energy versus measured energy consumption
How big is the energy requirement that is calculated in connection with the design of the building in relation to the energy used when the building is constructed and in operation?

Case 5: A study of the options for in-door climate and energy renovation in primary schools
This project examines whether or not there is a correlation between energy consumption (in terms of energy labels of the building) and the poor indoor climate in the public schools in Denmark?

On the basis of the problem formations, it is, of course, not possible to tell how well the learners have managed to meet all the learning outcomes outlined in the curriculum. However, it is possible to see if the problem formations are aligned with the topic of the semester and what type of problem formations the learners are able to come-up with.

4 DISCUSSION

This paper presents five different examples of Master's dissertation problem formations, which were randomly selected within the Master's of Building Physics programme. As the examples demonstrate, the learners identified innovative and real-life problems from their respective employment. Even though their backgrounds and jobs are very different, they all managed to draw up problem formations from their professional life, which also match the programme of study of the Master's of Building Physics.

The five problem formations were identified within the same study programme (curriculum) but they are diverse due to the different professional areas that the students worked in (Kolmos, 2004). The problem formations case 3 *'What is the relationship between the measured and experienced thermal and atmospheric indoor climate in a number of offices in the City of Rødovre and the City of Copenhagen?'* and case 4 *'How big is the energy requirement that is calculated in connection with the design of the building in relation to the energy used when the building is constructed and in operation?'* and case 5 *'This project examines whether or not there is a correlation between energy consumption (in terms of energy labels of the building) and the poor indoor climate in the public schools in Denmark?'* are all problem formations that can be identified as 'a wondering' since the learners explore phenomena which creates curiosity that can be disclosed. They can also be identified as retrospective projects because they seek justifications and explanations in regards to the phenomena. The problem formation case 1 '*How do the different types of insulation plates react to each other and does it matter what type of surface treatment is used?'* can be categorised as 'a problematic situation' because the project explores a lack of knowledge within different isolation plates and in their use. The problem formation is also designed to solve a practical problem, which is characterised as a prospective project. This is also the case for the problem formation case 2 '*What are the damp conditions in a shared bathroom in a basement, bedroom with shower cabinet and existing back stairs?',* which produces a concrete solution to a practical problem. However, the problem formations can be identified as 'an un-explored potential' because the project explores the conditions for establishing bathrooms in a back staircase.

This analysis, of the five problem formations reveals their differences. Even when identified within the same curriculum, the diversity is clear. Nevertheless, they all are 'discipline projects' (Kolmos et al. 2008) because the method, discipline and subjects are given beforehand and the learners have chosen the subject within a rather narrow area of building physics.

Additionally, only one of the selected problem formations has been completed through group work (two learners). The other four have been completed by individual learners, which compared to Aalborg University's ordinary Master's students (MSc) is a high share of individualists. This might be due to the real-life problem formations: the learners are work-motivated and want to explore their 'own' professional practice and context.

The five selected problem formations reflect the learners' ability and shows that they are able to identify real-life problems within the frame of the Master's of Building Physics curriculum. However, the learners have identified diverse problems due to their different professional contexts and practice.

5 CONCLUSION

In this paper, the part-time Master's of Building Physics programme was presented as a case for the analysis to answer the question '*what types of problem formations are learners able to identify from their working-life. It will also ask if this is aligned with the requirements of the part-time Master's study programme.* In conclusion, the analysis shows that the learners have ability and they are able to identify real-life problems within the frames of the Master's of Building Physics study programme. The problem formations are all aligned with the two overall identified topics of the semester: the need for energy savings and damp-sensitivity in construction. However, this rather narrowly identified topic leads to 'discipline projects' through which the problem formations are solved. When it comes to '*what type of problem formations the learners are able to identify'* this case shows that the five random selected problem formations are initiated by a wondering, a problematic situation and an un-explored potential. These three understandings of problems are represented in the case and they are retrospective and prospective perceptions of the problem formations. The diversity of the problem formations reflects the learners' work-related motivation because the problem formations are all initiated by their professional practice and context.

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Lifelong learning for the development of industrially oriented engineering skills:
4x4InSchools project

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ABSTRACT

Lifelong learning is a key factor for the development of a sustainable workforce. Recognized qualifications, such as engineering, alongside with transversal skills enhance individual employability. The authors aim to explore the rationale of one out-of-school and hands-on program, Project 4x4InShools (4x4IS), as one of the pillars for the development of engineering and technical skills aiming to develop a positive vision of industrial and technical careers. The long-term objective is to raise awareness and knowledge of industry, industrial processes and its impact on everyday life towards industry and future engineering or technical career development. Namely careers in the metalworking sector or related industrial clusters. 4x4IS it's an international project with countries from five continents. This paper will focus on the Portuguese experience that encompasses youngsters from 15-18 years.

The lack of qualified industrial technicians and engineers, and consequently the lack of a qualified workforce has been on the agendas of governments worldwide. This issue gets more pronounced since Europe faces an aging workforce. This work rests on the belief that the promotion of technical and industrial skills is an important tool for vocational education and lifelong learning in consideration for sustainable development practises. The "new" industry must compete by adding value to industrial processes and products. These assets are made possible by innovative engineering and countries with innovation inputs related to human resources training and development (engineering education) directly linked with higher competitiveness standards. Thus,

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4X4IS main objective is to bring youngsters closer to industry, believing that everyone can make a difference for individuals, countries and economic prosperity.

Conference Key Areas: Attractiveness of Engineering Education, Skills and Engineering Education, Continuing Engineering Education and Lifelong Learning

Keywords: Lifelong learning, Sustainability, Project 4x4IS; Industry

INTRODUCTION

Nowadays youngsters (their educational tutors and other stakeholders) have negative images and perceptions of the metal industry and industrially related careers, that tend to be dirty, heavy, noisy and physically exhausting. According to this global ecosystem, industry related careers, up to here, were not socially valued and were unattractive to young people searching for a future profession. It is recognized that the industrial sector is unable to inspire and motivate enough young people to enter engineering programs or technical training paths related to industry. Future predictions show a significant fall in meeting business and industrial needs [1 - 5]. According to previous studies youngsters' tend to choose "easier" paths and careers with another public image and recognition [6]. Various researchers have studied students' attitudes towards "industry", "science" and "technology". Researches show that youngsters often have stereotypical images and that those images impact their attitudes toward science, industry and technology [7-16]. It appears that if a youngster can see himself/herself in a career, then, the likelihood of that person persecuting an educational program to prepare him/her to that career increases [17].

This diminished interest in engineering, industry and industrial related careers has been long associated with several factors such as: perceptions and images of industry, lack of knowledge, lack of understanding the contribution of engineering for everyday life, teaching methods, curricula, mismatch between values and the way technical subjects are approached, career guidance, youngsters lack of understanding and appreciation for their potential future role in society [18-23].

"Young people need to see the point of it all. They especially want practical application (not just practical work). This might be learning about a job, developing personal skills, experiencing team work or having a subject explained to them in terms of its contemporary context" [23, p.2]. Youngsters need these divergent approaches to learning versus most schools' curriculum approaches. It's unquestionable that lifelong learning with all the associated strategies are central issues for the development of a capable workforce and productive countries.

The Royal Academy of Engineering predicts a shortfall of 200,000 qualified engineers in the UK by 2020 [24]. The skills shortage [1] is an ongoing challenge for the project. The project 4x4 in Schools addresses this issue and builds the skills and talent of young people aiming their future career paths.

Fig. 1. 4x4ISchools Project Logo

1 THE PROJECT 4X4 IN SCHOOLS

1.1 4x4 in schools

The Jaguar Land Rover's 4x4 Global Challenge is an annual competition for 11-19 years' olds to design and build a radio-controlled, four-wheel drive model vehicle that features Land Rover's all-terrain characteristics. Over the course of a school year, students research, design and manufacture their vehicle, and perform tests before they compete with teams from other schools at the competition stage. Jaguar Land Rover (JLR), and international partners provide guidance and support throughout the process, including visits to participants' schools and youth groups. An average of 116,000 young people participated in the challenge each season starting on 2015/16.

In the last semester of 2015, JLR launched the Land Rover 4x4 in Schools programme globally in partnership with various in-country coordinators, including Portugal. Teams from countries as far afield as Australia, United States of America or South Korea competed in their national challenge competitions and the best teams from 15 countries meet every year for the World Final.

The 4x4 Challenge is operated in partnership with the Institution of Engineering and Technology (IET), JCB Academy (JCB), Science, Technology, Engineering and Mathematics Education Coalition (STEM), DENFORD and several leading engineering and education organisations. Young people participating in the scheme can be accredited for their achievements through schemes such as CREST, ASDAN and the Duke of Edinburgh Award and the Arkwright Trust.

The base for the program design is the creation of an ecosystem that potentiates capabilities and competencies toward future industrial careers, anchoring strategies on collaborative learning, active learning [25-32] creative thinking, project based learning, among others.

1.2 4x4IS objectives

- The challenge is educational but also provides participants with the opportunity to experience something that is realistic, as well as relevant to the operations within industry.
- Provides an experience where students can develop and embed knowledge and skills which may be later required in further education or their chosen career.
- Is motivating, exciting, challenging and fun for both the students and adults involved.
- Provides young people with the opportunity to work as part of a team or independently to develop problem solving skills and techniques.

- Enables real-life engineers (STEM Ambassadors) to connect with the future of the industry by sharing their engineering knowledge, expertise, enthusiasm and commitment with students from a range of backgrounds.
- Provides an opportunity for students to learn and develop through participation in a hands-on practical experience.
- Enables young people to gain understanding and awareness of what engineering is, encouraging them to actively think about a technical career.
- Integrates subject knowledge from key areas of the curriculum with the wider agenda of work-related learning, enterprise, key skills and personal development.
- Enables young people to be recognised for their achievements through schemes such as CREST, ASDAN and The Duke of Edinburgh Award.

1.3 4x4IS activities

The teams have access to several support resources, such as on-line support or a designated JLR tutor, 3D engineering software, computer numerical control machines (CNC), 3D printing machines. There are well defined rules for the competitions (either regional, national or world) that the teams must comply if they want to attain with the purposed objective. The teams must take in account several items when designing, developing and materializing their projects:

1. Each team must contain a minimum of 3 to a maximum of 6 students, each one with defined roles (e.g. Team manager, marketing manager).
2. Use Computer Aided Design (CAD) software to produce their ideas and model it in three dimensions (3D).
3. Use several manufacturing technologies to produce their own 4x4 vehicle.
4. To manufacture the body shell each team must choose either to use technology available at the school/college or at a real manufacturing company as a sponsor.
5. Follow the specifications concerning several rules, each car body must have some electronic features such turn lights when the environment is dark, tilt sound when the vehicle has a lateral inclination.
6. Produce a design folder including initial ideas; design development and evidence of the developed work, maximum 20 pages (A3 size).
7. Develop partnerships. 4x4inschools teams are encouraged to develop partnerships and seek assistance from academic, businesses and industry throughout this engineering process. However, all aspects of this engineering and industry partnership should be represented in the team's portfolio. This includes CAD designs, electronics, and the creation/production of the portfolio, which should remain the responsibility of the students in the team.
8. Prepare and deliver a 10 minutes' verbal presentation on their work with or without visual aids.
9. Learn all skills by self-learning methods or by seeking help from partners referred in item.

Fig. 2: 4x4inschools track

For the youngsters' teams these are complex projects, for so, they are reminded about some considerations such as:

- Resources: CAD/CAE packages help them to draw and to develop their ideas in 3D. As with most drawing packages, it takes time to learn how to use the software. CNC and 3D printing machines allow youngsters to see the project take "body" but the technology use must be studied and applied with caution. Wind/smoke tunnels allow youngsters to see the scientific aerodynamic principles and test them.
- ICT tools: the resources used are complex, and so are the results to be achieved, and the ways to support self-learning. ICT tools allows youngsters to manage their time and learning in more efficient ways. They can communicate and share doubts, help each other, have access to privileged material, and see real case studies, alongside with the JLR tutor support.
- Research: Teams are asked to investigate existing 4x4 car designs to find out the latest developments occurring in the world of 4-wheel drive design. Concentrate research on areas that could help teams, for example, gears, car body shell design, and try to apply the principles to the team ideas and in-hands projects.
- Testing: teams may want to consider testing a variety of car designs, or car parts to evaluate their performance in pass the obstacles.
- Manufacturing considerations: Rookie teams' have access to a beginner 4x4inschools Kit which is constituted by simple radio-controlled vehicle, but teams need to change at least the body shell and upgrade the electronics. Professional teams can build their own vehicle from zero.

Fig. 3: World final 2016

2 THE PORTUGUESE EXPERIENCE

2.1 4x4 IS Portugal

The cooperation between JLR and the Portuguese Technological Centers started in 2015, and it was organized two national finals. The project was developed in a consortium and the experience was obtained from similar projects for sensitize young students for Industry and Technical careers and related study areas. The consortium is a partnership with eight Portuguese Technological Centers spread in the Portuguese territory, from north to south.

Until the beginning of 2017 the consortium organized two national finals where 14 teams participated each year. It was possible to promote several immersion sessions directed at high schools (42 schools) encompassing more than 45.000 students. For the season 22016/017 it's already ongoing work with 14 teams' ant its foreseeable to make aware of the project and its objectives approximately 120.000 youngsters.

For the season 2015/16 the challenge actively engaged 87 young people, 78 males and 9 females with ages from 13 to 19. More than 50% of those with ages between 15 and 16 years old. The global activities within the project encompassed 38.388 young students, for the season 2015/16.

Table 1. Season 2015/16 demographic data

Targets	Schools	Students	Aware
Planned	15	90	15.000
Reached	18	87	23.388

Table 2. Season 2015/16 students by age group

Age	%
13	3,4%
14	10,3%
15	10,3%
16	25,3%
17	25,3%
18	20,7%
19	4,6%

Every year since the beginning it has been organized a National Final with the aim of selecting the best team for representing Portugal in the World Finals. Depending on getting extra financial support or sponsorship, it could be possible to select a second team to go to the World Championship, and provide teams in the two levels of the competition (beginner and professional).

Since the first time the Portuguese teams faced the challenge the perceptions were very good from the different national and international stakeholders. The youngsters differentiated on the resilient way that obstacles were faced and dealt with – e.g. technical and economic. All international rules 4x4inschools for the selection of the best teams were applied in the Portuguese Final and in the World final. The teams have permanent support from JLR tutor, technological centres, schools and teachers, among others, to manage their efforts during school time and free time aiming to the accomplishment of the project objectives without compromising academic achievement. As ongoing work the 4x4 IS Portugal team is conducting a longitudinal study, that started on the season 2015/16 aiming to assess perceptions and future training and development choices along with professional paths.

3 CONCLUSIONS

4X4 in Schools self-learning approach, supported by JLR and in-country partners, showed that it is very important for youngsters to apply their knowledge, skills and proficiency to tasks with an overall perceived meaning and using several different means (distance support, face to face meetings, collaborative work, sharing and developing knowledge through communities of practice) simulating as close as possible real industrial settings. And on the other hand, the contents and the final product with metal industrial relevance make youngsters aware of the impact that individual skills have on a wider project development and the results.

The authors believe that youngsters individually and has a team can be “trendsetters” who set their own learning and development paths and strategies. This concept points to the importance of e-learning, with all technological tools provided, in informal and non-formal learning has a mean for individual and group skill development towards sustainable development.

Young students need to experience “scenarios” in a hands-on approach with active learning strategies, to contextualize opportunities that the Metal Industries, the car industry and the industrial sector in general can provide. Making the linkage of the importance of technical and industrial related paths not only to individual fulfilment but also for the promotion of a sustainable industry contributing for the re-industrialization and for prosper countries and/or regions.

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Creating a Smart Learning Space:

Learning With and Learning From Student Generated Data about Learning

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ABSTRACT

In a course from our Social and Human Sciences master program, students are taught the social and behavioural sciences of learning ("learning sciences"). Students also learn how to conduct social and behavioural research by collecting data on campus during semester long projects. Proposed by internal "clients" from the school, the projects bring data on students learning both to teachers and to the institution, thus transforming the school into a lab for research and development on teaching and lifelong learning in science and engineering – a Smart Learning Space. This paper describes the design of this course together with examples of projects and their impact at different levels in the school. In particular, this course has laid the foundations for a culture of evidence-based and data-driven teaching and learning within the institution. We discuss the challenges we had to tackle as well as some perspectives for the future.

Conference Key Areas: Engineering Education Research, Continuing Engineering Education and Lifelong Learning

Keywords: Lifelong learning; Evidence-informed engineering teaching and learning;

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INTRODUCTION

Engineers who graduate today will, in ten years' time, be working in a radically changed environment. Their ability to respond effectively will depend on their capacity to continue to learn and develop throughout their career. Hence, 'lifelong learning' has been identified as a key competence in engineering education [1, 2]. A second key issue in recent years has been the growing realization of the importance of evidence-informed teaching in science and engineering [3, 4] as well as more generally. An optional Learning Sciences course offered to Science and Engineering students has sought to address both these issues.

While the role of social and human sciences in engineering education is often ill defined, there is a clear rationale for including learning sciences and social and behavioural research skills within engineering programmes. Beyond the learning for students themselves, the data generated from learning research can inform educational decisions taken by learners, teachers and the school more generally, transforming the school itself into a teaching and research and development lab.

This paper will first outline the research base behind these concerns, will then describe the course and some of its outputs and will then look at its impact within the engineering school more generally.

1 RELATED WORK

Social and Human Sciences have been seen as a required component in the training of engineers for many decades [5]. Despite this fact, there remains a lack of clarity as to their role, with rationales offered including: (a) the development of personal qualities such as modesty, openness and creativity [6,7]; and (b) the development of 'professional skills' of working in multi-disciplinary teams, adopting ethical practice, being aware of social impacts and causes of technology, and communicating effectively in international and intercultural contexts [2].

Of any social scientific or humanities discipline, learning sciences has a particular and valuable role to play in engineering education. Lifelong learning has been identified as among the key 'professional' skills of engineers [1,2] and an ability to think about learning has been found to be associated both with increased attainment in formal education and with an increased ability to apply classroom learning to 'real-life' situations [8]. Learning sciences also plays a role in enhancing students' interdisciplinary competences since learning science is, by definition, an interdisciplinary space, drawing on neurology, sociology, educational psychology, information sciences, and anthropology. This mix of social, behavioural, and hard science disciplines provides a fertile space for engineering students to engage in the interface between disciplines. Studying how to research learning also provides practical skills in social research, while the ethical standards which apply in social and behavioural science research provide an opportunity to engage students in learning how to apply ethical principles such as self-determination, informed consent, vulnerable populations, as well as physical, psychological, and sociological risk.

Beyond these practical utilities for the learner, however, the study of learning sciences also provides an opportunity for the engineering school as a whole to become a learning organization. There is now clear research evidence that many commonly used higher education teaching practices are found to be less effective than underused alternatives such as collaborative learning, concept maps, use of visualization technology, use of conceptually-oriented tasks, and use of interactive teaching approaches [3,4,9]. However, although this research evidence tells us that some methods of teaching and learning work better than others "in general" (that is, they are "evidence-informed"), their implementation in particular contexts and settings will often depend on locally-collected evidence about effectiveness – an approach which is known internationally as Scholarship of Teaching and Learning (SOTL) [10]. Engaging in learning sciences research can provide this evidence.

The next section describes one attempt to do this, in practice.

2 THE SMART LEARNING SPACE

Within the social and human sciences strand of courses, a learning sciences course has been offered at Master level in Ecole Polytechnique Fédérale de Lausanne (EPFL) since 2012. The course has two goals: (a) introducing students to learning sciences research, with a particular focus on what it has to say about how they themselves learn, and (b) teaching skills of designing and conducting a piece of quantitative research on learning.

Around 60 students register for the course each year with 45 to 55 continuing to complete the research project.

In the first semester, learning sciences are introduced through interactive lectures and through a series of in-class experiments. These experiments mean that students are confronted with data about their own learning in different situations which ensures that the findings are integrated by students at a personal level rather than being seen as abstract representation of learners "in general". These classes also mean that students have an experience of how experiments and social surveys are actually designed. The experiments also generate real-life data which, in turn, is used in exercise/tutorial sessions by students to practice skills of social data analysis.

In the second semester, students use the knowledge and skills developed to carry out a research project, from the design phase to the reporting phase, in groups of 3 or 4. For the projects to be open-ended and realistic enough to provide an authentic and rich learning environment, project topics have to be research questions that can be answered with data collected locally. Students are assessed based upon a research report and a poster that they produce. In the first year of the course, students generated their own project titles, however from 2013 on, students were provided with a list of possible titles with each project being required to be (a) focused on learning and (b) of use to some stakeholder within the school (e.g., a teacher, other students, departments, or administrative units). Initially potential "clients" were largely sourced through personal connections by the teacher. Since 2014, the results of the student projects have been presented each year at a public poster session and again at the annual faculty retreat, and this has led to a growing interest in the projects within the school. In the academic year 2017-18 there are 13 different projects, with clients including teachers in Chemistry and Environmental Sciences, the school's Marketing, Gender Equality, MOOC, and Teaching Support units, the Library, and the Vice Presidency for Innovation.

The research that students carry out within the school, in turn, feeds back into the institution. It has helped teachers to test innovative teaching approaches and to validate their assessment methods. It has provided feedback on what Bachelor students have learned and where they struggle which, in turn, has allowed teachers to adjust their approaches to teaching and assessment. It has provided the school's pedagogic team with information about how students experience tutorials/exercises which in turn has allowed tutor training to be re-developed to better meet local needs. It has also provided data about learning which is fed back to students and which allows them reflect on and change their approaches to learning. In this sense, the course creates a virtuous cycle of individual learning, while producing data which allows for institutional learning. In this way, the whole school becomes a teaching and research and development lab in learning sciences. It is this idea that we refer to as the "Smart Learning Space".

Given that the research is being carried out by students who lack extensive training in learning sciences and in social research methods it is not surprising that the quality of their results can be variable. In many cases, however, the quality has been exceptional and a number of the studies have been presented by the students and the course teacher at international conferences.

3 RESULTS

Over the last five years, over 60 projects have been completed by students. While the projects have been diverse, a notable sub-set of projects has focused on the learning and challenges of our first-year students. Rather than present a random selection of different projects, a number of these projects which showed thematic continuity are presented in this section.

In 2014, one study compared exam grades from 236 first-year students with their score on an internationally normed test of conceptual understanding in classical mechanics called the Force Concept Inventory (FCI) [11]. The goal was to validate the course exam, and indeed the study showed that the exam did in fact test student conceptual understanding. However the data also showed that quite a few students who scored reasonably well when tested on their conceptual understanding still failed the exam. This data therefore made clear that, while understanding physics is a requirement for passing first-year courses in the institution, it is not enough [14].

One hypothesis to be explored as to the reasons for student failure was that the students were using inappropriate strategies in seeking to solve the problems. As Schoenfeld has noted, university exercises differ from those faced in high school in that high school exercises often require only the recognition of an exercise type and the application of an algorithm (called algorithmic exercises), while at university level exercises can often require the construction of an algorithm itself (referred to as problem-solving exercises) [12]. It was hypothesised that students were failing to recognise which exercises were simply algorithmic and which required actual problem solving. This idea was tested through a number of studies, looking at how students categorised mathematical problems [15], and through the use of a talk aloud protocol to explore the differences between student's self-reported problem solving approaches and their actual problem solving [16]. Further data was collected from a review of 136 first year student exams in order to catalogue the error types which arose most frequently [17].

The growing body of evidence within the school also prompted teachers to carry out their own studies. One, which focused on this question of student problem solving methods , also provided evidence that students who successfully identified an exercise as requiring a problem solving approach, and who understood how to apply such an approach, tended to be more successful in solving the kinds of complex problems posed in our first year exams [18].

Together, these studies provided convincing evidence that the difficulty for many of our students was not in their content knowledge, but in their methodological approach to problems and in their beliefs about such problems. This evidence has, in turn, led the school's Vice Presidency for Education in 2017 to adopt a strategic project on improving first year students' methodological skills in solving complex problems. This project draws on a number of strands including:

- A newly published book on problem solving and study skills for science and engineering students [19]
- A companion MOOC and learning companion website/app with in-build personal analytics to allow students to get direct feedback on aspects of their approaches to learning and problem solving
- An increased focus on modelling of and feedback on problem solving methods by professors
- A pilot project to assess the use of peer feedback as a tool in supporting students' learning of problem solving.

4 ISSUES AND CHALLEGES

While the impact and value of the course is evident, its development and implementation have not always been easy.

No resources have been allocated to the course since it started other than a single teacher who is responsible for managing teaching and experiments in a class of 60 learners and for overseeing between 13 and 18 projects each year. Resources required for gathering data, preparing posters, and for providing additional technical supervision and support for students have been begged or borrowed from supportive colleagues and units.

Secondly, ensuring that the projects were designed with an appropriate ethical basis was a challenge. Since the timeframe of the project was a single semester, students could not reasonably be asked to go through the time-consuming ethical approval process. At the same time, the projects needed to be ethical in their approach. The solution to this difficulty was to have a research protocol for the course pre-approved by the school's human research ethics committee which set a series of boundary conditions for the research projects. Students are required to demonstrate that their research design respects this protocol.

A third difficulty arises from the interdisciplinarity of the projects: students with training in mathematics, computational sciences, and machine learning are often able to apply sophisticated statistical and analytical techniques which are beyond the knowledge base of the teacher. This is an extremely desirable difficulty and demonstrates the exciting opportunities that arise in interdisciplinary fields. However it is also a challenge that needs to be carefully addressed in the assessment of the students' work. In such cases, clients have been invited to provide advice on the methods and techniques used, while the ultimate responsibility for grading rests with the teacher.

A more intractable difficulty arises from the dangers of over-taxing classes with data collection: thirteen groups of students each targeting the same population and each hoping to maximise their sample size has a danger of wearing out the goodwill of their fellow students as well as of the professors who are regularly requested to provide access to their classes. This difficulty does not have an easy solution, and has, on occasion, required active intervention on behalf of the course teacher to manage frustrations.

5 CONCLUSION AND PERSPECTIVES

As an interdisciplinary space that addresses lifelong learning and the transfer of competences from classroom to professional practice, which develops research and data analysis skills, and which addresses questions of social context and ethical practice, the arguments for learning sciences being available to engineering and science students are evident. Beyond this, our learning science course has created a context in which the whole school has been reframed as a teaching and research and development lab on engineering and science education – a Smart Learning Space.

The development of the course has not been easy. Lack of resources, ensuring ethical practice, assessing interdisciplinary work and avoiding friction within the school are all ongoing challenges to be managed. At the same time, the evident learning of students and the obvious value of their research to other learners, to teachers and to the school as a whole evident. Herbert Simon, both a renowned Computer Scientist and a Nobel Prize winner for Economics, once said that "Improvement in post-secondary education will require converting teaching from a solo sport to a community-based research activity" [13]. The study of learning sciences and learning research by students within our engineering school has provided an opportunity to build exactly this kind of community-based research on learning in our school.

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6.

Open and Online Engineering Education

ATHENS Course on Application of Ionizing Radiation

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ABSTRACT

The **ATHENS Programme** (Advanced Technology Higher Education Network/Socrates) is a 1-week exchange session, held twice a year (usually in March and November), by a network of 15 leading European technological universities. The Czech Technical University takes part in this programme since 2003. The case study of one of the courses, the Course on Application of Ionizing Radiation, is a subject of this paper. The course consists of 14 hours of lectures, 8 hours of experimental exercises and 3 hours of experimental demonstrations. The excursion into the Proton Therapy Centre and to the National Technical Museum is also included. This programme covers representative applications of ionizing radiation in various branches of human activities. In general, using radiation for diagnostics and therapy in medicine is more or less known to general public, however the course covers also the less known and discussed fields, as e.g. applications in geology and geophysics, art and archaeometry, and for analytical purposes. Some information about radiation protection and environmental radioactivity is also included. 20 students took part in this course in the March 2017 Session, from 8 universities. Except description of the course, the paper summarises also some feedback from students, which serves as the background for improving future runs of the course.

Conference Key Areas: Physics and Engineering Education, Skills and Engineering Education, Curriculum Development

Keywords: ATHENS course, application of ionizing radiation, course programme, feedback.

INTRODUCTION

The **ATHENS Programme** (Advanced Technology Higher Education Network/Socrates Programme) consists of 1-week exchange sessions, held twice a year (usually in March and November), organised by a network of 15 leading European universities of technology. The programme is aimed at carrying out intensive specialization courses, given at each member institution, enabling students to attend one of the courses offered by the network universities during 7 days. Since the groups of students are international, the language of the courses is English.The objective is to give students a brief immersion in another European education system. Each institution defines the number of credits given to its students participating in ATHENS courses (generally 2 or 3 ECTS credits, but some universities including CTU give no credits). Students are asked to evaluate the course they attended by filling an on-line evaluation form at the end of each Session. This experience, in many cases, gives students the desire to carry out studies of a longer duration (MSc and PhD levels) at an institution different from their home institution and thus facilitates exchanges between students of the major European technological institutions. About 60 courses are offered in each ATHENS Session.

The programme is coordinated by the ParisTech. It was established with the support of the European Communities SOCRATES Programme with annual subsidy from 1997-2001. Today, the Programme is mainly founded by contributions from the member universities. This is a disadvantage, as universities have usually limited and insufficient budgets all over the Europe and they do not cover full expenses to students (e.g., CTU covers about 60 % of living expenses and full travel expenses, if they do not exceed some limits given by varying distances to the destinations). The courses cover the wide spectrum of fields, mostly in science and technology, but they are also opened to arts and humanities [1].

Usefulness of this programme is out of any doubts. Science and technology are not the most popular disciplines among young people and any international programme at the good level can contribute to the attractiveness of studies at technical universities. And, moreover, such short time stays do not interfere substantially with study plans at the mother university, but they can bring an intensive view into a different country, a different university, a different branch of study and a different study system.

The Czech Technical University takes part in this programme since 2003. Its faculties offered the following courses for the ATHENS March 2017 Session [2]:

- Application of Ionising Radiation
- Text Searching Algorithms
- The PIV Method in Fluid Mechanics
- Management and Economics
- Introduction to Vibrational Spectroscopy
- Talent Management

The case study of one of these courses, the Course on Application of Ionising Radiation, is a subject of this paper.

1 OBJECTIVES AND STRUCTURE OF THE COURSE

The course is carried out by the Department of Dosimetry and Application of Ionising Radiation of the Faculty of Nuclear Sciences and Physical Engineering of the Czech Technical University in Prague. This faculty was established in 1955 in connection with starting the Czechoslovak nuclear programme, and though it added also some non-nuclear topics into its profile (mostly applied mathematics and non-nuclear parts of physics) during the years of its existence, it is still one of the strongest educational institutions in nuclear branches of science and technology in Europe. It covers practically the whole spectrum of nuclear and radiation theory, experimental practice and applications, having even its own small school nuclear reactor and its own small tokamak, both mostly for educational purposes.

The objective of the course is to obtain an overview of the theoretical and experimental background, concerning the application of ionizing radiation and radionuclides in industry and medicine. Depending on the mode of application, information is in most cases obtained through effects of radiation on matter. Detection and evaluation of radiation can give the desired information about these effects. The state of applications is described in lectures, but it is also implemented in the laboratory classes and experimental demonstrations.

The programme consists of:

A) Seven 2-hour lectures:

- Characteristic of Ionizing Radiation and Radioactivity
- X Ray Fluorescence Analysis
- Application of Ionizing Radiation in Geology and Geophysics
- Application of Radiation in Art and Archaeometry
- Radon-Problem in Radiation Protection
- Application of Ionizing Radiation in Medicine
- Personal Dosimetry and Radiation Protection

B) Four 2-hour experimental exercises:

- Polymer-gel dosimetry
- Spectrometry of Gamma Radiation with HP(Ge) Detector
- X Ray Fluorescence Analysis
- Personal Dosimetry - TLD

C) Two 2-hour experimental demonstrations:

- GOLEM - Tokamak thermonuclear installation
- Application of Ionizing Radiation in Medicine

As seen, this programme covers representative applications of ionizing radiation in various branches of human activities. Generally, using radiation for diagnostics and therapy in medicine is more or less known (though usually not from the point of view of physical principles) in general public, however the course covers also the less known fields, as e.g. applications in geology and geophysics, art and archaeometry, and for analytical purposes. Moreover, also scientific books about applications of ionising radiation (except applications in medicine and health physics) are not too frequently published. It is evident that it is not possible to cover all the issues connected with extensive use of ionizing radiation within a week, but the programme of the course can arouse students' interest in it, including links to the further educational literature for serious candidates.Let us bring at least two references for those, who want to make themselves more familiar with these issues, or for those, who want to follow us in our effort to extend knowledge of students in this field. [3, 4].

Some social activities are also included, mostly with the aim to make participants familiar with the city and the students' life. First of all, this is the orientation meeting during the first day of their stay, which gives to participants the basic information about the city and the university, and then some so-called European dimension activities: the Prague guided walk, the Prague discovery game, which is an unusual sightseeing in a form of a special game for groups, which ends by a dinner at a secret place, the Country presentations in the popular youth club, and finally, the Farewell dinner in the students' restaurant. Some of these activities are organised by our students from the CTU Student Union and from the CTU International Student Club.

As a part of the social programme, the excursion into the National Technical Museum was also included. NTM is one of the most popular and important museums in Prague and, after recent complete restoration and renovation of both the building and the collections, it is also one of the best technical museums in Europe. It is to some extent oriented not only to technology, but also to science [5].

The programme is intended for advanced students, who should be familiar withgeneral mathematics and physics at the level of standard courses at technical universities. Moreover, some knowledge of atomic and nuclear physics and of interaction of ionising radiation with matter is necessary.

Students receive copies of ppt presentations of all lectures and manuals for the practical exercises in advance. The course is finished by a written exam of 2 hours duration, which, however, is relatively simple and failure is very rare.

2 THE POINT OF VIEW OF LECTURERS

20 students (which is the maximum capacity due to the capacity of laboratories for practical exercises) took part in the course in the March 2017 Session, from 8 universities (9 students from the KU Leuven, 3 from the TU Wien, 2 from the École Supérieure de Physique et de Chimie Industrielles de la Ville de Paris, 1 from the Mines ParisTech, 1 from the Warsaw University of Technology, 2 from the Politecnico di Milano, 1 from the Universidad Politécnica de Madrid and 1 from the Technische Universität München). The main problem of these courses (not only of this one, but also of the other courses in the past and on the other topics) was that the participants were put together mostly by their interest on the topic. Though they all were from the top technical universities, they were as a minimum in the 4th year of study, and some knowledge of radiation physics was a necessary prerequisite, they had different background in physics and mathematics. This means that both lectures and exercises needed to be built on rather general explanatory level, to be understandable for all participants. On the other hand, we had not noticed any language problems, the level of English of all participating students was very good.

March or November dates of the courses, which are prescribed by the ATHENS Programme, are not too suitably chosen from the point of view of usual weather conditions. Participants may arrive on Friday and have a free weekend, which they can use for sightseeing. Prague is a very nice and interesting city, but these months are not the best ones for this purpose (on the other hand, this period is out of the main touristic season and Prague is not so overcrowded by tourists). However, the more important problem is that these dates coincide with teaching in the summer or in the winter semester, and therefore it is a bit difficult to harmonize the course schedule with the schedule of standard courses for our students. This difficulty not so much concerns the lectures, which is easier to organise, but finding space for laboratory exercises, which substantially contribute to the attractiveness of the course, is not easy.

And last but not least, organising and teaching in these courses asks for some enthusiasm of both teachers and students. As mentioned above, the ATHENS

Programme started with the support of the European Communities, which helped to prepare the structure of the courses and was a perfect starting motion. However, it is nowadays financed by participating universities and participants, which means that it operates with the limited budget, cheap accommodation for participants has comfort corresponding to the low costs, etc.

3 THE POINT OF VIEW OF STUDENTS

The feedback from students was obtained by discussion with them, and by a questionnaire they complete. They marked each lecture and exercise in the scale from 1 (the best) to 4 (the worst), which followed the old system of classification of exams before introducing the Bologna system and was fully satisfactory for this purpose. The mean value of such classification was mostly between 1.5 and 2, usually with slightly better values for exercises than for lectures. Surprisingly, the excursion into the Prague Proton Therapy Centre, the very modern medical installation, using the most advanced radiation therapy methods, which was included this year as the practical demonstration of application of ionising radiation in medicine, obtained relatively low rating (2,36). Possible explanation is the little pedagogical experience of a Center employee who accompanied the students and gave them an interpretation. General organisation and the level of course materials were also evaluated, the ratings were very positive this year (no mark 3 or 4, the mean values 1,24 and 1,28).

Students may also use this opportunity for verbal expression of their opinion. Unfortunately, this is sometimes readable only with difficulties, and sometimes the opinion of various students is self-contradictory, nevertheless it gives some more complex picture and feedback. Let us give some responses to individual lectures (without any order of importance and without any language corrections):

- A little too much material on some slides; some introductory theory (on slides, not orally) would be useful.
- Great material, maybe spend more time on this material.
- A little monotonous.
- Nice effort of interactivity.
- Too many examples of application.
- Out of interest field.
- Very clean and illustrative lecture.
- Out of interest but good lecture anyhow.
- It is sad that it comes on Friday morning.
- I am not interested in art, but I understand it is an important topic.
- Too much theory, more examples would be better.
- Too much applications and examples.
- Sometimes too much details.
- Interesting because of examples he brought.
- A lot of repetitive examples.
- Maybe he has to speak more quickly and increase the program.
- The first part (Technical) was good, but the examples were too many.
- Not enough detail, would be good to have more insight about diagnostic techniques.
- It was nice to have all the examples.

And some responses to practical exercises:

- Not much theory, chemistry explanations would be useful.
- A bit short in time.
- Theory is not well explained and much more complicated than we were told.
- Interesting technique, good assistant.
- The assistant did not look very enthusiastic.
- It was a pleasure to go to those practical exercises.
- Interesting, but not so many to do.
- We were not allowed to do much, not so interesting.
- I appreciate the professor. It was very funny.

About the visit in the Proton Therapy Centre:

- Lack of motivation and I did not understood at all the explanation, what is bad, because it would be very interesting.
- Nice centre and technology, but the guide was not skilled enough to attract the full audience.
- The guide could not explain it very well, otherwise it might be interesting.
- It was experience for my whole life. I was really interested!!!
- It was interesting to see the concrete implementation, but I would like to have more links with the theoretical aspects.
- Bad general explanations for the entire group from the guide.
- Interesting, but the guide was not passionate about presenting it.
- Maybe it is better to do a lecture before the visit.

As seen from these more or less randomly selected responses (however legibility of the hand-written comments played also some role in this selection), this survey, in which all participants of the course took place, gave the wide, though sometimes a bit contradictory view to the course. Some repeating comments to individual parts of the course should be used in preparing the next run. For example, some lectures were criticised for too many slides, too much text on slides or for too many similar examples of applications. There is no problem to reduce it. Revising and extending theoretical explanations of practical exercises would also be useful. Good relations of our department with the Proton Therapy Centre allow us to ask next time for some other expert from the staff for guiding and explanations. The problem, which, however, cannot be easily solved, is connected with differing interests of participants. They know the topics of the course in advance from the complete programme on the web pages of the ATHENS Programme, and if they claim in their responses, that they are not interested in chemistry, art or anything else, they must be reconciled with the fact, that these issues are mentioned. But it is possible to say, that in general the theoretical and practical parts of lectures, exercises and the course as a whole are well balanced.

4 CONCLUSIONS

The ATHENS Programme is a good example of activities, which liven up the “standard” university courses and extend the spectrum of topics taught in them with minimum time load for students. Nevertheless, they lose one week during the running semester at their university. One week stay at the university abroad is quite short time for making acquaintance with the university, the city and the country. However, it can awaken deeper interest in the university or in the topics of the course. Good quality is the necessary prerequisite of universities participating in this programme, and therefore, good quality of courses, lectures and students can also be expected.

The course on application of ionising radiation has been step by step improved according the responses of participants during the past years. Some improvements are still possible, as nobody and nothing is perfect, but we see that majority of students express their satisfaction with its quality. Moreover, the topics of the course are included into study programmes only at a few European universities. The Faculty of Nuclear Sciences and Physical Engineering of the Czech Technical University can take advantage from its more than 60 years long tradition in the field of nuclear sciences.

The ATHENS Programme is probably less known than some other programmes of student exchanges, especially as the ERASMUS Programme, and it is also less universal, being limited only to 15 participating technical universities. Its contribution to the European dimensions of engineering education is, however, non-negligible. And, said with some exaggeration, we are prepared to polish our course to full perfection.

The next ATHENS session will be held on 11-18 November 2017.

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Teacher development in Massive Open Online Courses

Evaluating reflective practice in a sustainability MOOC

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ABSTRACT

Massive Open Online Courses (MOOCs) appear particularly relevant in education for sustainability. Teachers need to critically reflect on their teaching to develop as teachers and improve student learning, but the MOOC related literature has paid little attention to teacher development. In this paper, we apply and evaluate a framework for teacher development – Brookfield's critically reflective practitioner – in a MOOC context. We present a case study of two teachers who developed and delivered the *Sustainability in Everyday Life* MOOC. We analyse how they used Brookfield's four reflective lenses: the autobiographical lens, the student lens, the peer lens, and the scholarship lens. While all four lenses contributed to the reflection process, they were insufficient in a MOOC context. Additional and important reflective lenses include the perspectives of the organisational leadership, the public and media as well as learning analytics. We discuss the implications of those additional lenses in the MOOC context, but they could be relevant for modern higher education in general.

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Keywords: Massive open online course (MOOC), teacher development, critically reflective practitioner, reflective lenses, sustainability, E-learning

INTRODUCTION

Massive Open Online Courses (MOOCs) have recently become a significant force in higher education, attracting universities and companies to invest in the development of and research about this new learning environments ([1], [2], [3]). The promise of MOOCs to provide open, high-quality educational resources to a broad audience ([4], [5]) make them particularly relevant in sustainability education, even though the previously promised revolutionary effects on higher education learning have not yet fully materialized ([6], [7]). Some of the unresolved problems include high dropout rates [8], teaching and quality issues [4] and the concern that MOOCs mostly attract learners with high socio-economic and educational status [9], as well as a high IT affinity [2]. The quality of course resources has a major influence on learner engagement in MOOCs [10]. Yet for the teachers, their experience of developing and running a MOOC usually differs significantly from normal campus teaching [1]. That raises the question of how they can and should develop as teachers in a MOOC environment and whether this process differs from campus teacher development.

1 BACKGROUND: TEACHER DEVELOPMENT AND REFLECTIVE PRACTICE

One approach to teacher development in the educational literature is the concept of *reflective practice* ([11], [12]). Reflection entails "*those intellectual and affective activities in which individuals engage to explore their experiences in order to lead to a new understanding and appreciation*" [11]. Reflective practice is the continuous use of reflection as a tool for revisiting experience in order to learn from it and frame complex problems of educational practice [12]. Various models of reflection and reflective practice have been developed. Among the most prominent are Brookfield's critically reflective practitioner [13], Kolb and Fry's concept of experiential learning [14], Argyris and Schön's idea of single- and double-loop learning [15], which led to the concept of triple-loop learning [13], and Gibbs' structured debriefing [16]. Most models of reflective practice share the premise that prior experience is examined and the result deliberately used to improve current practice. This is often triggered by a need or a disruption of the usual and can involve several iterations, levels and perspectives [17]. Thus, an important element to support reflective practice is feedback to assess and manage teaching performance.

However, little attention has been paid to teacher development in the MOOC related literature. Student engagement and learning success have been the most important MOOC research themes, followed by MOOC design and curriculum [18]. Teacher development was not part of the list at all. Thus, there is a need for a systematic framework for teacher development in the context of MOOCs. In this work, we attempt to apply and evaluate Brookfield's *critically reflective practitioner* [13] model in the MOOC context. After describing Brookfield's model in more detail, we analyze how two MOOC teachers used it to reflect upon their teaching practice in the MOOC *Sustainability in Everyday Life*. Based on this analysis, we assess the value of each model component and identify important perspectives that are missing.

2 BROOKFIELD'S CRITICALLY REFLECTIVE PRACTITIONER

According to Brookfield, teachers need to become critically reflective practitioners to improve their teaching practice. This is not a trivial endeavor, as individuals are typically "*trapped within the perceptual frameworks that determine how we view our experiences*" [13]. Teachers can strive to overcome this limitation by using different perspectives, or *reflective lenses*, that provide different and new angles on what they are and do. This enables teachers to see beyond their own interpretive filters and to detect false assumptions, and is therefore superior to exclusively relying on own experiences. Brookfield identifies four reflective lenses: 1) the *autobiographical* lens or the teachers' own experiences as learners, 2) the *student* lens or their students' experiences, 3) the *peer* lens or their colleagues' experiences, and 4) the *scholarship* lens or drawing on the educational literature.

2.1 The autobiographical lens

The autobiographical lens is the foundation where teachers focus on their prior experiences as learners. By examining their autobiographies, teachers are taking on the role of the student, enabling them to better see their practice from their students' perspective. Through the autobiographical lens, teachers can "*become aware of the paradigmatic assumptions and instinctive reasonings that frame how we work*" [13].

2.2 The student lens

Self-reflection is the basis of reflective practice. But Brookfield encourages teachers to also engage with student feedback to enhance student learning and possibly reveal *"those actions and assumptions that either confirm or challenge existing power relationships in the classroom"* [13].

2.3 The peer lens

The peer lens stresses the importance of feedback from colleagues. Colleagues usually have similar experiences as the teacher on a broader level, but might have different approaches to deal with issues when it comes to more detailed practices.

2.4 The scholarship lens

Brookfield's final lens is the scholarship lens, or engaging with the literature on higher education. Reading educational literature or conducting educational research can provide various perspectives on the teaching situation. It also equips teachers with a more advanced vocabulary to describe and discuss their practice to "*understand the link between their private troubles and broader political processes*" [13].

3 METHOD

In order to assess Brookfield's framework in a MOOC context, we conducted a qualitative case study of the MOOC *Sustainability in Everyday Life* offered by Chalmers University of Technology [19].

3.1 The MOOC *Sustainability in Everyday Life*

Sustainability in Everyday Life was developed as one of Chalmers' first MOOCs because of the university's strong emphasis on sustainable development. This introductory-level course aimed at developing the learner's capacity to grasp the complexities of sustainable development to enable them to make better-informed sustainable choices and decisions in everyday life. The course was developed from scratch since here was no prior campus course or material. The course included five modules that each consisted of an introductory video, several mini-lectures with test yourself quizzes, weekly assignments (mainly multiple-choice quizzes), and a peer graded writing assignment as a final exam. The MOOC ran during summer 2015 with about 10k learners and had a re-run during autumn 2016 with about 5k learners.

3.2 Data collection

Data were collected from two Chalmers teachers who developed and delivered the MOOC and used Brookfield's framework to reflect upon their teaching. We used an ethnographic approach to study how the teachers used the framework and to assess the value of the different reflective lenses. Data were collected through 1) observations of the teachers during the course development and delivery phases, 2) interviews with both teachers before the course, 3) focus group meetings after the course, and 4) reflective diaries written by the teachers.

4 RESULTS – USING THE REFLECTIVE LENSES IN MOOC TEACHING

4.1 The autobiographical lens

Through the reflective diaries, it is possible to follow the teachers' experiences. Both teachers have a background in systems thinking, and prefer a deductive teaching approach, beginning with the big picture and then adding the appropriate details :

> *I think we have also tried to do this in the MOOC by starting with an overview for each of the five topics that are addressed (the introductory lecture) and then go into more detailed subjects that are part of these topics.*

The teachers' prior experiences led to some differences. Teacher B pointed out that (s)he, while having poor mathematical skills throughout high school, experienced a tremendous improvement during university studies, since (s)he enjoyed the math-related courses. Based on this experience, teacher B believes that enjoyment is a key factor for creating motivation, both on campus and in a MOOC:

> *I also try to make my teaching enjoyable for the students, because I am convinced that this will increase the motivation of some students at least to do well.*

During the design and development of the MOOC, (s)he stressed that it should be fun to do the MOOC, both for the teachers and the learners. Teacher A also experienced some struggles as a student, particularly for subjects that were "less interesting". This often manifested itself as issues with connecting sub-complexes of knowledge. In contrast to teacher B, teacher A therefore stressed the importance of details and understanding connections, even if that is not always pleasant:

> *I realised the importance of taking care of the details and actually do the job! Learning is hard work, not always something I enjoy, but the knowledge is great fun.*

This view influenced this teacher's view on instructional design. Good teaching should help students to identify the topics that they need to learn through exercises, projects and discussions:

> *I believe that dialogue, questions, and talking are important parts in learning and teaching which create co-learning and discovery of knowledge which also the students appreciate. That part is really fun!*

This highlights the importance of interactivity in learning and clearly impacted the MOOC's design, particularly in the planning phase, where interactivity was a guiding concept that got somewhat compromised in the implementation phase due to the technical limitations set by the MOOC platform.

4.2 The student lens

The student lens was mainly used when the teachers examined the comments in the discussion forum and the feedback in the course evaluations. Both were anonymous and the feedback was at times quite negative, especially during the first run of the MOOC, where harsh language, e.g. through writing in capital letters ("shouting"), was used in the discussion forum to criticise the early assignments. Though it can be hard to accept negative feedback, the teachers felt that it was nevertheless useful:

> *To some extent at least, the harsh criticism during the first run helped us to improve the MOOC a fair bit.*

The teachers reacted to the negative feedback by engaging a beta tester to identify mistakes in quizzes and assignments before they were released. This contributed to an overall improved quality. Some learners thought the workload was higher than expected, but overall the feedback after the first run was positive and learners appeared to be satisfied with the course and their learning outcomes. The quality of the video material was generally perceived as good, an indicator that the theoretical foundations of the different topics were sound. The learners' feedback was mainly used to revise the quizzes and assignments for the re-run of the MOOC. This revision led to a more civilised and constructive climate in the discussion forum. The discussion forum also revealed the learners' engagement and passion for the course topic. This change of climate and the course evaluation pointed to an improvement of the course's learning activities.

4.3 The peer lens

The peer lens was primarily used during the development of the MOOC, where the two teachers interacted with different groups of peers at different times. The colleagues at their division were important for identifying topics for the videos, and for recording and providing video material to the MOOC.

Another group of important peers was the production team, both during the development and the running of the MOOC. In the development phase, the production team provided guidelines and practical solutions for various issues. Among other things, this included video production and presentation techniques, manuscript preparation, assignment and exercise design, platform implementation and content organisation. The production team contributed to the reflection processes with its feedback and by pragmatism, problem solving and agility, particularly during the intense start of the MOOC.

During the re-run, members of the production team were beta testers of the revised content and they helped with monitoring the forum. If there were any technical issues with the videos, exercises or the exam they could quickly take corrective measures. The peers at the teachers' division were interested in taking part in the evaluations and also using the MOOC for research purposes. They also helped providing arguments to gain further funding for MOOC development and re-design.

4.4 The scholarship lens

The scholarship lens included both the study of educational literature and a number of presentations and publications by both teachers. The literature on MOOCs was used by the teachers to support the development phase and to reflect upon the course results as a benchmark. For the course design, literature on best practice was consulted that provided suggestions regarding video length, activation exercises and presentation style.

Both teachers used the experience of the MOOC to conduct pedagogical research on the MOOC that was presented at several conferences and published in journals and as book chapters [20]. A major topic of reflection in these publications was the different roles that teachers take in a MOOC in order to make it successful.

4.5 Evaluating the four reflective lenses

The four reflective lenses have been useful for the teachers to reflect on MOOC teaching practice. Each of the lenses contributed in a somewhat different way to the reflection process, as demonstrated. Overall, the teachers experienced the autobiographical lens and the student lens as most influential. It is however difficult to generalize this judgement given, for example, the crucial feedback from peers on certain aspects of the MOOC. The teachers also mentioned several other sources of feedback with additional perspectives that might be somewhat particular to the MOOC context and did not seem to fit into any of the lenses above. These lenses are discussed in the next section.

5 DISCUSSION – ADDITIONAL REFLECTIVE LENSES IN MOOC TEACHING

First, as the learner interaction in a MOOC happens in an online environment, the teachers felt that a lot of data are generated that can be analysed to reflect upon the MOOC. They used *learning analytics* to see, for example, different activity trends, completion rates of assignments and videos, and correlate that with other factors such as video length, to identify outliers in the material that need adjustment.

Second, for the teachers, it became apparent that the quality of a MOOC is not only judged in relation to learning, but also to other objectives. In this regard, the Chalmers *leadership perspective* provided an additional reflective lens. Though not directly involved in the production of the MOOC, this important stakeholder had objectives such as open access to the learning resources, increased visibility and improved campus education through the MOOC. These goals are not by default connected to good teaching, but since they are perceived as important for the project as a whole, the teachers are assessed and receive feedback along those dimensions as well. This might result in somewhat conflicting recommendations for teaching practice in the MOOC. Related to the objective of increased visibility, the teachers also incorporated feedback from a marketing perspective that was mainly provided by the marketing departments at Chalmers and the MOOC platform. It also concerned more teaching related aspects such as the course title, the formulation of learning objectives, the course description and syllabus, as well as the engagement with learners on social media platforms. The critical reflection regarding those aspects did not only relate to the course goals and intended learning outcomes, but also to marketability, e.g. in search engine optimization and job market demand.

Finally, *the media and the public* also provided a reflective lens. The teachers gave several interviews in various media. In an article published in the local newspaper, the content of the MOOC was heavily criticised and the teachers (and Chalmers) were accused of being normative and of blaming everyone who did not appreciate the learning outcomes of the MOOC. To be publicly criticised in the local media was perceived as scary and affected the reflection process of the teachers about the MOOC practice and how it should be communicated to the media and the public.

In sum, we have identified three additional and important perspectives or reflective lenses that teachers needed to take into account in MOOC teaching practice: the learning analytics lens, the leadership lens (including marketing), and the media and public lens. Each of those additional lenses contribute to the reflection process in its own way. These additional lenses are probably more relevant in a MOOC context than in campus teaching, since teaching in a MOOC takes place in a more exposed and complex environment than most campus teaching. Thus, more factors must be considered in MOOC teaching as a whole. In principle, all of those aspects could also be relevant for campus teaching, but since campus teaching usually takes place in a more well-defined and institutionalized environment, those factors are not as obvious and eventually also handled by other roles than the teacher. However, the modern university is slowly transforming and the learning analytics perspective is certainly relevant for campus teaching today which increasingly uses learning management systems and digital tools. Further research should examine those aspects.

6 CONCLUSIONS

In this article, we examined how two teachers used Brookfield's model of the critically reflective practitioner to reflect on their teaching practice in a MOOC. We conclude that the four reflective lenses in Brookfield's model are not sufficient to be a reflective teacher in a MOOC context, but need to be augmented by at least three more lenses. Learning analytics, the leadership and marketing perspectives as well as the interaction with media and society have all been demonstrated to be relevant. These aspects are not part of campus courses and are additional perspectives for teachers to reflect about. It is apparent that the reflective practitioner in the MOOC context has to reflect on a wider range of aspects than in traditional teaching to become a good teacher, but also has access to a wider range of feedback.

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An Internet of Engineering Lab Things

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ABSTRACT

We have completed the first phase of a large-scale synchronous remote engineering laboratory with large class sets of experiments, and low latency video, and data and control interactions. We based our system around a large class set of 88 National Instruments Educational Laboratory Virtual Instrumentation Suites (NI ELVIS) and 324 top boards. Of the 240 top boards available to the second stage electronics course that will first use the lab, there are six types. Two were available commercially, and four were designed in-house. We report on the curriculum context that drove the design processes behind these boards, with a particular focus on the challenge of giving distance learners of electronics the same learning opportunities as campus-based students. The boards are accessed through a reconfigurable HTML5 interface (one per experiment) that mimics the reconfigurable nature of a typical electronics test bench. Virtually instant responsivity is provided via peer-to-peer video streams and websocket connections for data and control.

Conference Key Areas: Open and Online Engineering Education, Curriculum Development, Attractiveness of Engineering Education

Keywords: Electronics, synchronous laboratories, peer-to-peer communications, low-latency control, data, and video

INTRODUCTION

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Preparing engineering students for their careers now means preparing them to operate in a connected world. With commercial activities spanning the globe, it is no longer possible to assume that graduate engineers will be working in the same time zone as their colleagues or their equipment, let alone in the same building. Other vital applications of remote equipment in the professional engineering world include cases where the environment is too hazardous for humans, perhaps due to extreme pressure, temperature, radiation, contaminants, moving machinery or inaccessibility. Together our two organisations (educator and equipment supplier) are well placed to allow students to explore the remote usage of equipment during their engineering degree, because all students are distance learners. The question we have posed ourselves, is how can distance learners of electronics experience the same learning opportunities as campus based-students? Particular aspects of interest to us are the ease of access to the equipment, the ability to configure your working area to suit your preferences, and the speed of the interaction.

1 CONTEXT

1.1 State of the art

The remote presentation of practical work can take a number of forms. Simulation-based and hardware-based approaches both have their merits. For example, simulation environments are highly scalable, and are becoming ever more realistic with the introduction of virtual reality techniques [1]. Hardware based approaches have the benefit of including difficult-to-compute stochastic and non-linear effects without risk of introducing misleading artefacts due to the limitations of simulations. With the growing prevalence of computing devices in laboratory environments, the involvement of computers in mediating the learning process would seem inevitable [2].

Students typically either access a hardware-based remote experiment directly, and interact with it in real time (synchronously), or set parameters for a batch job to run when the equipment can schedule the experiment (asynchronously). Asynchronous experiments can service many students by running well-controlled experiments in an efficient manner. Synchronous experiments tend to be less resource efficient because they permit extended, continuous student exploration, but they offer value in that a variety of conditions can be explored in a safe manner, some erroneously, providing self-led experiential learning [3]. Synchronous interactions with remote laboratories allow tutor support [4]. Synchronous remote laboratories are also dependent on the communications infrastructure. It is well known that even small delays can cause the human brain to expend effort in memorisation [5], so latency is undesirable. The continuing world-wide effort to provide routine broadband connectivity provides an opportunity for synchronous remote laboratory experiences to reach a wider geographic audience without suffering from noticeable delay. This has been a major interest for us.

Data gathering in remote laboratories appears to produce better learning outcomes when performed individually [6]. This indicates the value in selecting equipment for remote experiments that is inexpensive enough that large class sets can be commissioned. Aside from the resource scheduling benefits, this also helps address one of the barriers to institutional laboratory sharing [7]. Large class sets of equipment can address the immediate needs of organisations that have large classes (numbering several hundreds or more) that wish to add practical work provision with a short lead time.

1.2 Local curriculum

Building on [the academic institution's] existing expertise in remote laboratories, we will allow students to have remote hands-on learning experience without having to invest in individual hardware for each student. We have implemented large class sets

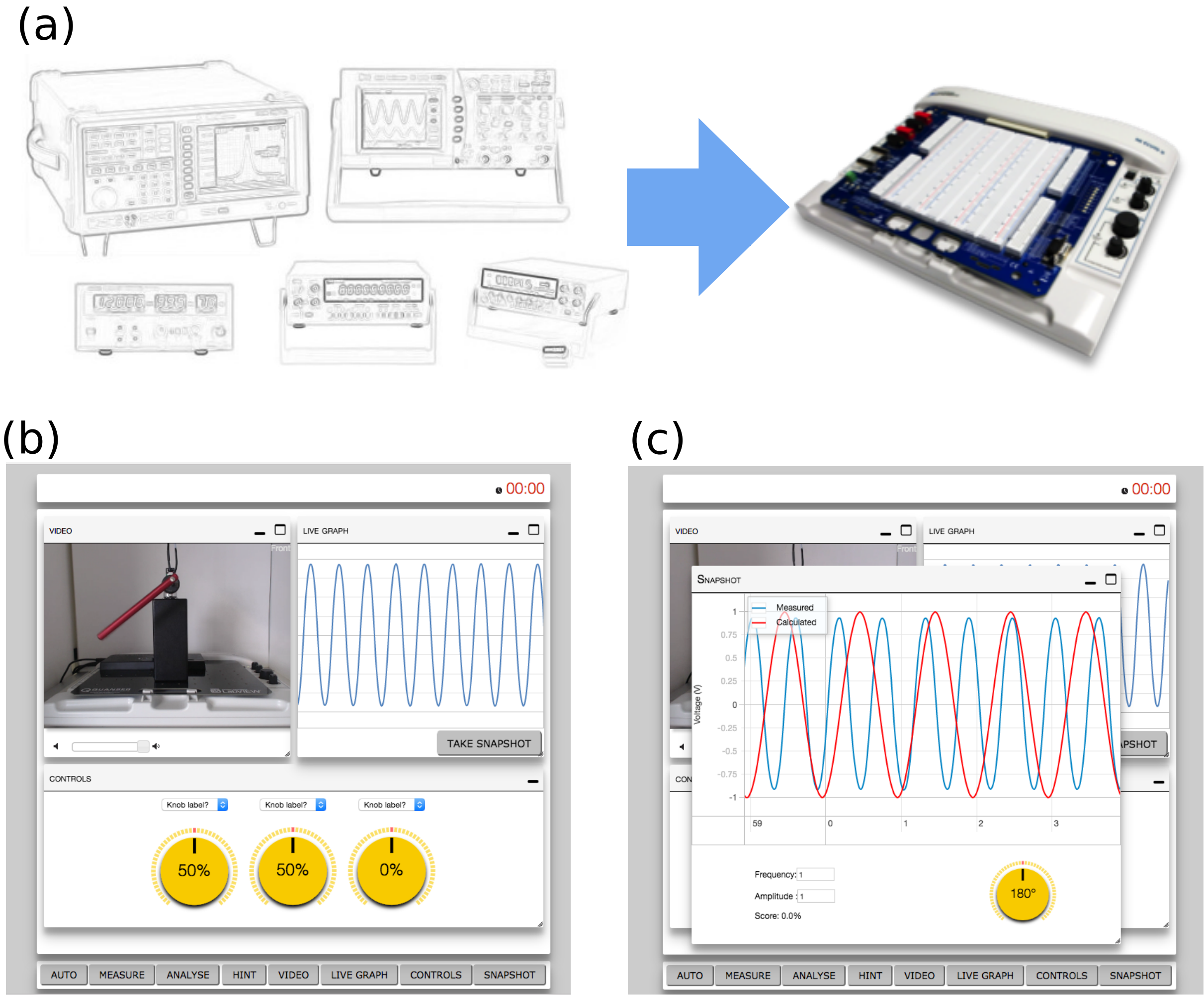

Fig. 1. Reconfigurable interface mimics the reconfigurable nature of an electronics test bench (a) schematic of a test bench, (b,c) screenshots of the web interface for an electronics activity relating to alternating current (at present stage of development).

of experiments, based around a set of 88 National Instruments ELVIS II+ boards, with connectivity to the PC running experiments in LabVIEW via a USB interface.

The NI ELVIS includes 12 instruments such as an oscilloscope (100 MS/s), digital multimeter (5.5 digits), function generator (10 V_{pp}), variable power supply (+15 V), Bode analyzer, and other common lab instruments in a compact form factor allowing for a space efficient set-up. All instruments and IOs are available and accessible through software and are connected to the devices to test and control physically through a connector. The connector is open allowing connectivity to off-the shelf top-boards or custom designed boards.

We have built rack space and internet connections sufficient to support over two hundred simultaneous experiments, each connected to a single student or a small group. This equates to nearly 5000 hour-long sessions available per day.

Our first major curriculum usage is for a second stage electronics course, and we are provisioning the lab with 40 sets of each experiment, including a mixture of the off-the-shelf top boards from Quanser (pendulum, mechatronic actuators), and custom designed boards (sensing, ranging, digital electronics). This enables us to use the same set-up based on the NI ELVIS platform.

1.3 Infrastructure

We have built a communications infrastructure around peer-to-peer video and websockets, to enable virtually instantaneous responsivity no matter where on earth the students may be, relative to the equipment, so long as broadband connectivity is available. We have successfully accessed experiments in trials from the UK, Europe, the USA, Hong Kong, China and New Zealand, whilst retaining perceived lag-free operation.

2 INTERFACE

2.1 HTML5

Students connect to the equipment via an HTML5 interface, which gives them authentic access to genuine real-time data, and enables a wide range of computing and mobile devices to be used. A live video, live data streams, controls, and analysis routines are available in each interface. The interfaces are customised for each experiment. An example of a screen is shown in Fig. 1(b,c). We have moveable and resizable windows within the webpage that mimic the way that typical bench equipment can be moved and reconfigured as the practical work proceeds.

3 EXPERIMENTS

3.1 Approach

Our first use of this particular remote laboratory is in a new stage two electronics course that is one quarter of a year's study contribution to an accredited general engineering degree. The course highlights the role of sensors, logic and actuators in enabling electronics systems to interact with the real world, as shown in Figure 2.

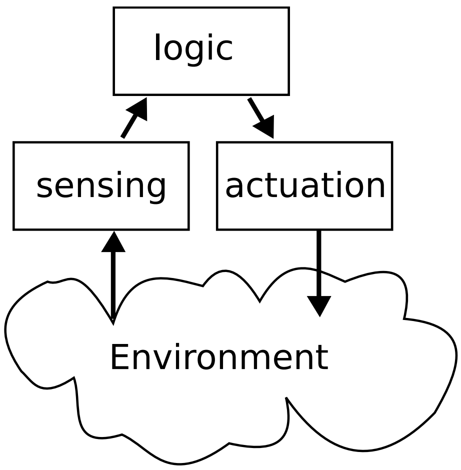

Fig. 2. The sensing, logic and actuation cycle that we focus on in our second stage electronics course

Since the degree course does not have a pure electronics engineering focus, we are using a driven pendulum as a mechanical source of signals that are analogous to alternating current waveforms, thus bridging more mechanically-minded students into the abstract world of invisible electronic signals. It also serves as mathematical preparation for future exercises on the Fourier series, by challenging them to correctly identify the amplitude and frequency of the sine wave they produced from the pendulum (see Fig 1.c).

We selected a second commercially available top-board for the last experiment. For the remaining experiments, we developed our own ELVIS top-boards so that we could take advantage of the remote learning environment most effectively. Photographs of the latest prototypes of our top boards are shown in Fig.3, with the light/strain board in Fig. 3(a), the ranging board in Fig. 3(b), the Fourier exercise in Fig. 3(c), and the digital exercise in Fig. 3(d).

Table 1. ELVIS-based experiments for stage two electronics course

Name	No.	Source	Learning
Pendulum	44	Quanser	Distinguish amplitude and frequency of AC signals
Sensors	40	Own	Explore role of resistors in buffering circuits
Ranging	40	Own	Manipulate raw sensor data to obtain meaning
Fourier	40	Own	Ability to identify patterns in noisy data
Digital	40	Own	Operation of logic gates
Motors	40	Quanser	Strengths and weakness of different motors

The sensors board measures light and strain in two separate experiments. The strain experiment has a structural beam subjected to bending by a servo, with two strain gauges. One is driven by a constant current source, the other is in a Wheatstone bridge that has an amplifier circuit on the output. Students can then directly compare the results obtained by each approach and assess them against criteria such as circuit complexity and signal quality. The light experiment contains three pairs of light emitting diodes and photodiodes (two visible, one infrared) and a rotating drum with a surface that is progressively shaded from white to black. One of the visible photodiodes is connected to a commercially-available current-to-voltage amplifier. The other two photodiodes (one visible, one infrared) are connected to current-to-voltage amplifiers with programmable feedback resistors. This allows the students to see the effect of adjusting the resistor value across a wide range, and to gauge the sensitivity of the circuit.

The ranging board has ultrasonic and infrared ranging sensors, and a calibration target that moves linearly. One sensor reports a distance measurement directly, while the other gives a voltage measurement that is non-linearly related to the distance. The students must unravel the calibration challenge, and then can scan a rotating area that contains three objects (cylinder, square section tube and triangular section tube). We have included a triangular object so that at certain angles of the rotating table, it will disappear from the ranging trace by deflecting the probe signals, and if it is shadowing another object, that ‘disappears’ as well. In this way, students will be able to appreciate challenges encountered by real world sensing systems such as those in autonomous cars.

The Fourier board allows the students to control the generation of a rectangular wave of 12.5%, 25% or 50% duty cycle, so that the Fourier decomposition exercise is conducted on a signal that they have generated themselves. The different duty cycles produce different harmonic patterns, and there are additional peaks arising from imperfections in the system. The interface has an exercise that encourages students to exercise judgement over whether a peak in the frequency domain is part of the expected signal, or from the noise.

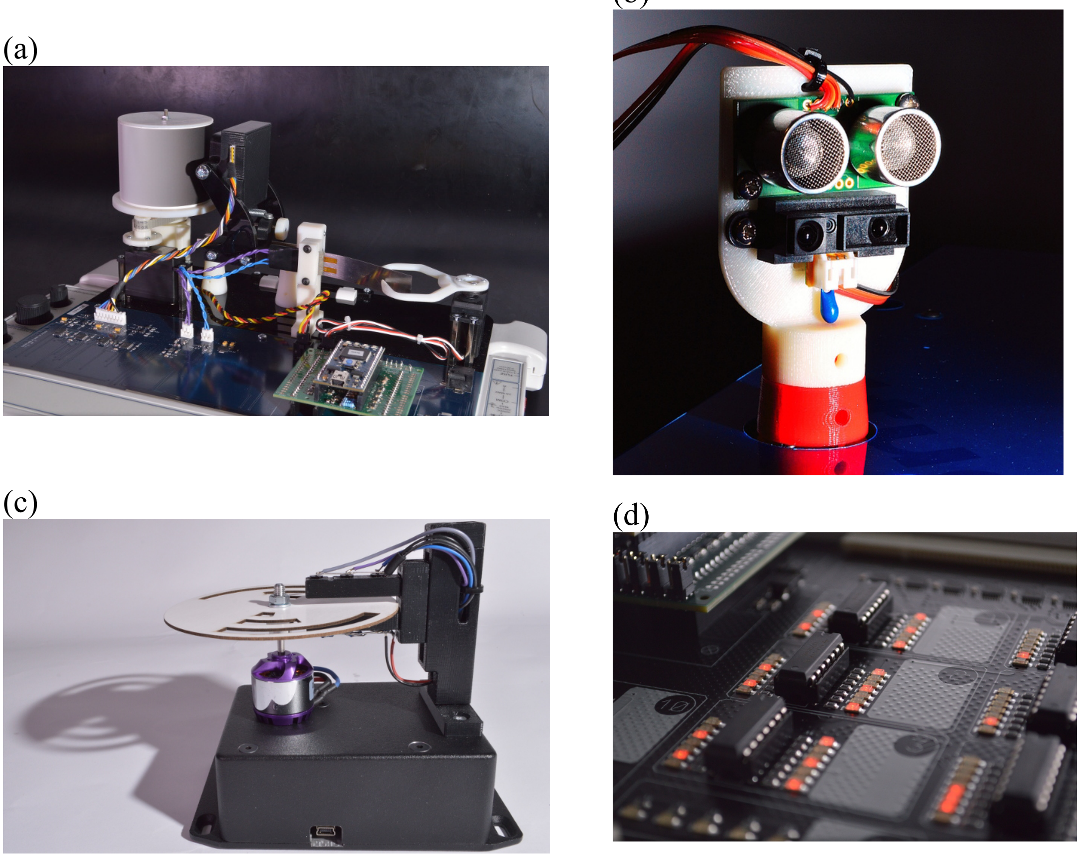

Fig. 3 Custom top-boards for ELVIS designed in house for remote laboratories in a second stage electronics course (a) light and strain sensors, (b) ultrasonic and infrared ranging sensors (rest of board with automated targets not shown), (c) rectangular-wave generator for Fourier exercise, (d) close-up of part of the digital electronics board.

The digital board is intended to expose to view the inner workings of circuits comprised of logic gates, allowing logic values to be probed directly, anywhere in the circuit. It is also intended to replicate the challenge of a conventional laboratory where abstract logic circuits must be converted into concrete wiring diagrams before they can be physically realised. Neither of these goals is particularly well met by programmable logic systems, such as field programmable gate arrays (FPGA), programmable logic controllers (PLC) and microcontrollers. For these systems, the inner connections cannot be directly probed, and often the wiring diagrams (or their equivalent) are calculated automatically for the user.

Instead, we have put a dozen 74LS series CMOS chips onto a board along with light emitting diodes on every input and output. We provide a schematic editor in the HTML5 interface that represents those chips, in the positions that occupy on the board, and let the student connect the pins by drawing wires. The student is free to wire the chips in any way they wish. The wiring is accomplished in the digital board by using a clocked virtual wiring network. The wiring network comprises a serial-to-parallel register to write to all the input pins, and a parallel-to-serial register to read all the output pins after they have settled. A wire drawn by the student is implemented as a table lookup in the output values. This approach can handle all the possible circuits that the student can wire up. For example, the board readily handles the feedback loops and race conditions found in an edge-triggered set-reset flip-flop implemented with two pairs of cross-coupled NAND gates (nine NAND gates in total).

4 SUMMARY AND ACKNOWLEDGMENTS

We have completed the first phase of a large-scale synchronous remote engineering laboratory. We had begun the task by asking how can distance learners of electronics experience the same learning opportunities as campus based-students? For ease of access to the equipment, and supporting the preference of distance learners to individually gather remote data, we implemented large class sets of experiments. So far we have 88 NI ELVIS base units and 324 top boards, including custom and off-the-shelf designs. This offers an overall value proposition that is attractive compared to asynchronous and virtual environments.

The NI ELVIS units combine multiple test instruments into a single unit. Together with our HTML5 interfaces, which have movable and resizable windows, we mimic the reconfigurable nature of a conventional electronics test bench. We also made the interaction virtually instantaneous by using peer-to-peer video and websocket connections for data and control. Via an appropriate broadband connection, these are virtually lag-free from almost anywhere in the world.

Thus we can say that with the appropriate choice of communications infrastructure, and experimental equipment, the pedagogic needs of remote engineering education can be met using synchronous remote laboratories. Together our two organisations have demonstrated our alignment on the future of engineering education, whether remote or face-to-face, so as to prepare students to thrive in a connected world.

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"Learning Analytics is about Learning, not about Analytics."
A reflection on the current state of affairs.

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ABSTRACT

Learning Analytics is a form of educational datamining that is used on the level of the classroom and the student. This information can be used to predict behaviour and address that, or it can be used for teachers and students to reflect on their learning processes and behaviour. Two examples of LA are presented: one with data from a VLE, one with student progress data and in these examples it is shown where the challenges for the near future of LA lay: there is a need for technology assessment of these technologies, the focus needs to be on learning and appropriate interventions to enhance learning, and on the teachers who are the real key players in the successful application of learning analytics to enhance learning.

Conference Key Areas: open and online engineering education, engineering education research

Keywords: Learning analytics, engineering education, VLE

INTRODUCTION

Big data are presented qualified as the fuel of the future. Clearly it is not something to ignore and with the increasing use of technology, education is also challenged to engage with it. The analysis of big data for education is referred to as educational data mining and when it is applied to the classroom is often referred to as learning analytics (LA). This paper is about the use of learning analytics for the meso- and micro-environment of teaching and learning: the levels of the classroom and the students. The emerging development of digital tools for teaching and learning is

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creating a playing field of data. Companies very quickly learned how to benefit from the use of data in various ways, think of how Amazon.com makes recommendations for books and products based on previous orders and browsing history and behaviour of customers with similar interests. Fortunately, it has and it will increasingly affect education, but it proves to be a tough challenge to let education benefit from these developments. This paper is about the promises of big data or in this case learning analytics to help improve education and what we as educators can do about it to make it work

In recent years, lots of energy has been put into the development and deployment of virtual learning environments (VLEs) and MOOCs and in research into these developments, assuming that these technologies will have a large impact on education, but these efforts have not yielded major changes or many new insights that have enhanced teaching and learning (Gašević, Kovanović, & Joksimović, 2017).

In this paper, we discuss the state of affairs with learning analytics using two recent examples that should help practitioners understand where the current challenges in research and praxis are and what they can expect of LA in the (near) future.

1 LEARNING ANALYTICS

1.1 What is it?

The history of higher education is littered with imperfect technologies: Slides, overheads, film, video, educational television, multimedia CDs, Second Life, PowerPoint slides, chat rooms, forums, learning management systems. All promised to revolutionize learning and change the face of education. So far only the computer and the internet have lived up to such expectations. With the introduction of the internet and web-based applications like VLEs it became possible to online collect data about learning processes and achievements from students using these technologies and make them available for analysis. The idea behind learning analytics is to use this data to inform/support educational decision-makings. According to SoLAR '*learning analytics is the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs*' (Siemens & Gašević, 2012). Gašević, Kovanović and Joksimović (2017) quote Reimann (2016) who notes that, while the use of data in educational research and learning sciences has been present for quite some time, learning analytics differs from the "traditional" data analyses in education as it focuses on the longitudinal collection of a large number of data points from authentic learning environments. "Although the field of learning analytics supports the collection of a wide range of data, a bulk of existing work in learning analytics is dedicated to digital traces collected through the interaction of people with technology, content, and/or other people (Gašević et al., 2017). An important task of learning analytics is the development of measures that can a) offer practical insights into learning processes and outcomes, and b) be theoretically interpreted (Gašević et al, Dawson, & Siemens, 2015). Both are important: if LA is to give practical insights, it means that the variables that are used in the analytics are actionable. For instance, from student success research it is well know that gender has a major impact on success, but just recruiting more women into the population will not aid student success as such. With LA it would be far more interesting to explore in what areas of the curriculum we can identify areas where we can intervene meaningfully building on the body of knowledge on teaching and learning.

1.2 Academic analytics versus learning analytics

The focus of what we do in classrooms often is on the student and the teachers, but these stakeholders operate within the context of an organisation. McKenny and Mor (2015) incorporate these three perspectives in their model on how learning analytics, learning design and teacher inquiry synergistically support a rationale core consisting of aims, context, vision and values underlying education. This rationale should be a consistent and explicit understanding of: teaching and learning aims; context; pedagogical vision; and educational values within an organisation. While many teachers welcome the processes of learning analytics, learning design and inquiry, few have sufficient resources and expertise to engage with each in a sustained and systematic manner. The conceptual model shown in Figure 1 illustrates that each process is guided by, and can contribute to the refinement of the same rationale. In this model learning analytics looks at data, teaching/learning practices and social structures to inform teaching and learning design and as such, forms the input for learning design and teacher inquiry. Again, this would only work if the learning analytics are based on actionable variables. These three perspectives build on and contribute to the same rationale and, additionally, the three core processes can synergise. All of these processes are complex and with every process a teacher is confronted with several challenges, which will require time and expertise to deal with (McKenney & Mor, 2015).

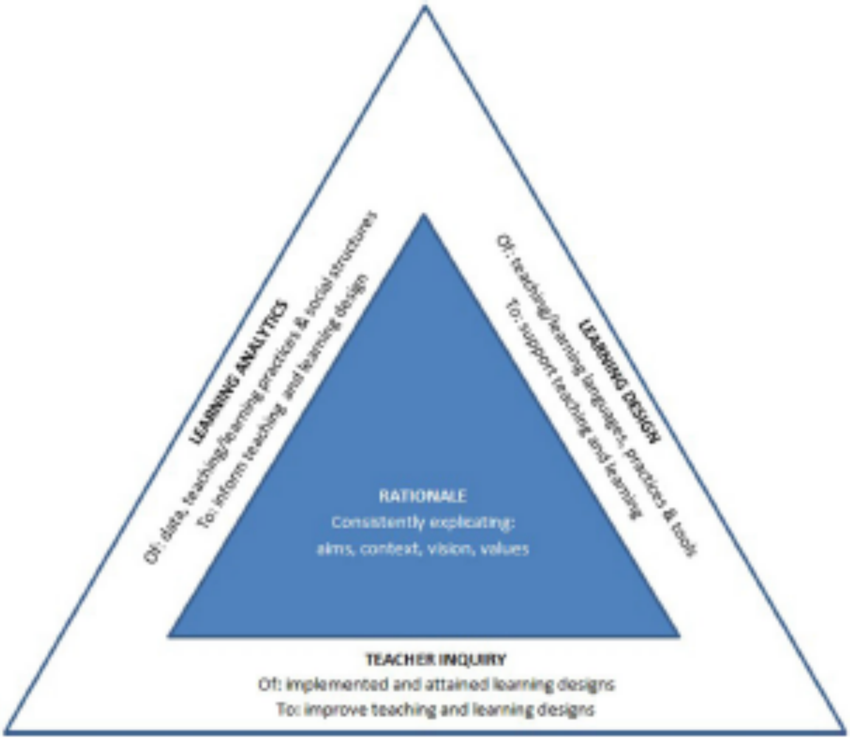

Figure 1: Learning analytics, learning design and teacher inquiry synergistically support core rationale (McKenney & Mor, 2015)

Within the field of learning analytics researchers often discern between academic analytics, which is the analytics used for marketing and administrative purposes (the macro level which is often also referred to as institutional research) and learning analytics, the analytics that could be used by teachers for purposes of digital classroom management (the meso-level) or to improve the students' learning, or could be used by students to reflect on their learning processes and make decisions regarding their learning pathways (the micro-level).

In this paper, we will not discuss this macro-level of academic analytics, but we need to be aware that it is on this organisational level where most decisions are made that influence the meso- and micro-levels of education. Examples include the decision regarding which VLE is used, which applications within this VLE are available to teachers, what data are being collected and if and how they are presented, the facilitation of the teacher to use the data, etc. In this light, learning analytics are very much an institutional endeavour, that need to accommodate the teacher by delivering timely and accurate data to use in a meaningful way in a classroom. By ignoring the institutional level, the teacher is put in an unfavourable position, as there is little this person can do to make the transition from macro- and meso-level to the pedagogical micro-level.

1.3 Issues with adoption and implementation

Challenges with the adoption, implementation and evaluation of learning analytics have been described more extensively by e.g. Sclater (2014) and SURF (2015). In this section, we capture the major outcomes of this ongoing discussion. Learning analytics is an interdisciplinary domain with many disciplines contributing to the research. So far, however, it is mainly the disciplines of data science and to a lesser extent, education that are involved in research on learning analytics. This is reflected in the kind of research that has had a lot of exposure within the learning analytics community. The data scientists have invested a lot of time in exploring the data using datamining techniques. This research has been successful in identifying students at risk for example, but the variables that have discriminatory power are often non-actionable variables, that are difficult to interpret in the light of possible pedagogical interventions and much of the research is affected by problems of overfitting (Gašević et al., 2017). Most of the phenomena predicted in this kind of research are not linear and the relation between cause and effect often is unclear (Forsman, Linder, Moll, Fraser, & Andersson, 2014). From a traditional educational perspective, the approach would be to find a theory that could explain or support mitigation of issues experienced in the classroom and build data collection and analysis from there. With such an approach the theory will guide the teacher or researcher in what kind of data needs to be collected and how the outcomes can be interpreted and used for pedagogical didactical interventions in the classroom or learning process of the students. Most teachers in engineering education, however, are not facilitated nor have the expertise to work in such a structured way, as was also observed by McKenny and Mor (2015).

In recent years, many encompassing models for implementation of analytics have been developed using another perspective. Often these models are generic and address institutions as a whole or implementation as an abstract and strategic process. Colvin at al. (2016) and Greller and Drachsler (2012) observe that learning analytics are not linear or uni-dimensional phenomena, but that (implementations of) learning analytics are complex, shaped by interdependent ‘soft and hard’ dimensions. Hard dimensions pertain to the availability of data due to technological or privacy issues, tooling and instrumentation. The soft dimensions pertain to stakeholders’ knowledge and skills to collect, process, analyse and interpret data, and the conventions and norms as to what is accepted within the context of the institution (Gašević et al., 2017; SURF, 2015). Bos (2016) found in her work on the adoption and effectiveness of using educational technology in higher education that, if implementation of technology is solely left to teachers, chances are that it will not be implemented effectively nor efficiently, while it is the teachers who should play a pivotal role in making the link between the analytics and the pedagogical didactical interventions on the micro-level of teaching and learning. Rienties, Toetenel and Bryan (2015) argue that it is high time that researchers, teachers and managers start working together to combine efforts in learning analytics research to understand how context, learner characteristics such as motivation and behaviour, and learning design to impact the learners.

2 APPLICATIONS OF LEARNING ANALYTICS: PREDICTION OR REFLECTION

Greller and Drachsler (2012) state that learning analytics can focus on two kinds of applications: prediction and reflection. Prediction is intended to identify at risk students at the earliest instance as possible before or during a course. Within every course or subject other variables may contribute to whether or not a student is at risk. If a student is identified, a system could either be programmed in such a way that the student will be offered additional, adaptive, feedback or material or the decision to intervene and how to intervene could be placed with the teacher of the course. Most learning analytics research, especially in MOOCs research, is focused on predicting whether or not students will finish the course. The variables that prove to be of importance for predicting completion are variables well known from student success research (see e.g. Van den Bogaard, 2012): gender, prior achievement, motivation and student behaviour in the course account for most of the variance. However, most of these variables are not actionable and in that sense the research into MOOCs does not show a lot of innovation in itself. Predictive analytics are a first step to adaptive learning environments where a student is offered a pathway through the learning environment based on characteristics, behaviour and performance in a virtual learning environment, however, little progress is being made with developing diverse pathways through the MOOCs or with experimenting with new arrangements for learning (Gašević & Dawson, 2015; Skrypnyk, Hennis, & De Vries, 2015).

With reflective analytics, the aim is to provide feedback to the teacher and/or the learner for critical self-reflection to obtain self-knowledge. On an individual level this pertains to the learning processes by offering information on progress. On the institutional level, it could enhance monitoring process and use that to suggest interventions. This could for instance be feedback on how well the student is performing in comparison to other students in the course, or a summary of how the student has been participating in the course, e.g. has the student only been online just prior to deadlines or has the student been studying consistently over time. Reflective analytics can also provide the teacher with information that is useful for ‘digital classroom management’. In the regular classroom, it is relatively easy for teachers to keep track of which students contribute to the class and who comes prepared, in a VLE this is much harder to keep track of. Reflective analytics can provide teachers with real time information on how the students are participating, what kinds of contributions they make to the class in the VLE, etc. With this kind of analytics it is essential to consider what data needs to be logged to facilitate effective reflection. Again, it is up to the teacher and/or student how to respond to the information. For effective use of reflective analytics, it is important that dashboards are provided to the users. Defining effective dashboards is a field in its own right and we will not touch on that topic in this paper (SURF, 2015).

Predictive analytics and reflective analytics are both yet not fully matured: the technology is still under development, tools are being developed and institutions are working hard to create infrastructures to collect, combine and present data in a more efficient manner. The developments in this field are rapid and involve things such as Artificial Intelligence (AI) and machine learning, however it will take time before these applications are sufficiently accessible for teachers who would like to use analytics in their virtual classrooms. The use of student data will definitely evoke privacy and ethics issues that need to be considered by the institutions and students, such as the question of algorithms taking over parts of our teaching, which pertains to technology assessment and requires a dialogue between all the stakeholders in education and analytics. Until than, we have a lot of data already available and we need to further develop out thinking about what and how to use this resource for the well-being of teaching and learning. The available data is often relatively easy to understand. In the next section of this paper we discuss a few applications of analytics in engineering education that can serve as examples of analytics and that can aid in building an understanding of the use of data that may make it easier to catch on as soon as new applications to run analytics become available.

2.1 Example 1: Analytics of VLE data in X University of Technology

X University of Technology uses Blackboard as a VLE, in which all user data are logged and stored. We ran a small experiment with analytics. It took place in the first semester of the academic year of 2013/2014. It concerned logging data directly from the servers of the VLE for two courses, one in civil engineering on Fluid Mechanics (in BA2) and one in mechanical engineering on Thermodynamics (in BA1), of which it was known that the teachers used the VLE extensively. In this paper, we report on the thermodynamics course. For the duration of the course all the log data, click data and ping data, which indicate how long a certain window was open, were downloaded from the servers. At the end of the course this data was combined with the final grades obtained for the course. This data was analysed using educational datamining techniques for subgroup analysis where we looked at which variables in the data gave the highest predictive score out of one, two and three variables for three different outputs: predicting a fail, predicting a pass and predicting the final grade (LIACS, 2017). The outcomes of the prediction of a fail are presented in Table 1.

Table 1: Predictive variables failing the Thermodynamics course.

Output variables	N predictive variables	Thermodynamics course (Mech. Eng, BA1)
Predicting a fail	1 variable	64 % predicted correctly
		n distinct sessions <= 13
	2 variables	69 % predicted correctly
		n times access to content X <=48 n distinct sessions <=14
	3 variables	73 % predicted correctly
		n times access to content X <=48 average duration of the intervals between access in hours <=424 n distinct sessions <=14

Overall it is safe to state that engagement in the VLE is a good predictor for passing the course with a good grade (Van den Bogaard, 2012). The actual question is whether or not it is possible to discern between the students at risk and the students who are doing well based on these analyses? The outcomes in the table show how complicated it is to answer that question. There are different variables for each depth of analysis of the outcome variable. Even if the same variable shows up, the cut off scores tend to vary. When we study the predictor variables, we note that not all of these variables are straight forward to interpret. For instance, the predictor variable 'average duration of the intervals between access in hours <=424' in the

Thermodynamics course, it is hard to understand how students who wait less than approximately 17 days between sessions would be more likely to fail than students who do not.
Overall some clear patterns emerge, but it would be very difficult to translate that into reliable analytics that will accurately predict the success of each individual student. It is important to recognise that the variables that came up in the post hoc analysis, may not necessarily be the variables that have predictive powers during the course. Outcomes of analytics for these course prior to the course, during and after the course may be very different.

2.2 Example 2: Reflective analytics in the ABLE project

Within the Erasmus+ project on Achieving Benefits through LEarning Analytics (ABLE), the Nottingham Trent University (UK), KU Leuven (Belgium) and Leiden University (The Netherlands) were collaborating to develop dashboards for the students to reflect on their participation in education and on their progress (www.able-project.org, 2017). In Leuven and Leiden there are progress requirements in place for first year students, but student counsellors find that students at risk have a tendency to make uninformed decisions when it comes to resit exams. Students tend to attribute failure to a lack of effort and often believe that they can make up for lost exams by working very hard. Students often try to take too many resits and fail as a result. Student counsellors warn students about these decisions, but students lack the experience of the counsellors when it comes to making decisions regarding planning, resits, and barriers in the curriculum that require the students' attention. At Leuven a dashboard has been developed to aid the conversations between student counsellors and students on their options for resits. This dashboard is based on performance data from previous student cohorts and will show the odds of a student passing resit exams based on the performance of students in similar situations in previous years. This closes the information gap between a student counsellor and a student when discussing the options a student has for resits. The counsellor can inform students about the progress requirements in the programme and show options to students including the odds of passing.

The dashboard is currently being piloted by KU Leuven and Leiden University and it is found that most students and counsellors find this dashboard very useful to have more meaningful conversations on progress and resit options. In that sense the dashboard proves to be useful as a tool for reflection. It is based on data already available in any university at this point in time and therefor is an example of analytics that most universities or programmes could implement in a very short timeframe.

3 CONCLUSIONS AND REFLECTIONS

From this discussion and examples of learning analytics, we draw a number of conclusions, that we present here as four topics of discussion.

3.1 The need of technology assessment of learning analytics

The implications of learning analytics will be far reaching if this technology enters into a state of maturity that allows institutions and teachers to apply the results in their daily practice. It could mean that decisions over learning and, ultimately, on the lives of our students will be made based on or even by machine learning algorithms that are beyond the direct influence of humans. This brings about ethical considerations and it requires an informed dialogue between all stakeholders in education and learning analytics on the ownership and value of data, the analytics and the decisions made. The easiest way out is not to use any of the data that is available, but at the same time it might not be ethical not to use any of the data if it could provide better opportunities to students. It is important to start this discussion in our institutions, but also on a wider scale (Rathenau Institute, 2017; Institute for Technology Assessment, 2017)

3.2 A focus on technology versus a focus on learning

Most research into learning analytics has been done within the context of MOOCs with the focus on models and algorithms that can predict retention in online courses. This research has yielded many interesting outcomes, but few of them will have implications for education practices. This is partly due to the fact that participants in MOOCs tend to be professional learners with different attributes than students enrolled in a university (Hennis, Topolovec, Poquet, & Vries, 2016). Little research within the MOOC community has been done on experiments with learning design and learning arrangements and therefore pointers are lacking for how to offer online learning activities in more effective ways or offer more adaptive learning pathways. Most LA research so far did not focus on learning as such. As Bos (2016) found in her research on the effectiveness of blended learning applications in relation to study behaviour in a VLE, the effect diminished as soon as measures of student motivation were included in the models. As long as such variables and actionable variables are not included in the research, it will be very difficult to apply such research in the learning design as suggested by McKenny and Mor (2015). In the VLE example in this paper it is clear that the VLE will not automatically yield the right information that can be used to make meaningful changes to the learning environment either. If LA is to make a contribution to education, we have a lot of ground to cover in terms of applying LA in the right way and in a situation where the student and teacher are capable of using the data to improve the teaching and learning process.

3.3 Effectiveness and acceptance of interventions

Learning analytics can only be effective if the outcome can generate insights in the pedagogical didactic consequences for the teaching and learning practices. The VLE example in this paper showed that it is very difficult to interpret the outcomes of the VLE analytics. We do not really know why some of these variables show up in the analyses, nor what kind of interventions could be designed based on these analytics and what the analytics should present to clarify whether or not an intervention has been successful. Interventions should be designed based on a theoretical model that helps understand and explain effects, so it can be reproduced. Additionally, to design an effective intervention, we need to learn to understand the needs of our students. The ABLE project is a great example of this: Talking with the students using the dashboard made clear what the students needed. Interventions that are not designed with the learning in mind, are likely to have no effect or to have a detrimental effect. Gašević and Dawson (2015) state that the evaluations of interventions are often botched and are not as effective as researchers initially report. Without an understanding of theory and of what our students are willing to embrace, interventions are unlikely to have any sustained effects.

3.4 Learning analytics is about learning, let’s not forget the teachers!

We argued in this paper that there is a large body of knowledge on teaching and learning that should be used to deal with LA effectively. The main outcome of the VLE experiment is that prolonged engagement with the learning materials, in this case the VLE, is a strong predictor for success. This finding is consonant with Skrypnyk, Hennis and De Vries (2015). Feedback is essential for learning and we could use the VLE outcomes as a reminder that we need to look for ways of giving students meaningful feedback, in the VLEs and in our classrooms. How to do that effectively and efficiently, we do not know yet and the research on LA does not give us a lot of hints. The options of real time LA are promising to this purpose, because it will help teachers to consider what kind of feedback is useful for which kind of student. Grades should never come as a surprise to students. As LA is not yet mature enough to provide adaptive feedback to students, it is up to the teachers to make links between the meso- and micro-levels. It is known from research into student success that the interaction between teachers and students has most impact on student learning (Hattie, 2009; Van den Bogaard, 2015). If we leave the learning design and teacher inquiry to the teachers only, very little will happen. If we leave it to the managers and policy makers, there will only be developments on the macro- and meso- levels in organisations. We should create a situation where teachers are empowered and facilitated to engage with the data they already have. They can complement this with data that can be collected in simple ways and that is easy to interpret and actionable. The challenge is to come up with meaningful and effective interventions on the level of teaching and learning and the core rationale of the institution. Teachers do not have to wait for the technology and applications to mature. They could start today with the data that is already available to them. If they do, they will be ready to start using technology meaningfully and responsibly once it becomes available in the (near) future.

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Students' Perceptions of Online Tools in CAD Education

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ABSTRACT

This paper presents results from two web-based surveys (start-up and mid-term) executed during a first year CAD course. As a result, students' opinions about how different online tools support their learning and student's willingness to use rather technical CAD programs at home were studied. This information will help to focus and utilize teaching resources better and enables to move the teaching of CAD from learning the software to utilizing computer-aided tools and methods in a product design process.

Conference Key Areas: Engineering Skills, Open and Online Engineering Education, Curriculum Development

Keywords: computer aided design, blended learning, mechanical engineering

INTRODUCTION

In the field of mechanical engineering, computer aided tools are part of everyday life. Increased quality standards, new production methods and faster pace of product development drives the education at the universities. Traditionally, teaching of Computer Aided Design (CAD) relies on computer class exercises in fixed places and predefined times involving numerous teaching assistants to deal with questions and problems of the students. This approach has worked well during the years, when software was only installed in local computers using local licenses. Nowadays, based on the survey done for students in the freshman year CAD course, 94% of students have a laptop computer, 38% have a tablet computer and 44% have a desktop computer. The licensing policy and increased sharing of software encourage

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students to complete exercises whenever and wherever they choose. Developments in the web-based learning environments makes sharing and receiving exercises more efficient and accessible. This allows utilizing blended learning approach, which has provided good evidence to support learning in higher education [1]. In blended learning, both traditional classroom interaction and online learning are combined in order to increase "*pedagogical richness, access to knowledge, social interaction, personal agency, cost effectiveness, and ease of revision*" [2].

A study done by Hannay and Newvine [3] suggests that students believe they learn more, spend more time on studying and found additional instructor materials more useful in distance learning than in contact learning. Distance learning, like e-Learning and online learning, is a term describing learning that is done somewhere else than at university. The main difference between these terms is in the form of implementation.[4] Combining online elements with traditional classroom teaching can enrich students learning environment. To better support blended learning approach in CAD teaching, it is essential to systematically collect student's perceptions of online tools. Thus, research questions for this paper are:

- What kind of online materials are suitable for CAD teaching?
- What kind of tools/methods students prefer to use?
- Will the students utilize the online tools provided to do exercises time and place independent?

This information will help us to utilize the teaching resources better and the focus of teaching of CAD can be transferred from learning the software to utilizing computer-aided tools and methods in a product design process, i.e. from declarative to procedural knowledge [5].

1 METHODS

The feedback from a freshman CAD course was utilized in order to gain student's perspectives of online tools. *Computer-aided Tools in Engineering* is a 5 ECTS, two period (2x7 weeks) course introducing CAD modelling to engineering students. This course is a part of the bachelor's degree programme and it is an obligatory 1st year course to all students in the School of Engineering. Annually about 300 students complete this course.

Learning outcomes of the course are

- understanding the basics of computer aided tools
- ability to use computer aided tools.

The course is divided into two modules (*Fig. 1*): the common module, which all students take during the first teaching period (7 weeks), and the elective module (6 weeks), where students choose the most interesting one from the offered software modules.

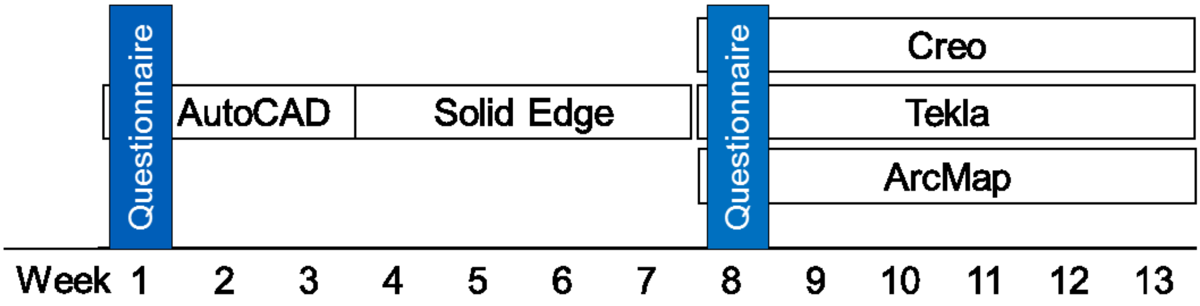

Fig. 1. Structure of the course

In the common module, basics of 2D and 3D modelling are introduced. Students start with two-dimensional drawing using Autodesk AutoCAD (3 weeks, 2 exercises) continuing to three-dimensional modelling using Siemens Solid Edge (4 weeks, 5 exercises). In this way, all students in the school become familiar with general tools used in both civil and mechanical engineering. The module contains lectures related to usage of the software and their general application fields. These skills are applied on the weekly supervised exercises on the computer room.

In the elective part, students choose a software module based on their interest. In the spring 2017, elective applications were PTC Creo for students interested in mechanical engineering, Tekla Structures for students interested in civil engineering and Esir ArcMap for students interested in surveying and environmental engineering.

The exercises during the 3D CAD common module are given and supported by various online materials and methods:

- Video without sound showing step-by-step how exercise is completed.
- Video without sound demonstrating how a certain tool works.
- Video with narrative demonstrating how a certain tool works.
- Viewable model in browser-based CAD of exercise specific object.
- PDF material showing step-by-step how exercise is completed.
- PDF material listing hints and suitable tools needed for the exercise.
- PDF in book format.
- Shared PowerPoint presentation with embedded videos demonstrating how tools work.
- Auto-assessed quiz about engineering drawing topics, standards etc.
- Interactive engineering drawing including explanations of related markings.
- FAQ forum about modelling and software.

This material was distributed using Moodle-based learning environment on the weekly basis or at the start of the module.

For this study, two questionnaires were carried out (*Fig. 1*): a start-up (N=330) and a mid-term questionnaire (N=279). They were all realised using Webropol, a web-based survey tool. Students were informed that results from these questionnaires would be collected and be used to develop teaching in the course and no further instructions were provided.

The start-up questionnaire was organized during the first week of the course. The questions considered the previous experience with computers and different software types (such as office tools, editors and, mobile applications) as well as what kind of devices the students own.

The mid-term questionnaire was arranged after the common module of the course and questions were related to online material.

2 RESULTS

The surveys were composed of mainly closed questions (5 or 10 point scale). Statistics for online surveys were obtained using statistical tools of the survey software (Webropol). The results are presented using the translated descriptors that were used in the questionnaires.

2.1 Software usage skills

On average, students had been using computers for 12.5 years and they estimated that they use computer for 4.5 hours per day. Students were also asked to estimate their software skills with different types of software on a scale from 1 to 10, where 1 is a novice and 10 an experienced user (*Table 1*).

Table 1. Students' software skills as estimated by themselves

Software type	Average skill
Email applications	7.3
Streaming applications	7.3
Office application suites	6.9
Mobile applications	6.7
Social media applications	6.4
Computer games	5.7
Mobile games	5.7
Programming editors	4.9
Mathematical software	4.1
Picture/movie editors	3.6
Activity applications	2.5
Web page editors	2.2
2D CAD	1.9
3D CAD	1.8

2.2 Preferred online tools or material

In the mid-term survey, students were additionally asked to estimate how the different types of course material supported their learning during the common part of the course. This result is presented in *Fig. 2* using diverging stacked bar charts as presented in [6]. The scale was 5-point Likert with "Didn't use" (*Fig. 3*) option.

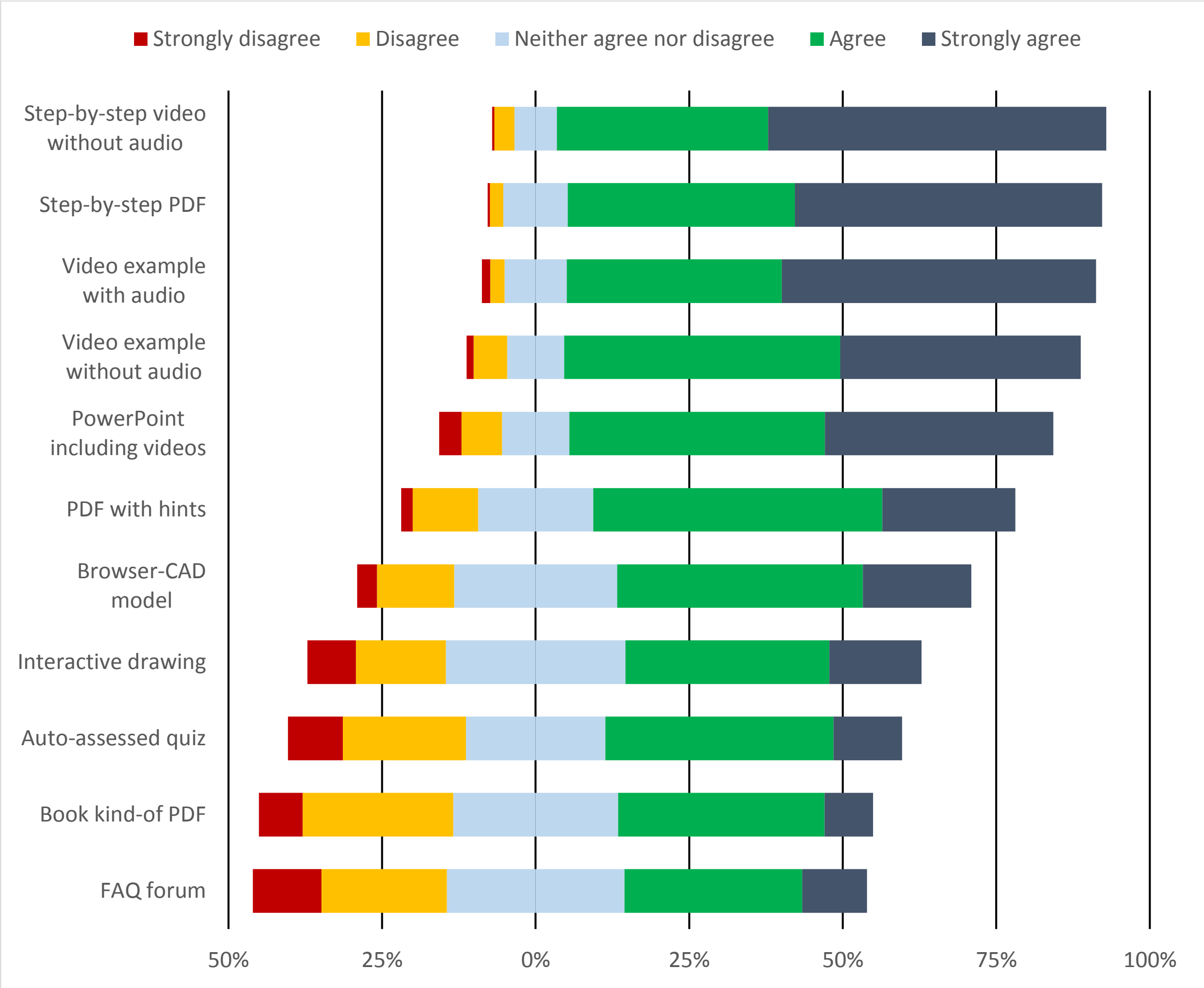

Fig. 2. Students' answers to question: "The following tools/materials supported my learning during 3D CAD part of the course"

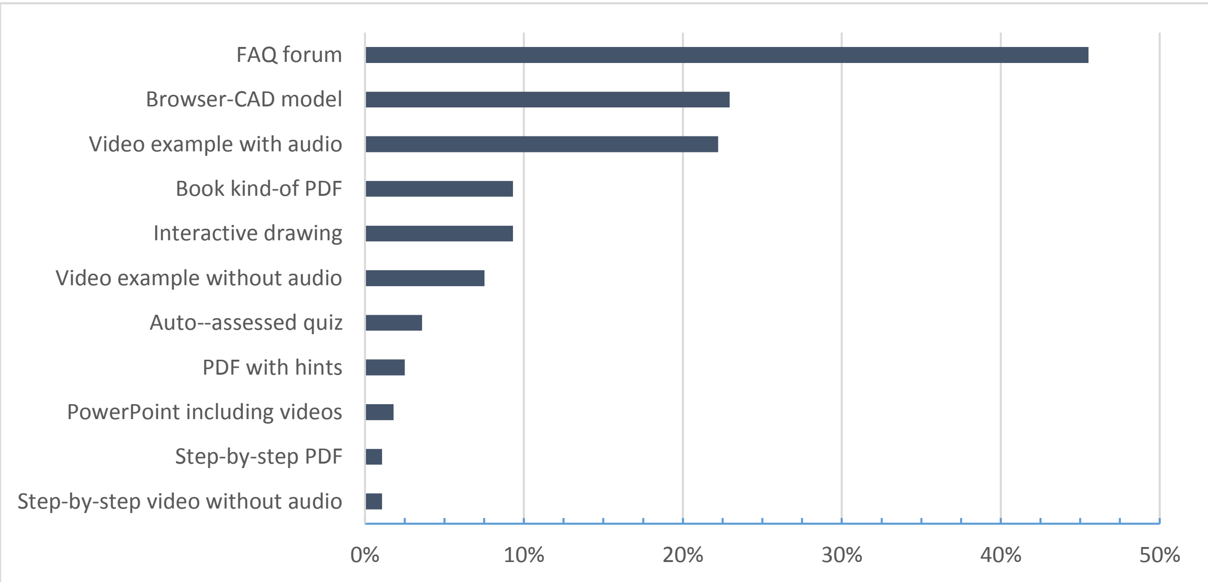

Fig. 3. Percentage of students who didn't use provided tools/materials

2.3 Utilization of provided software

In the mid-term survey students were asked if they had installed the provided 3D CAD software (Siemens Solid Edge) on their home computers (*Table 2*). The software and licence were distributed using the university's software download portal and no registration was required.

Table 2. Answers to survey questions related to software usage

Did you install 3D CAD software on your home computer?	**%**
Yes	54.8%
No	45.2%
If No, mention max three reasons	%
Insufficient performance	39.7%
Wanted no extra software	38.9%
Incompatible software	21.4%
Did not want to use own computer	15.1%
Found hard to install	15.1%
Incompatible hardware	3.2%

When asked how they carried out the weekly exercises, 69.5% of the students responded having started the task before the actual class exercise and 56.3% had completed it together with other students.

3 DISCUSSION

Students' starting skills with CAD tools were low (1.9 in 2D and 1.8 in 3D), which was expected for the freshman course. Students had good skills in social media (6.4), streaming (7.3), emailing (7.3) and office suites (6.9). Data also shows how confident students are with mobile application and gaming (6.7 and 5.7). These outcomes can be taken into account while creating or selecting study materials or designing courses in the future, i.e. ensuring that material supports mobile devises. The utilization of social media applications in CAD teaching needs to be looked into.

Students seem to prefer teaching materials that show step-by-step how the CAD model is created, both in video and PDF formats. Video materials were among the most preferred material types and presence of narrative in videos did not make a notable difference. This is an interesting finding and may lower the teacher's threshold to produce video materials.

Shared PowerPoint material including embedded videos were also preferred. This material type combines both written and video formats, both which were highly preferred by the students. From teacher's point of view, creating this kind of material is somewhat easier and tools are more familiar (contrary to video editing software). For the next year CAD course, more study in this field is preferred.

Surprisingly, three tested interactive material types (browser-CAD model, interactive drawing and auto-assessed quiz) were not preferred. One of the exercises was supported by both browser-CAD and step-by-step video, which might explain the lower grade of browser-CAD model – 23% of students did not use it at all.

Interactive drawing and auto-assessed quiz formed one of the exercises, in which students practiced the basic principles of 2D engineering drawings. This exercise was not so much about actual 3D modelling, but about documentation phase.

The least liked and used support material type (45.5% did not use it) was the FAQ forum. This forum was created in the course learning environment. It seems that there was no need to use the forum or students got the help from other sources. On the other hand, the usability of the forum may not satisfy the students' expectations.

Almost half of the students (45.2%) did not install the CAD software on their home computer. The main reasons were both technical – lack of performance (39.7% of those who did not install) and incompatible software (21.4%), as well as practical – students did not want to install extra software (38.9%). It seems that computer classes are suitable for students, maybe because they offer a place to study together.

Development of online course support material is a continuous process while the field is constantly changing and students adopt new tools and applications especially in the mobile world.

4 ACKNOWLEDGMENTS

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M-Learning as a convenient support to the learning process in computer science

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ABSTRACT

Many studies undertaken in the field of education have revealed that m-learning is emerging more and more as an effective learning method with the use of smartphones. Always turned on and easily transported, smartphones can be used anywhere, at any given time and in any context. Considering the potential of m-learning, we seek to understand this novelty as a support in the learning process, especially in computer science education. To reach this end, we asked a group of students their opinion in the form of a survey, in order to know the most beneficial aspects of a mobile application in education. The outcome of this survey helped us to develop a mobile application from which students could access course news, work timing, frequently asked questions and results. After using this application, a second survey highlights students' interest. We thus show that, especially for courses such as programming courses, m-learning plays a full role as it offers accessibility to valuable information which comes in a continuous flow to support the learning process and as it offers an environment where interaction with the learning tool can be adapted and adjusted to the learner's style and needs.

Conference Key Areas: Open and Online Engineering Education

Keywords: convenient support, learning computer science, m-learning, mobile application

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INTRODUCTION

For years, we have been following educational paradigms that promote formal and well-structured learning. In these paradigms, the teaching work is reserved for designated people who oversee delivering knowledge to learners. Currently, the focus in higher education has moved from that concept of teaching to one that develops the idea of learning. In many universities, a paradigm shift has put the focus on student learning. Rather than focussing on the skills, capacities and best practices of teaching, universities are now analysing student performance [1]. The use of mobile devices is one of the main aspects of this educational change. These devices have led to a new learning style known as mobile learning or m-learning, offering dynamic, connected, and collaborative methods of finding and exchanging information. [2], Along with various developments in the field of information and communication technology, the smartphone has become a common tool, giving opportunities to learn on the go. By invoking the concept "m-learning", one thinks spontaneously about the possibility of learning without being in a fixed or determined place [3]. It should be stated that m-learning is not a mere function of mobile devices within an e-learning spectrum, but a useful part of an increasingly rich and complex learning process [4].

To be able to fully benefit from m-learning, the understanding of its novelty is a must. This requires moving beyond superficial definition and examining the capabilities of mobile devices and the context in which the learner accesses the learning content [5]. It is a re-thinking of learning originating from the student's perspective.

Understood in this way, m-learning is an extension of e-learning. Generally, e-learning refers to learning and teaching supported by electronic tools of all kinds. In e-learning, there is always a gap in time between the learning process and its application. Although electronic tools are used in m-learning, the learning and its application form a whole because they happen simultaneously. The goal is to give necessary information at the exact time. M-learning offers learners the opportunity to quickly check relevant and necessary information for the task to be accomplished.

Recognizing these differences, our efforts focus on conceiving m-learning as a useful support to the learning activity. Thus, the remaining sections of this paper continue as follows: The next section highlights a new perspective on m-learning. Then we present m-learning in a context of learning computer science. Before the conclusion, we describe our test results which confirm our argument.

1 M-LEARNING FROM A NEW PERSPECTIVE

1.1 Viewing M-learning as a Support

In the context of academic training, the number of supports to acquire knowledge is constantly increasing. Various new ways of learning are being invented with new learning tools. Today, many young students are using smartphones to access a variety of content in various fields. It may be relevant to offer them ways to support their learning with an application available right in their hands at anytime and for as long as they choose [6].

However, the use of smartphones comes with challenges. Considering the advantages and limitations of mobile devices, the design of a fully-structured mobile learning course encounters several setbacks. Because of the screen size of a mobile phone, m-learning content is often designed in small chunks, easy to digest on the go. This content is not a fully-developed course, just pieces of information necessary for the learning process [7].

In this context, m-learning should be thought of as a complementary way to augment or enhance all types of learning [8]. It is a performance support that focusses on applying and bringing to life the knowledge gained through formal instruction [7].

In providing performance support, mobile learning allows learners the freedom and flexibility to learn, not only when and where they choose, but also in view of satisfying specific needs. Learners can pull information up in the moment as required to support their work tasks. It is a learner-centric solution that puts the learner in control of his learning requirements, instilling greater confidence and offering an educational experience that is just enough and just in time [2].

Instead of relying on the knowledge that you acquired long ago and hoping you memorised everything then, mobile learning as support gives you the resources you need to deal with daily academic problems. Conceived as a support, m-learning offers students information they need to move on with their assignments and to instantly answer questions about the tasks they are performing [7].

1.2 Mobility Principle

In our society, the mobile device has become a permanent companion of the young and the adult, the rich and the poor. As one of many common and affordable electronic devices, the majority of people possess a smartphone [9]. Being in a constantly evolving environment where information is constantly changing, using smartphones in an m-learning environment becomes important to keep track of all updates and to support your learning while on the move.

The principle of mobility endows m-learning with a specific role. It empowers students to move freely within, beyond and between multiple environments and between topics and disciplinary contents and contexts. It means that learning is not confined to formal educational contexts; it is extended within opportunities such as home and work, and is offered not as a one-way exchange from lecturer to students, but as two-way learning within participating communities [1]. Mobility allows m-learning to become an environment where the learning content is available when it is needed most [10].

1.3 Personalisation Principle

It is a fact that the usage of m-learning is growing, and is affecting people's lives by introducing innovation and methods. The reason for this growth is not only for comfort of use and mobility, but also improvements in interaction and functionality in different contexts. It is crucial that the learner's contextual information is very useful for adapting his learning flow. The added value that m-learning can provide is therefore necessarily through personalisation. This idea of personalisation refers to the possibility for the learner to display the learning content according to his choices. This allows the display of specific content to increase performance. It offers an adaptive m-learning environment where the learner is exposed to learning materials that fit his individual learning styles.

In this sense, with the possibility of personalisation, m-learning becomes a useful support in a truly mobile learning context. It includes personal mood, interests, and willingness to learn, taking into account the current location and other people's influence [11]. If conceived as a support, m-learning must be an environment where interaction with the learning tool can be adapted and adjusted to the learner's style and need.

As m-learning is increasingly becoming a popular mode of learning, the learner can use mobile terminals to access a variety of information without constraints or limitations[12], all the more so if he has the option of personalising his learning process according to his availability and the circumstances surrounding him [5].

2 THE CONTEXT OF COMPUTER SCIENCE LEARNING

In talking about m-learning, computer science learning is not an exception. There is ongoing research where researchers are working on tools to support the learning of programming on mobile phones [13]. Solutions have been developed that would enable students to learn programming using mobile phones. The biggest challenge for all the attempts is how to turn mobile phones into functional programming environments, even though they haven't been designed with programming functionalities.

However, it is still difficult to think of having an exclusive m-learning formula for that domain. It is obvious that for teaching a programming course, the computer is still an unavoidable tool. In this context, the use of mobile applications can therefore only be considered as a complementary tool to support the learning activity. So, what can such applications bring to us? Which services can be relevant? What are the factors that may affect the effective use of mobile devices in a programming lecture?

It is true that mobile phones support strong features like computers and can now offer incredible learning experiences. But in the context of learning computer science, input and output methods are important. Keypad and screens are very essential for programming learners and if it is generally agreed that using multi-monitor workstation significantly increases the productivity [14][15], the smartphone's screen and keypad are not convenient for many learning activities.

Besides, computer science courses involve particular constraints which do not exist in other courses. One of many characteristics of computer science courses is that they comprise many learning activities for which smartphones cannot be used. For example, the mastery of configuration of the integrated development environment (IDE) in the programming task, practical application of programming methodology, effective organisation of teamwork by using version control system (VCS), to name but a few, are integral components of learning. Unfortunately, they are difficult to envision other than by using a workstation.

Considering these limitations, in a programming class, m-learning finds its place as a collaborative tool that offers updates about the work, notifications, comments, deadlines, new assignments and so on. The important point to mention about m-learning in this case is the emphasis on the support and the collaborative nature of mobile learning applications [16].

3 METHODOLOGY

The goal of our study is to examine how mobile devices can be used as a support tool to complement other learning approaches, especially in computer science.

3.1 The Use of Smartphones in Student's Everyday Life

One question guided our interest: How do students informally use their smartphones for educational purposes? In order to have a clear preliminary orientation, we sought the opinion of a group of students, in the form of a survey, about the most beneficial aspects of a mobile application in an educational field.

In this exercise, 135 students in an undergrad programming course from Laval University responded to various general questions in an online survey. It appears that it is very natural for students to collaborate and use their phones to obtain instant information. As shown in Table 1, within an academic setting, most students exchange information with their classmates using smartphones and they use their phones to access online information about a topic. Moreover, a large majority consult their correspondence (e-mails, academic notifications) on mobile devices, and use these mobile devices to keep track of their daily work and update their address books. Also, the majority consults the course website on their mobile devices relatively often. However, while many believe that mobile devices promote exchange, discussion and collaboration, it was noticed that few use it to participate in forums linked to the course. But almost half of them use it for social media.

Table 1. Students' answers on how they use their smartphones in everyday life.

Use in everyday life	Percentage of responses
Exchanging information with others	81
Online search for information on a topic	77
Keeping well-informed of current events related to personal activities	65
Keeping the calendar and address book up to date	58
Reading articles from newsletters or magazines	53
Sharing opinion reactions on a subject	34
Other	13

During this survey, the majority affirmed that promoting the use of mobile devices in education is a good idea and can provide many advantages. Indeed, the respondents would be very interested in a mobile application that allows them to access information related to the courses they are taking or related to their academic progress. They are also in favour of a mobile application to access academic news, updates and specific links about course materials, but their views diverge on the use of a mobile application to access administrative information. The summary of their answers is shown in Table 2.

Table 2. Interest in a mobile application allowing access to information-related courses.

Information-related courses	Percentage of responses
News, updates, specific links to information	61
Information about academic progress	61
Administrative information	52
Information from student associations	21
Other	8

In addition, respondents were able to make several proposals such as being able to access their results,to configure their own alerts, for example, the schedule of the courses in which they are enrolled, dates for deadlines. This first survey allowed us to consider the development of a prototype application enabling us to confirm the orientations on the services to be taken into consideration as well as their degree of relevance.

3.2 Prototype

For this purpose, we conceived and developed a mobile application tool viewing m-learning as support, meaning a tool that offers instantly valuable information necessary to move on with the learning task at hand. The design of this mobile application tool presents one interface for the student. In this interface, if the student is enrolled in the course, he is directly connected to the course website through the mobile application. The course news tab is a place where the professor can describe the work to be done, display information about the code solutions that provide support or guidance to carry out the work, or even post solutions for similar problems. The frequently asked questions tab is about technical problems encountered when students are working with the programming code. It is a place where they can post a piece of code and the output from it to illustrate their question. It offers room for testing their work as they move on. Mainly, this learning tool served as a support to keep the student informed about course progress. The interface has four layouts designed using Extensible Markup Language (XML). These layouts are: the news tab, answers to frequently asked questions (FAQs), a time-management aid, and the results tab. All these tabs are presented using nested doll patterns displayed on the top of the screen.

3.3 Results and Discussion

We tried out the application with a group of students enrolled in an undergrad C++ programming course; 42 students participated in the exercise. After the experiment, we invited them to respond to a short survey to get their feedback and appreciation of the application. Responses allowed trends to be identified. The analysis is intended to verify the current and future impact of the use of a mobile application in computer education. The results trace a picture of what can frequently be done with the smartphone.

What is interesting is that more than 78% affirm the importance of the mobile application in their studies. Most students express the need for a mobile application offering easy access to course news and student questions about tests and various assignments as well as the professor's answers and comments on these questions. They also wanted the mobile application to display tests recalls and various work deadlines, or course results. Even though the initiatives of a mobile learning application at Laval University remain recent, respondents could see the benefits. A large majority of respondents found access to news, work deadlines and frequently asked questions very important or important. But only 60% found access to work results very important or important. The details of responses are presented in Fig. 1.

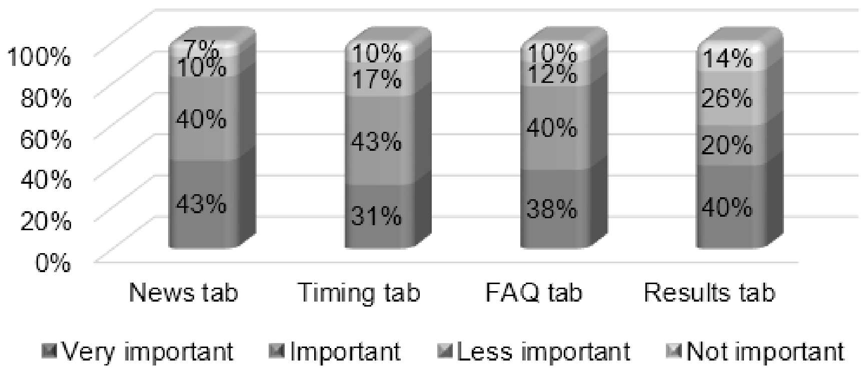

Fig. 1. Students' answers on the importance in their studies of the "services" offered by each tab of the application.

It's a clear indication that students are more interested in mobile applications which supply information arriving in a continuous flow to assist them in their daily work. Although some have mentioned that the display of test results is not important, many see it as an added value to control their academic progress. Indeed, benefits are felt, both to position themselves in relation to the whole class and to stimulate themselves to do better.

Furthermore, the students' responses showed a marked interest in the possibility of being able to modify the graphical interface according to their needs as well as being able to set alerts. These responses corroborate our preliminary study as to the possibility of customising the mobile application according to one's interests and choices. Indeed, personalisation gives the ability to control learning and makes it an active experience in which the learner finds his place.

4 CONCLUSION

This paper proposed to address the essential aspects of m-learning with the use of smartphone as a complement to learning process. M-learning is often defined as a learning method where the learner is not subject to any constraint related to time or space. Then we focus on the access to information at anytime, anywhere and by anyone. Regarding smartphone advantages and limitations, we show what types of services specific to m-learning should be considered as a complement to support learning, especially in computer science.

To achieve this, we developed a mobile application to collect students' views about m-learning as a support. Responding to a survey, the majority of students who used this application expressed their appreciation and the need for an application which provides information arriving in a continuous flow to assist them in their daily work. Furthermore, their responses showed a marked interest in the possibility of being able to modify the graphical interface according to their needs. These responses corroborate our preliminary study as to the possibility of customising the mobile application.

The most immediate scope of future work is to include collaboration aspects which could make the application more interactive and be able to configure and display alarms and deadlines.

5 ACKNOWLEDGMENTS

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Digimentors – enhancing digital teaching skills of engineering educators in Tampere University of Applied Sciences

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ABSTRACT

Digitalization is a trend in education. To enhance teachers' digital skills, A digimentor service was launched in Tampere university of Applied Sciences at the beginning of 2016. Digitally experienced teachers were assigned as digimentors. Their mission is to give low threshold mentoring support to other teachers on the area of digitalization of teaching. To analyse the results of digimentoring, a survey to teachers in engineering education was made in April 2017. About 70 % of the teachers in engineering education answered to the survey. 53 % of answerers had used the service. 33 % of the answerers had not used, but were willing to use the service. Key results are summarized as follows. The digimentor service is seen as a good method to enhance teachers' digital skills. Its benefits lie on the facts that the service is a low threshold service, which is easily available. The most wanted and used services have been the help concerning the production and distribution of own educational videos and the effective use of learning management system (LMS) Moodle. The main

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reasons that the service was not used yet were the lack of time or lack of vision what to change.

Conference Key Areas: Open and Online Engineering Education, Continuing Engineering Education and Lifelong Learning, Curriculum Development

Keywords: Digital teaching skills, Online engineering education, Mentoring

INTRODUCTION

Students entering universities already have skills in digital tools and they are already familiar with digital learning. If engineering educators deny pedagogical and digital development, the attractiveness of engineering education is in danger. In terms of sustainable development and continuing engineering education, digital tools open new possibilities to distance-learning, making education more available to different student groups of age, prior education or geographical location. The digitalization does not only mean a total transform to online education. It also means that the advantages of modern tools and pedagogy are easily exploited throughout teaching. Use of modern teaching methods like Flipped learning [1] or Peer Instruction [2] require the effective use of modern educational tools.

To enhance the digital skills of teaching personnel, a group of digitally advanced teachers were assigned as digimentors, to work as a network, in Tampere University of Applied Sciences. The idea was to offer low-threshold mentor support that is easily available to teachers whenever needed. To monitor results and to develop digimentoring further, a survey to the teaching staff was made in the beginning of 2017. Due to low answering percentage, the same survey was re-made to the teachers of engineering education during April 2017. The results and conclusions from the later survey are presented in this paper.

1 ENHANCING PEDAGOGY AND DIGITAL SKILLS

1.1 Pedagogical methods that require digital skills

In current educational trend, education transfers more towards online education. Teacher in pure online teaching needs at least skills to use learning management systems like Moodle and skills to produce digital learning material and learning activities available to students. The successful online teaching requires also that teacher has abilities to be digitally present in the digital learning world.

The need of digital skills is not limited to online teaching only. The active engagement methods, like Flipped learning [1], Peer Instruction [2-3] and Interactive lecture demonstrations [4], which are proven to produce better learning outcomes [5], are easier to apply when at least some digital learning equipment like audience response system, "clickers", are used.

1.2 Digimentors enhancing teachers' digital skills

The slogan of Tampere University of Applied Sciences' digital strategy is *"Using possibilities offered by digitalisation towards higher quality and more effective higher education – Towards better student and customer experience together!"* [6].

Implementing the strategy requires enhancing the digital skills of the entire teaching staff. Development towards digital age is sensitive and personal process and teachers are on very different stages in the process. Therefore, some of the digitally most experienced well-known teachers were appointed as digimentors. A part of his or her work is to be available and help everyone who needs guidance in personal digitalization. Digimentors work as a network, so they are able to share their skills between each other. As a network, they are able to find solutions outside personal expertise. There are about 1 – 2 digimentors in every unit so each digmentor has from 30 to 70 mentees to mentor.

2 THE AIM OF THE STUDY

The aim of the study is to discover:

- How engineering teachers see the digitalization of teaching?
- How engineering teachers assess their own digital teaching skills
- How much digimentor service has been used
- What are the concrete subjects, in which digimentor service is seen helpful
- What are the advantages and disadvantages seen in digimentor service

3 DATA GATHERING

The data was gathered in Tampere University of Applied Sciences in its two schools of technology, using Google Forms questionnaire. The link to questionnaire was delivered to engineering educators using email. The questionnaire was open for two weeks on April 2017. About 70 % (N=72) of the engineering education teaching staff answered the questionnaire, although some of the questions were left empty. The questionnaire included multiple-choice questions, Likert-scale questions and open-ended questions. The distribution of answerers' teaching experience is presented in *Fig*. 1.

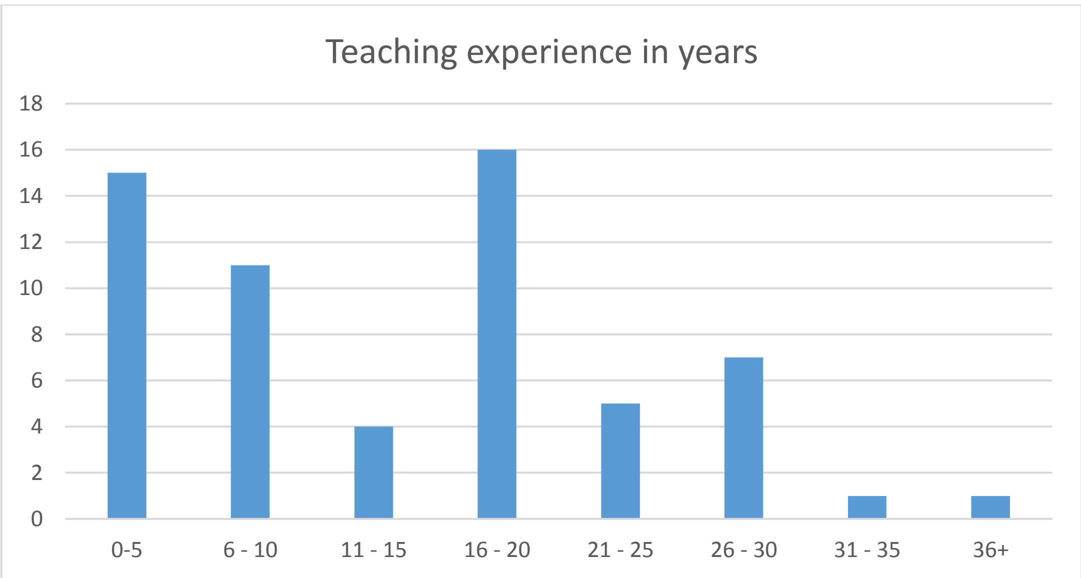


Fig. 1. Answerers' teaching experience

Fig. 1. The answerers are from large variety of experience in teaching.

4 RESULTS

4.1 The importance of digitalization and teachers' own digital skills

According to the study, teachers see the digitalization of teaching important. Most of them assess their own digital skills as medium or slightly above medium in the scale between 1 = Beginner and 5 = Expert. The distributions of the answers are in figures *Fig. 2.* and *Fig. 3.* The open-ended question, in which teachers described their digital skills, got many answers. Most common mentioned digital skills were the use of LMS Moodle, use and production of video material and use of digital quizzes. Some of the teachers had already taught an online course and many of them had experience in distance teaching and learning using adobe connect or similar software.

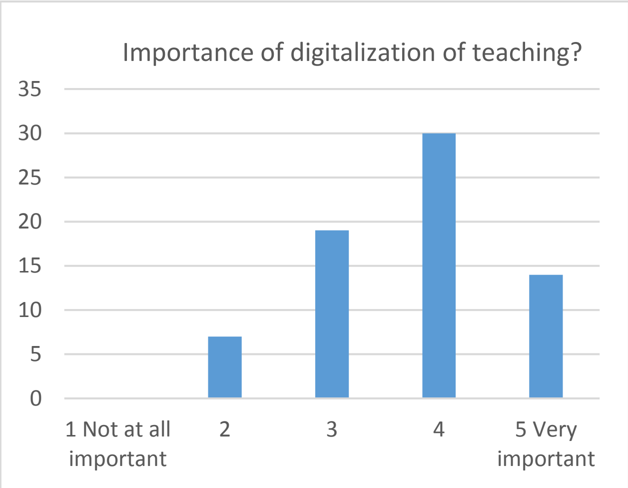


*Fig. 2.*Importance of digitalization

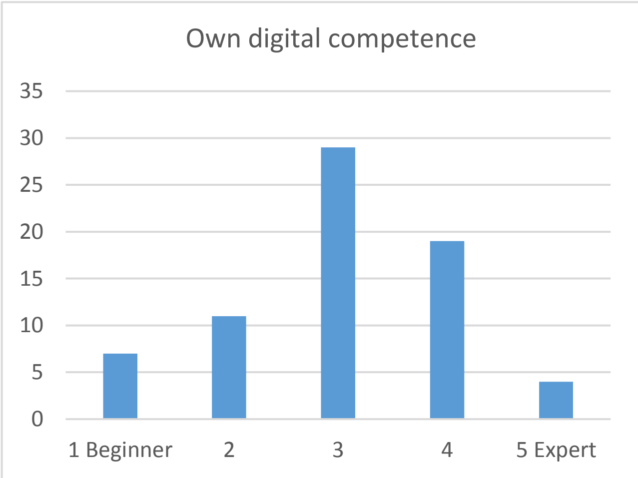
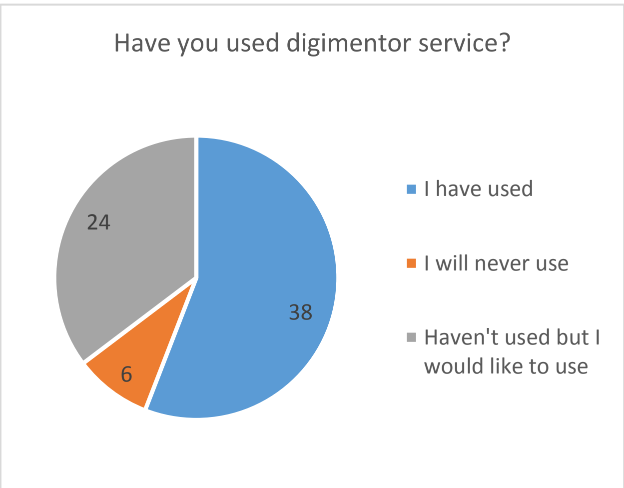


Fig. 3. Teacher's own digital competence

4.2 The digimentor service

Engineering educators were asked, if they had used the digimentor service. The answer distribution is presented in fig. 4.



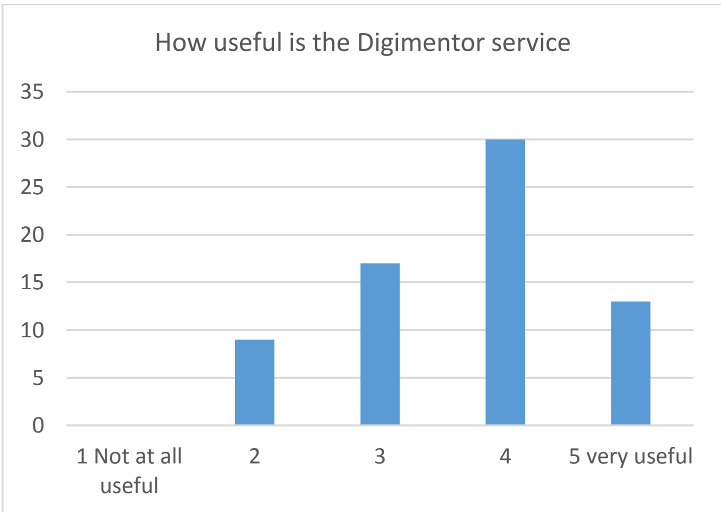
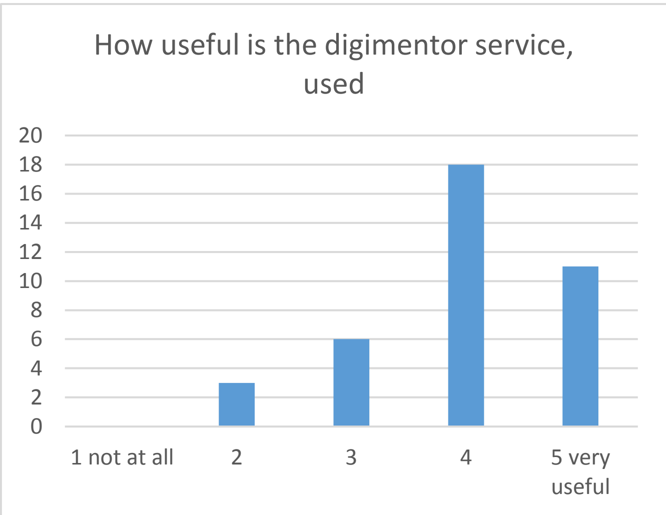


*Fig. 4.*Use of digimentor service *Fig. 5.* Usefulness, all answers

Among the answerers, 53 % (n = 38) had used the digimentor services during 15 months that the service had been available. 33 % (n = 24) had not used the service, but would like to use, 8 % (n = 6) announced that they have not used and will never use the service. As there were only 6 answerers and their teaching experience varied from 8 year to 42 years so it cannot be said that teaching experience divides teachers at willingness to use the service. One of the answerers was about to retire within one year. Four answers were empty.

The distribution of usefulness concerning digimentor services from all answerers is presented in *Fig*. 5. After all, even though there are 6 answerers who would never use the service, nobody considers it to be totally useless. The usefulness varies a bit between the teachers that have used the service and those who have not. The distributions of usefulness's between those who have used the digimentor service and those who have not are presented in *Fig*. 6. and *Fig*. 7. From figures 6. and 7. it can be seen that the digimentor service is seen more useful among those teachers who have used the service than those who don't.



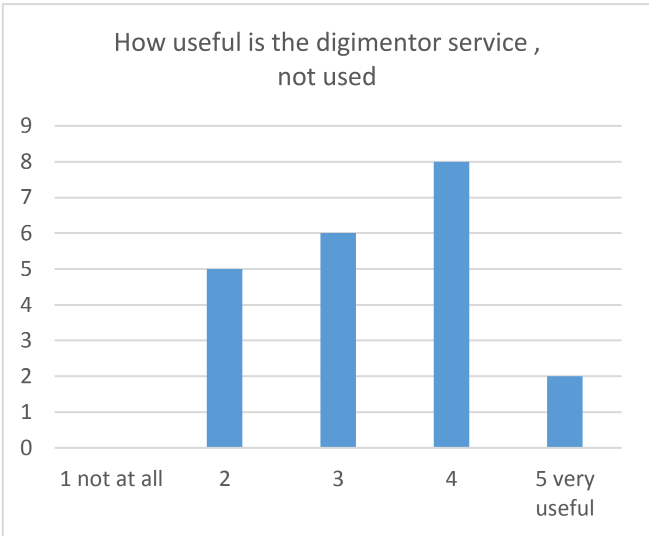


*Fig. 6.*The use of digimentor service, used *Fig. 7.*The use of digimentor service, not used

Open-ended and multiple-choice questions concerning reasons to use digimentors revealed some thoughts behind the decisions. Those 6 answerers, who announced that they will never use the service, gave explanations like "I already master the things I need" (4 answers) or "I don't need digitalization".

Among those 24 answerers, who announced that they have not used the digimentor service, but would like to use, the most common reason was the lack of time. The second common reason was the lack of ideas or vision, what to change in teaching. The most-mentioned subjects that this group would like to be mentored in future were production and distribution of own educational videos and effective use of LMS Moodle.

Those 38 answerers, who had used the digimentor servce, mentioned several subjects on which they had been mentored. The most mentioned subjects were videos, their educational use and the effective use of learning management system. Practical tips and hands-on pedagogical support were mentioned as the most concrete benefits gained. Overall the digimentor service was recognized as very helpful way of self-development and it is widely recommended to other teachers in the same stage of personal development. The distribution of answers to question, “Would you recommend the digimentor service to others” is presented in Fig. 8.

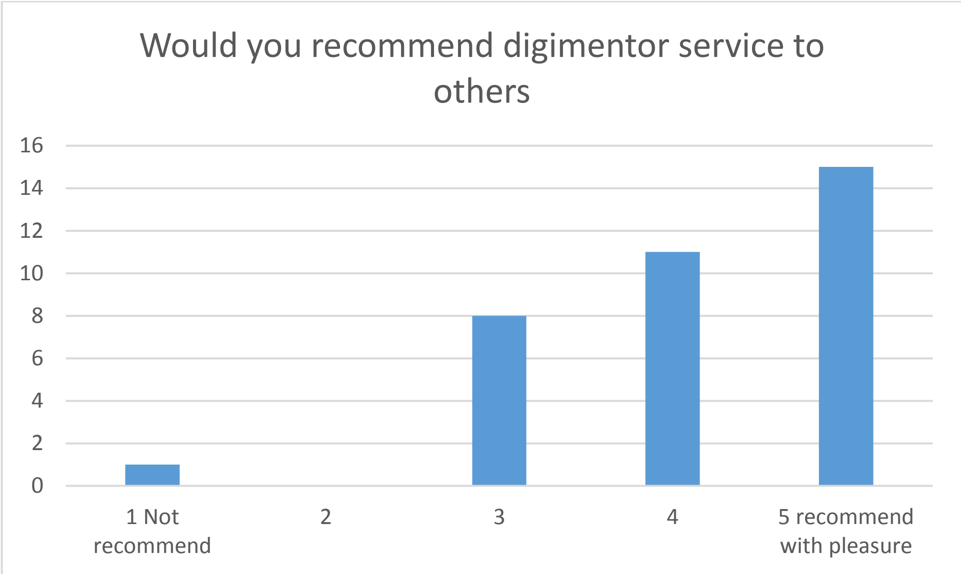


Fig. 8. Would you recommend to others

To improve digimentoring further, the answerers gave their ideas to develop the service further. The service itself was recognized as very helpful and well-working already. The improvements asked were larger workshops on most common subjects. The accessibility of the service could be improved. The digimentors were asked to be even more actively visible in the everyday life on campus. Short informative educational sessions connected to teachers’ meetings suggested being worth implementing. University-wide facilities and resources to make own educational videos were mentioned.

Open-ended feedback at the end of questionnaire got many positive and supportive comments concerning the service. The critical comments focused to cost-benefit ratio of the service. Are the benefits gained from the digimentor service worth of the money spent? There were also some skepticism if digitalization improves learning outcomes.

5 CONCLUSIONS

As a conclusion, it can be said that the most of the engineering teachers see the digitalization of teaching as the future of teaching and are willing to improve their digital skills, although some scepticism occurs. The digimentor service is seen as very helpful and easily approachable service to improve teachers’ own digital skills. The way to implement the support to digitalization via mentoring lowers the threshold to get help because the help comes from a person who you know and near in the working community. Help comes from a more experienced peer who is a little further on the path of digitalization. The fact that the service is warmly recommended to others reveals that the quality of the service is good enough and teachers have got help to the issues they need.

To enhance teachers' digital teaching skills more in the future, it is easiest to affect to the teachers who announced that they have "a lack of vision, what to change" This could happen with small informative demonstrations that are tied to teachers' normal meetings and public happenings.

The digimentoring in the Tampere University of Applied Sciences will continue at least to the end of this year, hopefully further. It will not only enhance the digitalization of teaching but also support sharing and collegial culture in the whole working community.

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Teaching Engineering Economy Using Internet

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ABSTRACT

Internet-based education is rapidly gaining popularity due to its availability, flexibility, accessibility, and cost effectiveness. In this research, the internet was used as an effective tool to enhance the teaching of the "Engineering Economy" course GENG315 at the foundation level in the college at a federal university in UAE. It is noticed that numerous related course material is available online as "YouTube" videos. Therefore, a carefully selected material was nominated and distributed to students during the course. A questionnaire survey was then conducted to analyze the impact of the experiment that reflects the positive aspects of video-based learning.

Conference Key Areas: Continuing Engineering Education and Lifelong Learning, Open and Online Engineering Education, Engineering Education Research

Keywords: Engineering Economy, Internet, YouTube, Active Learning

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INTRODUCTION

Nowadays the internet becomes widely used all over the world without any boundaries and limitations of the uses and applications. Actually, this imposes many advantages and disadvantages on the life in general and on the education in particular. However, one of the main advantages of the internet is deploying the knowledge everywhere without any restrictions. Using videos in teaching becomes recently a trend around the world to enhance the learning pedagogy and students outcomes attainments. Meanwhile nowadays with the rapid development of the communication and social media technologies, the students they become more distracted by the internet itself. Therefore adopting the E-Learning in teaching would be simulative factor to the students in all levels [1-3]. Moreover, the internet technology can be helpful and positive as a tool to diminish the negative impact of the internet like the social media, since the students may spend hours in browsing news and negleting their academic duties. YouTube, for example, became one of easy and free sources that can be accessed easily and can be used to upload videos that can be watched around the world. This channel has been used tremendously in teaching to enhance the learning experience and to keep permanently the material as an open resource for the students to study or to refresh their memories. Frongia et al. [4] analyzed the surgical proficiency and educational quality of YouTube videos demonstrating laparoscopic fundoplication (LF). A search was performed on YouTube for videos demonstrating the LF procedure. The surgical and educational proficiency was evaluated using the objective component rating scale, the educational quality rating score, and total video quality score. Technology Acceptance Model (TAM) of YouTube was studied by Chintalapati et al. [5], by developing scales to measure the factors explaining the behavioral intention and established the significance of the relationship between different variables and the behavioral intention validating the TAM. In the medical field, YouTube has its advantages in many ways. Duncan et al. [6] described the findings of a study undertaken to assess the quality of clinical skills videos available on the video sharing site YouTube by evaluating 100 YouTube sites, approximately 1500 min or 25 h worth of content across 10 common clinical skill-related topics. It was concluded that there is a clear need for the quality of YouTube videos to be subjected to a rigorous evaluation. Besides, it is recommended that lecturers should be more proactive in recommending suitable YouTube material as supplementary learning materials after appropriately checking for quality. On the other hand, YouTube offers visual access to childhood illnesses and disease processes to the medical students may not encounter during their regular pediatric clinical rotations. Videos from hospitals, healthcare organizations, news media, and personal accounts are all available to enhance and stimulate the learning process [7]. Moreover, YouTube offers nurse educators immediate access to healthcare related videos for the classroom. In classrooms that are equipped with Internet and projectors, educators can quickly access YouTube and utilize videos to meet classroom objectives, as explained by Agazio and Buckley [8]. In addition, Rapp et al. [9] discovered that the most widely used video source used in preparation for surgical procedures is YouTube. The relatively recent increase in video availability and use presents an opportunity to create new training tools for students, residents, and faculty in the surgical field, not as a replacement, but as an addition to established teaching methods. De Witt et.al. [10], studied the benefits of the use of YouTube as a tool for teaching and learning in the performing arts, and for maintaining students' interest and achievement in learning, as well as to determine the suitability of using YouTube as a tool for teaching the performing arts in future. The findings show the YouTube has the potential as an instructional tool in the performing arts in line with current trends of collaboration and social networking in education. YouTube videos were selected to enhance course topics and materials found in traditional text-based materials. Original videos were created in the style of Khan Academy, to prerecord short lectures promote in the literature on case teaching and flip format learning. Online course evaluations measured student progress on learning objectives [11]. In the present study, YouTube has been used to enhance the learning experience of the students in the foundation level of the college of engineering. Engineering economy course GENG 305 was selected for this purpose to investigate the effectiveness of the YouTube in enhancing the students'' performance in the course.

1 METHODOLOGY

In order to improve the students' understanding of the topics of the "Engineering Economy" course GENG315 in the college of engineering at UAEU, a pre-assessment was performed to figure out the topics that are considered as weak points for the students understanding. Therefore, a careful list of suggested videos from the YouTube was selected to perform the main goal of the task. *Table 1* illustrates the nominated subjects that were delivered to the students. When the targeted subjects were completely covered, the suggested topics were delivered to 40 students one week before the midterm, and later on the feebacks were collected after the exam.

Table 1. The suggested videos for engineering economy course

	YouTube links	Subjects
1	https://www.youtube.com/watch?v=zGRVVSC4UUQ	Evaluating investment by PW
2	https://www.youtube.com/watch?v=fM63moi1Qjo	Time value of money
3	https://www.youtube.com/watch?v=Q299WQqSGFo	Annuity
4	https://www.youtube.com/watch?v=n4QINzCCKGE	time value of money
5	https://www.youtube.com/watch?v=5lUgITdBF2M	Types of Interest
6	https://www.youtube.com/watch?v=VaZLXTULXqE	Present Worth - Fundamentals of Engineering Economics
7	https://www.youtube.com/watch?v=lLuKPh8WM6w	compound interest
8	https://www.youtube.com/watch?v=GeHu6YoG9B0	Present Worth
9	https://www.youtube.com/watch?v=SNoPFiFHkbA	Present and Future Value
10	https://www.youtube.com/watch?v=B3IdfBcXrLA&list=TLBq2QmPod-nQBJeVkRq0JdQlabXL23iIS	Simple and Compound Interest
11	https://www.youtube.com/watch?v=joBu9TnFngQ	Annuities: Annuity Due, Finding Future Value
12	https://www.youtube.com/watch?v=cVXYiWRZd7U	Compound Interest: Present Value/Future Value
13	https://www.youtube.com/watch?v=CnRJ6Jypsj4	Time Value of Money
14	https://www.youtube.com/watch?v=IonXkP0gI7o	Engineering Economics
15	https://www.youtube.com/watch?v=2nYkCfdiC3E	Future Worth - Fundamentals of Engineering Economics
16	https://www.youtube.com/watch?v=VyReAhTBvOw	Present value, future value, and compounding made easy
17	https://www.youtube.com/watch?v=FnzoTQMCIo4	Future Value of Money Calculation -Basic - tutorial video lesson review
18	https://www.youtube.com/watch?v=kega_QOCvxQ	Cash Flow - Fundamentals of Engineering Economics
19	https://www.youtube.com/watch?v=kwlWeijKUNo https://www.youtube.com/watch?v=FtAZD4R-Wh0 https://www.youtube.com/watch?v=NmzEqkiF3Eo https://www.youtube.com/watch?v=szlYT8uNJIl	New Car Buying vs. Leasing, Part 1 New Car Buying vs. Leasing, Part 2 New Car Buying vs. Leasing, Part 3 New Car Buying vs. Leasing, Part 4
20	https://www.youtube.com/watch?v=69mVcnewPbw	Break Even Analysis

2 QUESTIONNAIRE SURVEY

A questionnaire survey was designed and conducted among students to explore their feedback regarding the distributed course material and its level of usefulness. Their feedback was then used to analyze the impact of this experience on students' understanding of the subject topics and their performance in the course. *Table 2* shows the questions of the survey. Students were asked to provide a score on a scale from "1 to 5" for each question, where one represents "very low" agreement level and five is "very high" level of agreement.

Table 2. The distributed questionnaire survey

	Questions	Score:1-5
Q1	In general, do you prefer to study through videos	
Q2	Do you think that the videos selected were helpful	
Q3	Were the materials in general similar to the one you are studying	
Q4	Do you prefer your instructor to do videos	
Q5	Do you like presenter to be shown in the video	
Q6	Did you get helpful assistance from the watched videos	
Q7	Was the material of some videos distracting?	
Q8	Do you think that some videos contain materials not taking	
Q9	Is it better to have blended learning	
Q10	Are the videos clear enough to understand?	
Q11	Do you prefer to have videos on UAEU website rather than using YouTube	
Q12	Do you think videos are made for business purposes rather than education	
Q13	The main problem of the videos is the recording type	
Q14	Was the sound clear enough	
Q15	Good video material can help you to understand the subject	
Q16	Do you like to have videos of the presented lectures	
Q17	Do you like to have videos of extra solved cases	
Q18	Did you like to involve in this survey to improve teaching of the course	
Q19	Do you think that answering this survey will make change in this experience	
Q20	In general, do you think it is better for other courses to start using videos	

3 RESULTS AND DISCUSSION

Once the survey feedback was collected, the results were analyzed to investigate the impact on students' performance in studying the "Engineering Economy" course GENG315. Figure 1 shows the results of the responses (as a percentage) for the 20 questions considered in this study. In general, Q1 shows that 92.5% of the respondents showed their interest in studying through videos. On the other hand, 100% of students considered watching the videos is helpful to them, which is a positive sign, as illustrated by Q2 responses. In addition, 100% believe that the material selected coincided with the one they take in the course and this is an indication regarding the carefully selected videos that were nominated and reviewed based on the course subjects (i.e., Q3). However, frankly, they prefer that the course instructor records the videos and that the instructor photo to be shown in the prepared videos, both of them got 100%, this is revealed through Q4 and Q5 feedbacks.

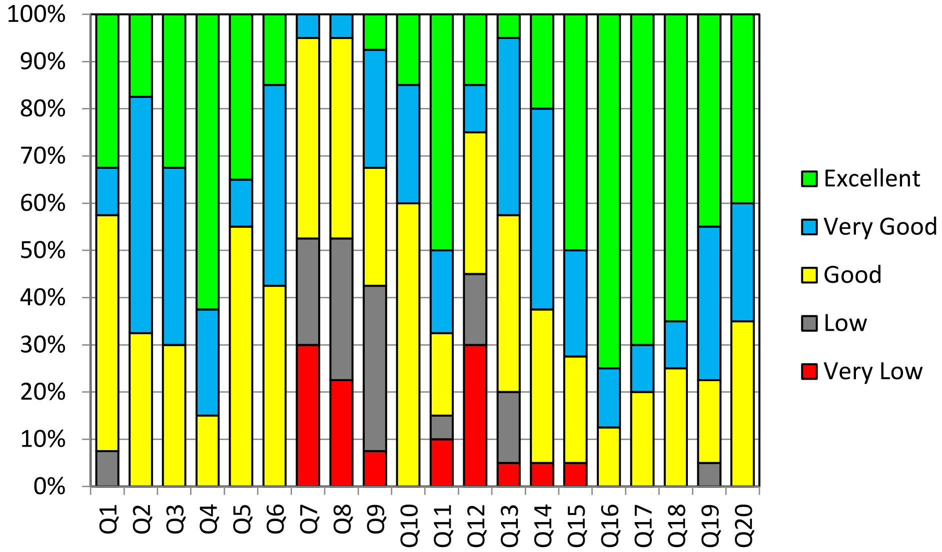

Fig. 1. The results of the distributed survey

In general, question 6 is linked with question 2, and both questions show close feedback about the helpfulness of the watched videos. The results of questions 7 of the survey revealed that 47.5% of students believe that some videos are distracting and that urges to establish course videos by the instructors themselves. In response to question 8, around the same percentage indicated that some videos contain irrelevant material to the course. Around 57.5% like to have blended learning that needs more efforts to deploy it in general in order to attract more students, as revealed by question 9 feedbacks, whereas question 11 shows that the selected videos are clear technically. All respondents believe that the nominated videos are clear enough while the majority of respondents (85%) believe that instructors should have videos posted on the university website to make it easy for them to browse it (i.e., Q11). The responses to question 12 indicate that around 55% of the students believe that the videos published are for marketing and advertisement purposes. Two technical problems are highlighted in response to questions 13 and 14 that attracted 80% and 95% respectively that is the recording type of the videos as well as the quality of the sound that made the students unhappy with these issues. Question 15 shows that around 95% of the respondents are satisfied with the video' material for a better grasp to the course while they prefer that videos be prepared and recorded by the course instructor. As part of the learning experience, all students believe that solving more problems is very helpful for students to grasp better the course material, as well as to have videos of the presented lectures, as shown in Q16 and Q17. In addition, all students believe that this survey will improve the teaching and learning of the course (i.e., Q18). In response to question 19, around 95% of the respondents are optimistic to see changes based on this initiative. Eventually, all students indicated that other courses should similar steps since this is the new global trend nowadays, this is recommended by question 20 feedbacks. The data received from the questionnaire responses was carefully analyzed and the Relative Importance Index (RII) [12], was calculated as shown in *Table 3* to determine the relative importance of the responses to each question. The Relative Importance Index (RII) was calculated using following equation:

$$RII_k^i(\%) = (n_1 + 2n_2 + 3n_3 + 4n_4 + 5n_5)/(n_1 + n_2 + n_3 + n_4 + n_5) \times 100$$

where $RII_k^i(\%)$ is the Relative Importance Index of each factor *i*, for each group of students, k, while n_1, n_2, n_3, n_4, and n_5 are the number of students who provided a score of 1, 2, 3, 4, and 5, respectively.

Table 3, illustrates the ranks of the calculated RII for the responses of the 20 questionnaire survey questions. The ranking was grouped into three main categories (shown in Figure 2). In conclusion, around 40% of the respondents strongly believe that using videos through the study of the course is very useful and using extra videos will, undoubtedly, enhance the learning process. Students also believe that introducing videos in classes will have positive changes and implications to the learning process. Moreover, the helpfulness of watching the videos and the similarity between the materials watched and that studied in the course are positive as well.

Table 3. Relative Importance Index (RII) of the collected feedbacks

	Question number of students	Rank	RII
Q16	Do you like to have videos of the presented lectures	1	93
Q17	Do you like to have videos of extra solved cases	2	90
Q4	Do you prefer your instructor to do videos	2	90
Q18	Did you like to involve in this survey to improve teaching of the course	4	88
Q19	Do you think that answering this survey will make change in this experience	5	84
Q15	Good video material can help you to understand the subject	6	83
Q20	In general, do you think it is better for other courses to start videos	7	81
Q3	Were the materials in general similar to the one you are studying	7	81
Q11	Do you prefer to have videos on UAEU website rather than using YouTube	9	79
Q2	Do you think that the videos selected were helpful	10	77
Q5	Do you like presenter to be shown in the video	11	76
Q6	Did you get helpful assistance from the videos seen	12	75
Q14	Was the sound clear enough	12	75
Q1	In general, do you prefer to study through videos	14	74
Q10	Are the videos clear enough to understand?	15	71
Q13	The main problem of the videos is the recording type	16	65
Q9	Is it better to have blended learning	17	58
Q12	Do you think videos are made for business purposes rather than education	18	53
Q8	Do you think that some videos contain materials not taking	19	46
Q7	Was the material of some videos are distracting	20	45

Around 25% of the respondents expressed their opinions regarding the negative impression about using YouTube videos in the learning process. The main concern, in the opinion of respondents, is the type of videos, being used for advertisement purposes, not relating material well as some of them were distracting the students. In fact, the authors believe that students misunderstood question 9, which was ranked 17 with an RII of 58%, and assessed it wrongly. The response to this question was supposed to be positive since blended learning is expected to improve the learning pedagogy and, therefore, the responses to this question are considered irrelevant.

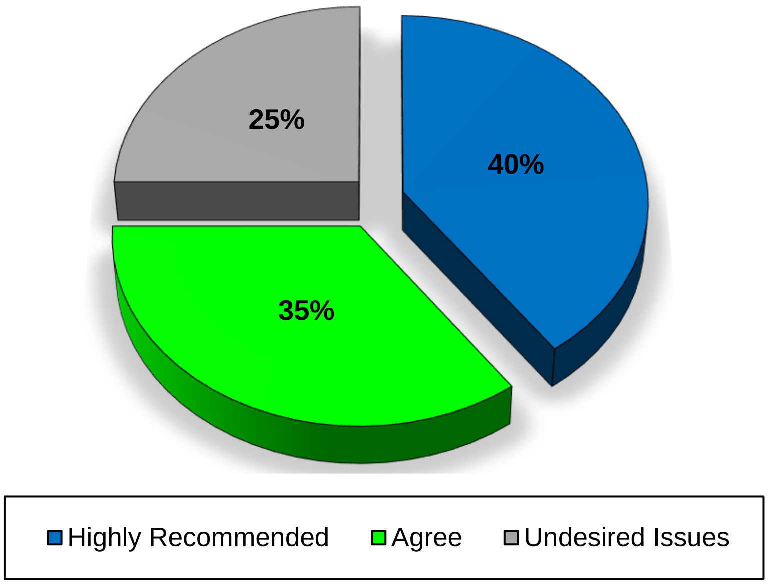

Fig. 2. Relative Importance Index: Percentage response

The medium range of the RII (71-79%) shown in Table 3 represents the 9 to 15 rank range. It is revealed that establishing videos by the university is important since videos are very helpful in the learning process. It is also preferred that instructors themselves record such videos to make sure that the quality is good and the sound and videos are clear. The top-ranked RII showed the significance impact of the watched videos with emphases on the importance of having videos for course lectures, especially for extra-solved problems related to course materials. Respondents also suggested that such videos should be recorded by course instructors. Questions 18 and 19 also provided positive students' feedback and the results depicted from the questionnaire survey responses suggest that the expected changes and improvements in the learning of the course are indeed an encouraging factor. Finally, it is worthwhile mentioning that the watched videos, related to the course material, were successfully selected for practicing and were very helpful for a better understanding of course material. Students, therefore, suggested following the same trend for the other courses.

4 SUMMARY

The present work shows the advantage of using the internet as a tool for learning purposes through using carefully selected videos to form YouTube channel. However, although there are some concerns from the students, but this survey highlights the need for building own learning videos for a better grasp. Further analysis is need after final exam results to compare the course outcomes of the course of the particularly investigated section, with results revealed by the present study to get a comprehensive image of the study advantages.

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Experiences of academic advising at Master's level in multicultural groups

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ABSTRACT

This work deals with academic advising in the Master's level studies in the Master's Programme in Chemical, Biochemical and Materials Engineering in Aalto University where one third of students entering the Master's level take their Bachelor's degree outside our university either in Finland or abroad. Surveys among the students and the academic advisors were performed in order to find out the common practises, experiences and expectations of the current state of the academic advising in our Master's degree programs. It was found out that the students are offered academic advising but all students don't take advantage of it. The students are mostly expecting the academic advisors to support them in the planning their studies, finding Master's thesis positions and topics and finding their professional strengths. The results of this study are used to further develop the academic advising practises in our school.

Conference Key Areas: Attractiveness of Engineering Education, Engineering Education Research, Curriculum Development

Keywords: Academic advising, Tutoring, Student support

INTRODUCTION

Academic advising is a concept that has many names and its content can vary from university to university. It is also referred as tutoring and academic mentoring.

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Academic advisors can be either administrators, for example planning officers, or professors or lecturers who teach and also have role as an advisor. The role of the professor or lecturer is more like supporting career planning and enhancing students' integration into academic community. Meanwhile the administrators help with various kinds of practicalities from filling of all papers required in the beginning of studies to reminding of important deadlines and following study success. [1-3]

Academic advising is exchange of information and knowledge and it aims to support the students to find their identity in studies and career. [4] It has been underlined that successful academic advising plays a significant role in socializing the students into the academic community, helping their professional development and even improving study retention. [5-6] The tutors should also be active listeners and have respect and empathy for the students in addition to having friendly and supportive attitude. [7]

The prevention of the student drop-out is an important aspect to handle by the academic advisors. It has been observed that the contact of the academic advisor has a big role in reducing the drop-outs and improving student retention. [8] On the basis of these observations methods for detecting and picking the possible drop-outs have been proposed to guide tutors to contact students at risk and also software for this has been implemented. [9]

1.1 Academic advising process in Aalto University School of Chemical Engineering

In Aalto University, effort has been put in developing academic advising procedures at both Bachelor's and Master's level. In this paper, we are focusing on Master's level academic advising in our recently renewed degree program.

In this context the academic advising means the tutoring of students by professors and lecturers and it includes guiding of the students to help them to develop and achieve their educational, professional and personal goals. Our planning officers organize the selection of academic advisors and group the students in each major. In addition the planning officers help the students in practical matters related to studies.

One academic advisor is appointed to group of 5-7 Master students. The students meet their academic advisor during their orientation week in the very beginning of their studies. After this, each academic advisor has their freedom to organize the academic advising process as they choose and a guideline is given to ensure that each academic advisor knows how to proceed.

The main aims of the academic advising in our school are to engage the students to the academic community, support the fluent study progress by guiding and motivating the students and generally give the students the feeling that the staff and school care about them and the study progress of each student. Academic advising is most intense in the beginning of the studies but it lasts all the way through the Master's degree which is scheduled for two years in our university.

Characteristic for our Master's study program is that approximately two thirds of the students come from the Bachelor's study program of our university and the rest come from other universities. Especially the international students entering the Master's program need different kind of guidance for the culture of the country and the university. The student groups for the academic advising are therefore organized so that they include both students from our own Bachelor's program as well as from other universities and countries so that the students can also act as peer mentors in the learning community for each other within the groups.

1.2 Scope of the study

The first strong motivation to look at academic advising just now is that our current Master’s programs have been run for two years since the renewal of the curriculum and it is good find out how the process actually works. The other issue that motivates this research is the fact that our university introduces tuition fees next fall. Thus it is of mutual interest of both students and staff to make the study path of each student even more effective and promote the retention of their studies and we consider that the academic advising can have an essential role here. In addition, the Master’s level studies is planned for two years which requires that the start of studies should be efficient already from the first study period and the follow-up of the students is to be used as tool to encourage them to proceed in their studies as planned. Furthermore, the principles of academic advising for our school have been rewritten during 2016 and therefore this study is conducted to see how these practices new have been implemented.

2 METHODOLOGY

The focus of this research is the process of academic advising at our school from the perspective of all the actors i.e. the academic advisors, the students and the planning officers. A questionnaire (Tables 1 and 2) among both students and academic advisors was carried out in January 2017 to study their experiences and expectations on the current system. Anonymous web based forms were used in this study. The invitation was sent to all professors and lecturers who have been nominated as academic advisors in our Master’s programs on years 2015 and 2016. Students selected to this study were students of two majors who started their Master’s studies in 2015 and 2016. This means that both first and second year students were included in the study. The questionnaire consisted of both multiple choice questions and open-ended questions which made it possible to get rich descriptions in order to formulate understanding the researched area/field. [10]

Table 1. Questionnaire for students

no	Question
1	How many times have you acted as an academic advisor of a student group at Aalto CHEM?
2	What is your major?
3	Do you know who your academic advisor is? (Yes/No)
4	How many times have you met with your academic advisor with your group?
5	How many times have you met with your academic advisor individually?
6	Is the academic advising meeting your expectations? (Yes/No)
7	Explain and define your previous answer. What expectations do you have?
8	Is your academic advisor easily available? (Yes/No/I haven’t contacted))
9	Do you feel that your academic advisor is interested in your development as a professional? (Yes/No/I don’t know)
10	Do you think that meeting with your academic advisor is useful? (Yes/No/I don’t know)
11	Why?
12	Evaluate the following statements (A lot/somewhat/Not at all)
	My advisor was prepared for my appointment
	My advisor listened to my concerns
	My advisor seemed genuinely interested in me

	My advisor is helpful in discussing my career plans and goals
	Overall, my advisor is a good source for academic advice about my university
13	Which topics have you discussed with your academic advisor?
14	Which topics do you wish to discuss with your academic advisor?
15	How often do you wish to meet with your academic advisor?
16	Any other comments on academic advising?

Table 2. Questionnaire for academic advisers

no	Question
1	How many times have you acted as an academic advisor of a student group at Aalto CHEM? (once/twice/three times/more)
2	How have you contacted your first year master student group during this academic year? (in the orientation/ group in a separate meeting/ personal meetings/ by e-mail/ chat in the corridors/ in the lectures)
3	If you have you met the students, how many times?
4	If you have you met the students, how many times?
5	Is it easy to agree on the meeting times?
6	Have the students participated in the group meetings?
7	Have you got enough support for advising the students?
8	If not, what kind of support do you wish?
9	Have you done any cooperation with another academic advisors? (no/ I have discussed about the topic with others/ I have had joint meetings with other advising groups/ something else)
10	Do you feel confident when acting as an academic advisor? (yes/somewhat/no)
11	How rewarding do you find the experience of being an academic advisor? (1-5, not rewarding at all-very rewarding)
12	How do you rate the effectiveness of academic advising process at Aalto CHEM? (1-5, not effective at all-very effective)
13	Students play an active role when meeting with their academic advisor. (1-5, strongly disagree-strongly agree)
14	What do you find to be the most rewarding aspect of academic advising?
15	What do you find to be the most frustrating or dissatisfying aspect of academic advising?
16	Any other aspects on academic advising at Aalto CHEM?

In order to be able to form the whole picture of academic advising three planning officers who has been involved in the academic advising process for couple of years were interviewed and the interviews were recorded. In the discussion they were asked to describe the present practices and analyze the academic advising process from their point of view. The researchers' role in the interviews could be somewhat biased since both are acquainted with the persons interviewed which leads easily to subjective interpretations of the answers.

Number of respondents was 15 (12 % of the invited) in the student survey and 9 within the teachers (26 % of the invited). The answers obtained were analyzed by the researchers individually and the final result was formed based on this. Qualitative methods were chosen [11] because the restricted number of the persons taking part in this study. For the open questions a narrative analysis method was used.

3 RESULTS AND DISCUSSION

3.1 Survey among the students

According to the survey, most of the students have met their academic advisor in a group meeting in the orientation. Thus it seems that the academic advising process starts efficiently and reaches the students in the very beginning of their studies. Some students reported that they had also had some private discussions with their academic advisors which indicates that the students know how to reach the academic advisors in case they have issues to discuss.

The students are expecting that academic advisors would support them in the planning of their studies, finding Master’s thesis position and topics and finding their professional strengths and be available to give feedback and ask questions.

> *“I would like the advisor to guide and support in finding my professional strengths.”*

> *“My expectations have been, that my advisor can be contacted if I need guiding in academic matters.”*

> *“Helping to find the master's thesis position/giving some more info about master's thesis or career options.”*

However, most of the students feel that they can manage without any support from academic advisors, which indicates that the information related to the studies is easily available. This is also reflected in the reply of some students as they did not even know who their academic advisor is.

Academic advising is not compulsory part of the studies and it doesn’t have a place in the timetable and therefore some of the students feel that it is not that important which is pointed out e.g. in the following response from a student:

> *“Would be nice to see how it would be but usually there are too many other things going on to even remember that such a thing as academic advisor exists.”*

> *“I have not officially had a meeting with my tutor, but we have talked”*

On the other hand, the students pick their own specialization rather early in their studies and if the academic advisor is not involved in the study path of the student some students rather contact other staff than the academic advisor as stated in the following response. All in all, it is not a bad situation if the students know how to reach someone from the staff to support them.

> *“I think I would prefer to ask help from professors from my own field than from my academic advisor.”*

3.2 Survey among the academic advisors

All the academic advisors reported that they have organised some meetings with their students and they feel that it is important to get to know the students. Thus it seems that people who act as academic advisors are committed to their duties and they know the practises and aims of academic advising in our school.

The academic advisors feel that their most important duties as academic advisors are to listen to the students and help them in their questions. They think that the most difficult is to find times for meetings with the students and get all the students to attend the meetings. It was especially pointed out that the domestic students who had background in the Bachelor’s program of our university do not attend the organized meetings. This was reflected also in the survey among the students as some students felt that there is no time for the meetings with the academic advisors or that the meetings are nor important.

> *"It seems that most of our old BSc students feel that they know what they are doing."*

In addition, as the academic advisors are teaching the courses that the students take, many questions related to academic advising are handled in unofficial discussions after the lectures when the teacher is available.

> *"They are also at my courses, it is easiest to ask if something needs resolving after the lectures."*

The academic advisors replied that they feel confident to act as an academic advisor either because they have got enough support form organization or colleagues or they have so much experience after being here for a long time. This further indicates the commitment of the academic advisors in their duties. In addition, it seems that the support and guiding for the academic advisors is well handled. Finally, the academic advisors seem to feel that the system should be kept as flexible as possible which is nicely highlighted in the following quotation:

> *"Please don't add any bureaucratic upper-level control into the process."*

3.3 Survey among the planning officers

The planning officers have the impression that the academic advising process starts well in the orientation week of new Master level students but after that it is very much dependent on the professor in charge of each major and individual academic advisors. The academic advising process could be more structured if there were at least a short educational meeting for all the academic advisors before the orientation week. At least the less experienced academic advisors could also benefit of a more structured, pre-planned academic advising. This could also make it easier for the academic advisors and the students to find common time that seemed to be one of biggest challenges.

One thing mentioned in all of the interviews was that academic advising process as a part of educational duties should be more appreciated also at the university level. The professors who are responsible of each Master's major paly here an important role by discussing about the importance of academic advising with all the teachers taking part in the process.

One important way to support students' studies is to follow their study success. It is good to discuss the studies even though everything seems to be fine. It is clearly seen that speaking about one's plans aloud clarifies them and it is especially important to find the weak points as early as possible to avoid drop-outs and prolonged studies. The planning officers play an important role since they have the access to student records and therefore are able to report about their study progress to academic advisors. It is a duty of every academic advisor to discuss with the students when they seem to have difficulties in obtaining enough credits and try to find the reasons for any delay as early as possible.

The students discuss about the Master's Thesis positions also with the planning officers. Especially international students who are not familiar with our academic culture for example how to contact professors more easily contact the planning officers first. In addition, planning exchange studies is a topic that the planning officers are dealing with the students. This is naturally more typical for the domestic students who want to know how to find an appropriate university and what kind of courses would best fit their studies.

4 CONCLUSIONS

The academic advising at Master's level was totally renewed two years ago when also the majors were reorganized. One of our challenges is that departments of our school used to act individually and now they are merged together quite recently. This can be seen also as variation in the culture of academic advising as previously different departments had their own practices. Thus it seems that we don't have a common way to carry out the academic advising in our school and practicalities of academic advising vary from major to major. These differences can be diminished if the responsible professors would discuss and share the best practices. We do have a plan for academic advising but guiding and support of academic advisors is not organized.

All in all, it seems that students are offered the support from the academic advisors but all students are not utilizing this opportunity either because they feel that they don't need it or because they don't have enough information about the system. On the other hand, the students are in different position: some need the info on practical issues as they start their studies in a new university whereas the students who continue from our own Bachelor's program do not need that much support in the practical issues.

As a conclusion it can be said that the academic advising at our university works effectively since the teachers and the students felt that most of the students' needs were fulfilled. However, there are evidently also needs to improve process as the academic advising is an important process to support the students to proceed in their studies efficiently completing their studies in two years as required. Our results show that the selection of academic advisors and their guidance are not to be sneezed. Listening students' needs and expectations provide a good tool when planning the practicalities of academic advising. In the future some students are to pay tuition fees which can lay stronger pressure on all the processes within Aalto CHEM. The academic advising that is organized optimally is definitely an effective tool also here as facilitating the discussion between students and teaching personnel.

The results of this study are valuable feedback on the current state and they will be utilized in the further development of the academic advising issues in our school. The idea of more efficient student guiding has been implemented and some further developmental actions are needed to ensure the most efficient academic performance of the students as well as to enhance the integration and commitment of the students to become active part of our learning community.

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Online Support of Project-based Learning

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ABSTRACT

Project based learning is widely used teaching method in engineering education. In addition to learning substance knowledge projects make it possible to develop ever so important work life expertise such as teamwork and organizing skills. Students are also motivated by projects because they have the possibility to put their knowledge in practice. For teachers project based teaching is often laborious effort, which requires many resources. There are also numerous challenges in projects courses starting from unsystematic progression of the projects and unclear instructions and ending to various social and communicational issues. Based on a survey, students consider open formed tasks, challenges in getting started, management of time, division of tasks and internal communication of the project team as major challenges in project work. Many times the interest of both teacher and students in project work is focused on the outcome of the project instead of the process and learning.

In this study, approaches to supporting different phases of students' projects with online tools are presented. Methods to help, for example, the team formation and communication, project management, documentation and reflection on learning were tested on several engineering project courses. Tools include online forms and questionnaires, video support material and video reports and online self-assessment.

Students' perceptions of the suitability and usefulness of the tested methods were surveyed using online questionnaires during the courses. The results provide us basic principles to utilize online tools in project-based courses. Students prefer multimedia instruction and clear description of the learning process during the project. In addition, the project reporting should be targeted to support future student projects. This study helps us to develop the guidance of the projects. Better-structured project instruction also makes it possible to change teacher's role from a project manager to enabler of the learning.

Internet tool supporting autonomous work – 20 years after

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ABSTRACT

Assigning each student a proper set of tasks to be solved on his own is an efficient tool in engineering education. Some 20 years ago, AMOS, an automated tool providing for student's autonomous work support has been put into operation at the Faculty of Electrical Eng., CTU Prague. Since then, the system has served to thousands of students. Basic system arrangements as well as some experience gained are shared within the scope of this paper.

Conference Key Areas: Open and Online Engineering Education, Engineering Education Research, Physics and Engineering Education

Keywords: Computer Aided Education

INTRODUCTION

Solving example tasks in a classroom is commonly used in engineering education. Assigning individualized tasks to each student and letting him/her to work on his own is possibly even better. Unfortunately that is also very time consuming. On the other hand, a lot of the work on the teacher side may be automated. Such an automation takes most of the boring tasks off the teacher shoulder, leaving more time for real creative work.

1 SYSTEM DESCRIPTION

1.1 Classic approach

Thirty years ago, each individualized task was pre-computed first and then printed on large paper sheets (using mainframe computers or PhD students). Bachelor students have then been assigned tasks with some individual input parameters, mostly read by the teacher. Issuing one task to hundred students took at least one hour. Students visited the poor professor many times to check results against great printed tables, causing numerous interrupts in his work and finally taking several hours of his time before correct solutions were achieved. Sometimes lookup errors in large tables caused incorrect input parameters or even correct replies to be declared incorrect.

1.2 Computerized approach

Each student has a unique identifier. This identifier is used to derive a unique seed number for a pseudo-random number generator. “Random” numbers are then used to create personalized tasks.

First implementation [1] used a list server, tasks were dispatched and results checked using e-mails. Such a solution under Microsoft DOS 3.2 has been in operation between 1997 and 2000. Since then, the system is available through a web page [2]. As operation systems and internet technology evolved, several implementations emerged. Linux Apache server, MySQL and PHP are currently used.

After a student logs in, he can find his tasks and send back his results for automated check any time. At the same time the system records student’s activity so that teachers may learn about their students.

The system keeps all necessary information to support several teachers and students belonging to different study programs, courses and years. Several different scenarios for task composition are in use.

1.3 Simple task example

The simple task scenario consists of a short story – eg. problem description, necessary picture(s) and a fixed set of questions. “Random” input parameters are generated for each student.

To check student answers, closed-form formulas are used to calculate correct replies. Answers are then compared against “exact” values and accepted if they fall within +-2% margins.

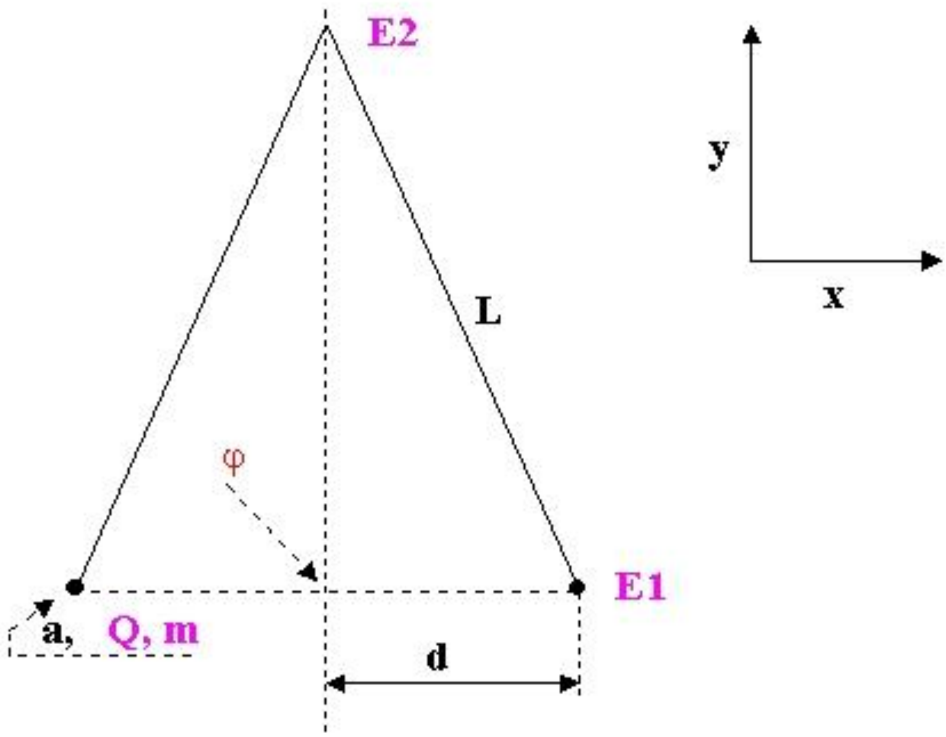

Fig. 1. Simple task. Picture used by the system.

An example used in basic electromagnetics course: Two conductive charged balls possessing small diameter **a** are hanging on two insulated lines of equal length **L** and negligible weight **m,** see Fig. 1. Each ball bears a positive charge **Q**. Coulomb repulsive force keeps the balls apart at mutual distance 2**d**. Given a, m, L and d, calculate Q, field strengths E1 and E2, potential … (abbreviated)..

1.4 Complex tasks

While simple tasks are based on closed form formulas, directly coded in PHP language, a number of interesting tasks lack closed form solutions and mostly require more calculation time. Such tasks are solved using in-house solvers and then stored in a database table. To provide for enough versions, 15000 instances are used.

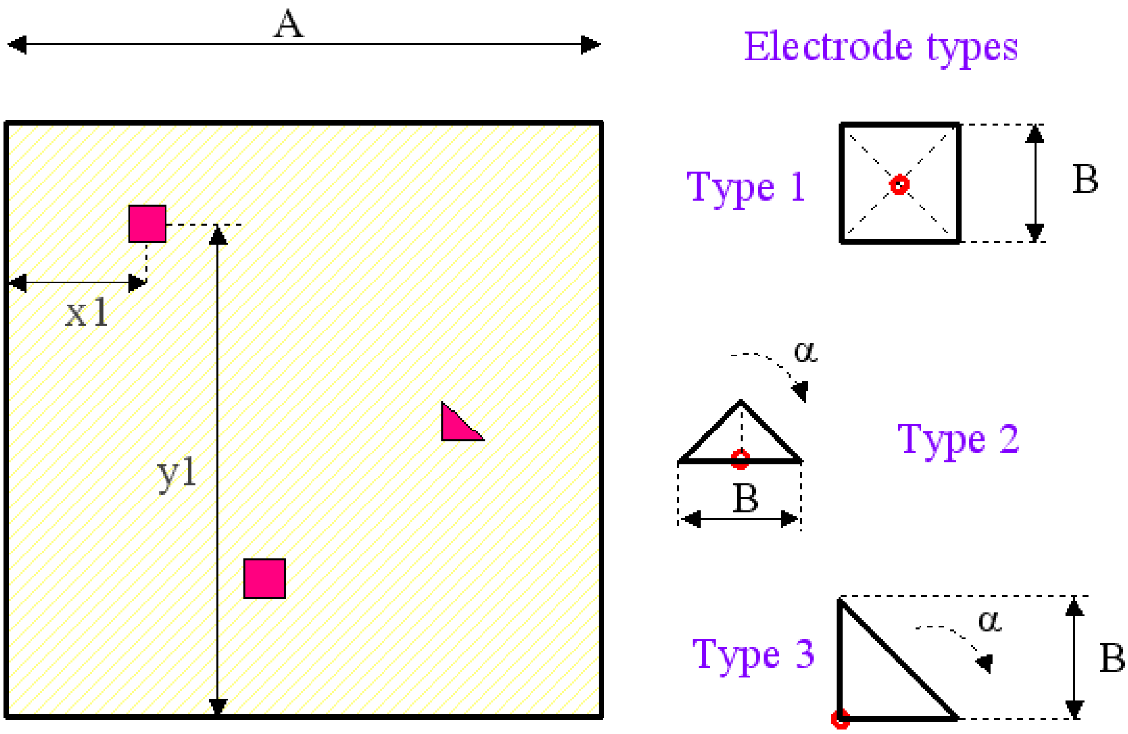

Fig. 2. Complex task example. Picture used by the system.

An example used in electromagnetics course requires numerical solution of a 2-D steady current field. Several electrodes of various crossection are placed inside a rectangular metallic tube, immersed in conductive media, see Fig. 2. Students are asked to find out currents per unit length, voltages, dissipated power etc., after being taught the basics of numerical solution of static fields using finite-difference method.

1.5 Inverse problems

Inverse problems are quite different from direct ones, the main difference for computer implementation being possibly the existence of a manifold of solutions. While straight problems begin with a set of sources and the unknown results are found as a direct consequence of source presence, inverse problems aim at establishing source(s) that would cause a known field.

As an example, students should provide a set of sources (charged balls, loops, straight wires) along with their position(s) and orientation(s) in order to achieve given electric field strengths at given points of "measurement".

In this case, replies received from students are used to calculate the solution, which is then compared against measurements and the reply is marked as correct if the difference between calculated and “measured” values was small enough. As this calculation must be done within a short time, only problems involving closed form expressions or simple fast iterations are supported.

1.6 Design type problems

Design type problems are important in engineering education. As an example, students should design a matching circuit in order to match a complex load to a 50Ω source at a given frequency or within a given frequency band.

Such problems may involve complex calculations. Quite often, specialized analysis software is available (such as SPICE for electronics) and may be used to handle all the calculation. Student’s design is submitted in a form of a SPICE formatted netlist, parsed and submitted to SPICE for analysis. After obtaining results, AMOS program checks whether the result is compliant with design goals [3].

2 EXPERIENCE GAINED

2.1 AMOS in use

As mentioned above, the system has been in use since 1997. Since then, it runs both in winter and summer terms, where the number of participating teachers/students may be as high as 30/1200 per term. It has been experimentally verified that setting a deadline at the end of a term results in some 95% of students starting with their homework within last two days. Currently we prefer to leave two weeks only for each task, where tasks are evenly distributed over the whole term.

2.2 Time budget

Setting aside initial work, e.g. analysis and programming, time consumption on the side of the professors and his assistants is about five hours per term. Professor introduces the system to students during the first lecture, switches tasks on for a particular subject and time and has to read and reply some e-mails. Assistants log in at the end of term to check student’s results, and may log in regularly to find poorly performing students in order to motivate them. The system provokes some students coming for consultation (not included in the time budget as this is teaching anyway).

Before the system has been introduced, there load on assistants was approximately fifteen minutes per student and task, summing up to some 400 hours in a case of 1200 students and one task only. The worse, this time load was difficult to organize into a continuous time block, resulting on disturbing assistants from other work for several weeks. Some assistants gave up soon and accepted any solution. This used to be a heavy burden limiting any increase in the number of tasks.

2.3 Outcomes

An automated system makes individual student’s work manageable. Proper tasks distributed over the whole term can help students to check their progress and fix problems in time.

The system is used mainly in bachelor level education. AMOS requires numerical replies to be accurate within some limit. This proved to be useful to our bachelor students as they learn that two digit accurate inputs can lead to less accurate results.

2.4 “Universal” online solvers

At a faculty of Electrical engineering with a strong record in informatics, it was a matter of several months only for students to react on the new system. One of the first tricks used to get around understanding the task(s) itself used a simple algorithm to find a solution for any numerical question in a finite number of simple steps follows:

1) Set up a test reply, smaller than any meaningful result (say 1E-22).
2) Send the reply for evaluation; if accepted then done.
3) Multiply the current reply by a factor of -1.005. Proceed with step 2) .

“Solvers” based on similar algorithm increase network traffic a lot, as well as the load on server. Although programming such a solver gives some experience to the student, the original purpose is not met this way. In order to prevent this bypass, a limit on the number of replies one student can send per one task should be set to a proper number (say 25).

2.5 Offline solvers

Soon, some of the students have shared their knowledge (eg. algorithms to solve tasks) in a form of notes, Excel files or even webpages. Although it is still possible to detect students who use “third party” solutions, the author is not in favour of doing so.

Instead of that, some efforts may help to make the case more interesting for students to do it on their own. It is vital to come with “new” tasks, therefore provoking a lot of students crawling for a consultation. It is important to keep the students feeling like a part of an interesting game instead of being simply forced to pass through something. Prizes for students who are the first to solve a new task, as well as prizes for students who find a mistake in the system help to keep the play going on.

3 SUMMARY

Computer programs that provide online support for student’s autonomous work are useful in engineering education - if properly used. Such systems may help students to improve their skills if they wish to do so and help to offload teacher from repeated boring part of the job. Still there is some effort needed from the professor: convincing students to get educated is a job that has no automated solution so far.

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Big Data Analytics for Education: Hadoop and Spark

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ABSTRACT

In the last decade, the amount of data generated has increased immensely because of IoT – Internet of Things, Social networks, and Cloud. Because of this increase in the amount of data generated, each time appears new platforms for processing data. Big Data platforms tools are increasingly used in enterprises but unfortunately are not widely taught or even applied in the academic context. Hence, young engineers that have not yet become acquainted with this subject see a harder integration on the job site. Therefore, to encourage the teaching of such subject and by having in mind the sustainability on engineering education we have done a survey on Open Source Big Data platforms. In this context, we investigated two open source Big Data solutions: Apache Hadoop and Apache Spark.

Conference Key Areas: Engineering Skills; Continuing Engineering Education and Lifelong Learning; Curriculum Development.

Keywords: Big Data platforms; Hadoop; Spark.

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1 INTRODUCTION

Every day, more companies look for the possibilities and opportunities that the data offer them. There are many platforms that allow capture and analyze data, such as Hadoop, but the problem comes when the platforms take a long time to process the data. For this, new and more powerful platforms are proposed, of which one in particular stands out Apache Spark. Spark allows managing large sets of data in "short time". This improvement in performance is possible by incorporating two new technologies to process data more quickly. These two technologies are the Resilient Distributed Datasets that allow the processing of data in memory and Directed Acyclic Graph divider for creating jobs in one, two or more stages. Apache Spark increasingly is being used more because it offers many advantages with respect to other platforms.

Apache Hadoop and Apache Spark have some differences that we will analyze. One of these differences is that Hadoop uses MapReduce model and Spark does not work with this model. The principal problem of MapReduce model are transactions that are very slow. For this reason, the idea of loading the data into memory appears, since memory access is much faster than disk access. In this way Apache Spark with two new technologies RDD and DAG appears. These two technologies permit Spark to get 100x faster in memory than Hadoop, or 10x faster on disk. The principal difference is that Hadoop stores all steps – Map and Reduce – in a hard disk, while Spark stores them in a memory RAM.

Nowadays, technology is used in almost all the areas of our day to day, such as the areas of education, scientific, or health. Most of these areas incorporate different technologies, which facilitate people work. Therefore, they become essential and it is necessary people with competences in its use.

In the area of education technologies are fully put in place and have become indispensable. Increasingly schools try to adapt education to the world of technology, incorporating computers, interactive platforms and virtual laboratories. These tools allow students to view content of a particular subject over the Internet, and make and submit certain practices.

In recent years with the increase in the use of technologies, more data are generated every day by people, and conventional databases had to move to accommodate larger amount of data. Different companies have developed platforms that allow to work with massive data sets, such as Hadoop or Spark open source platforms, that would allow individuals and students to analyse and extract information from the data.

The remainder of this paper is organized as follows. Section 2 describes the ecosystem and architecture of Big Data Platforms, Hadoop and Spark. Section 3 describes the differences between Hadoop and Spark. Section 4 describes the related work. Finally, section 5 presents our conclusions and future work.

2 BIG DATA PLATFORMS

2.1 Apache HADOOP

Hadoop is an open source software enabling distributed processing of large data sets across groups of computers using a simple programming model. It was created in 2004 by Doug Cutting; it has its origins in Apache Nutch, an open source web search engine [1]. It was designed to scale up to hundreds and even thousands of nodes and is also highly fault tolerant [2]. In the year 2008, it became a top-level Apache project because it was used by many major companies, such as Yahoo, Facebook and New York Times [3]. The largest contributor to the project is Yahoo!, which uses Hadoop in its business.

Hadoop is an Open Source Platform and is available for download at the following we address: https://hadoop.apache.org/.

The official website of Hadoop gives us a useful installation guide. On this web site, we can read how we can install Apache Hadoop, who uses Hadoop, and the news about the platform.

2.1.1 Apache Hadoop Ecosystem

Apache Hadoop has a strong ecosystem that provides many new possibilities. All projects that make up the Apache Hadoop ecosystem belong to Apache Software Foundation (ASF) [4]. In Figure 1, we can see all the projects that are part of the Apache Hadoop ecosystem.

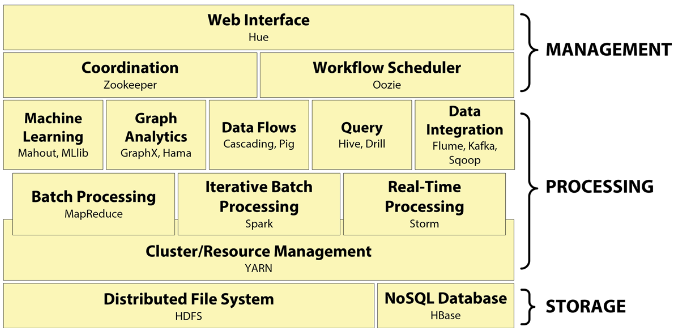

Fig. 1. Apache Hadoop Ecosystem from [4]

The ecosystem is divided into three groups of sub-projects. Management is responsible for the management of the platform. Processing is responsible for processing the application data. Storage is responsible for storing data within the platform. Several companies such as Cloudera [5] and MapR [7] offer distributions of Hadoop which bundle a number of these projects.

2.2 Apache SPARK

Apache Spark is a fast open source cluster computing framework for Big Data processing. It is based on Hadoop's MapReduce and it extends the MapReduce model to efficiently use it for more types of computations, which includes interactive queries and stream processing [3]. Apache Spark improves the performance up to 10 times faster than on-disk data processing and offers over 80 high-level applications that can interact with different programming languages such as Java, Scala, R and Python. The main feature of Spark is its in-memory cluster computing that increases the processing speed of an application. It is designed to cover a wide range of workloads such as batch applications, iterative algorithms, interactive queries and streaming. Apache Spark was developed in 2009 at the University of California, Berkeley AMLab. In 2013, it was donated to the Apache Software Foundation. It has over 200 contributors in 50+ organizations.

Apache Spark can be implemented in 3 ways: standalone deployment, using YARN, and Spark in MapReduce [8]. All of them use the HDFS data storage system as shown in Figure 2.

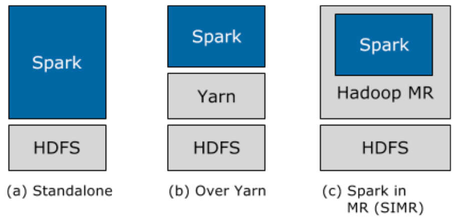

Fig. 2. Different ways to implement Apache Spark from [8]

- Standalone Deployment: Spark Standalone deployment means Spark occupies the place on top of HDFS. This way is the easiest to deploy and the one deployed with the built-in Spark EC2 scripts. Here, Spark and MapReduce will run side by side to cover all Spark jobs on a cluster.
- Hadoop Yarn Deployment: YARN is the Hadoop 2 resource manager, so it is a natural choice for those with existing Hadoop installations. It is the best solution for the enterprises that have tons of data on HDFS because they might have Hadoop users and groups and other things set up already. Spark leverages the YARN resource manager to allocate jobs on Hadoop nodes, and can run Spark applications themselves on a cluster in the cluster mode.
- Spark in MapReduce (SIMR): Spark in MapReduce is used to launch Spark job in addition to the standalone deployment. With SIMR, the user can start Spark and uses its shell without any administrative access.

Spark is an Open Source Platform and is available for download at the following we address: http://spark.apache.org/downloads.html.

Apache Spark has a good ecosystem because it has many important contributors. The Spark ecosystem is divided into three parts: Libraries, Spark Core and Cluster Managers. In Figure 3, we can see each of the parts that compose the ecosystem of Apache Spark [13].

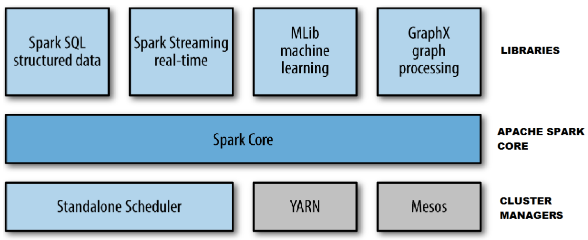

Fig. 3. Apache Spark ecosystem from [13]

Spark is easy to understand when compared to its predecessor, MapReduce, which revolutionized the way to work with large data sets offering a relatively simple model for writing programs that could be run in parallel on hundreds and thousands of machines simultaneously. Thanks to its architecture, MapReduce achieves almost a linear relationship of scalability as data grows if you can add more machines and take the same. Spark maintains linear scalability and fault tolerance of MapReduce, but extends its benefits thanks to several features [8].

Apache Spark has different APIs that facilitate tasks programmers. Now let us analyze each of them:

- Spark SQL is a library that provides Apache Spark the capacity to work with structured data. This library permits querying data in the SQL format and supports many sources of data, including Hive tables, Parquet and JSON. It allows developers to intermix SQL queries with RDDs in different programing languages, such as Python, Scala and Java. It was added to Spark in Version 1.0 [13].

- Spark Streaming is a component that allows data processing in real-time. It provides an API for manipulating data streams very similar to Spark Core's RDD API, making easier to the developers that work with real-time data. Spark Streaming was designed to provide the same degree of fault tolerance, throughput, and scalability as Spark Core [13].
- Machine Learning Library (MLlib) is a component of Apache Spark that provides multiple types of machine learning algorithms, such as classification, regression, clustering, and collaborative filtering. It also provides some lower-level Machine Learning primitives, including a generic gradient descent optimization algorithm. All of these methods are designed to scale out across a cluster [13].
- GraphX is an Apache Spark library for manipulating graphs and performing graph-parallel computations. GraphX, like Spark Streaming and Spark SQL, extends the Spark RDD API, allowing us to create directed multi-graph having properties attached to each edge and vertex. GraphX also provides various operators for manipulating graphs and a library of common graph algorithms [13].

3 BIG DATA PLATFORMS COMPARISION

In this section, we compare the two Big Data Platforms previously studied - Apache Hadoop and Apache Spark.

As it is known, Apache Hadoop and Apache Spark have some differences that we will analyze. One of these differences is that Hadoop uses the MapReduce model while Spark does not. The key problem of the MapReduce model is that transactions may be very slow. For this reason, the idea of loading the data into memory appears since memory access is much faster than disk access. In this way Apache Spark with two new technologies RDD and DAG appears. These two technologies permit Spark to get 100x faster in memory than Hadoop, or 10x faster on disk [12]. In Figure 7, we can see the differences between the intermediate calculations in Apache Spark and Apache Hadoop. The principal difference is that Hadoop stores all steps – Map and Reduce – in a hard disk, while Spark stores them in a memory RAM.

To clarify what the main differences between Spark and Hadoop are, we analyze the main terms: processing model, data processing, software requirements, programing languages and machine learning tools. First, we pay attention to processing model – this parameter gives us an important idea of the data that can be processed with each platform. In Figure 4, we can see the differences between the Hadoop and Spark processing model. Then we analyze data processing which is the way in which data are processed. There are two ways for data to be processed: in memory or on disk. Subsequently, we analyze the software requirements that are needed for the installation of either of the two platforms. Another very important point is programing languages which are the different languages that are accepted by the platform. Finally, we describe the machine learning tools consisting of different learning libraries accepted for each platform. Table 1 lists the details of these characteristics for each platform.

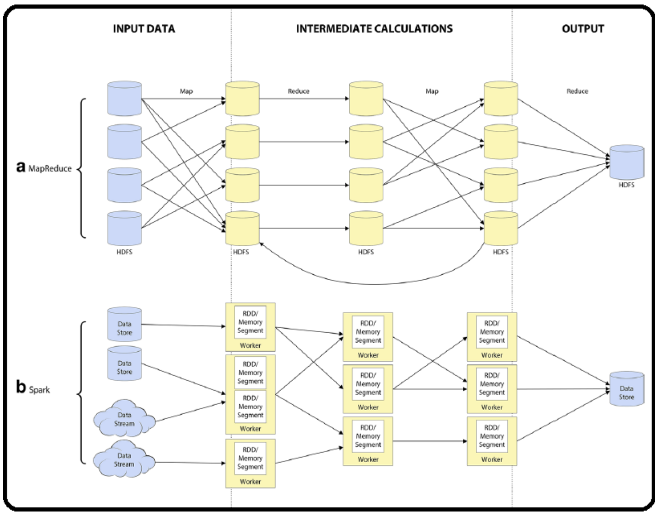

Fig. 4. Comparison of processing models between MapReduce and Apache Spark from [3]

Analyzing all the characteristics in Table 1, we can extract the following conclusions. When it comes to processing model, Spark is the best choice because it provides processing in both the batch and streaming model. On software requirements all frameworks require Java Development Kit (JDK), but Hadoop requires Secure Shell (SSH), too. When it comes to programming languages, the best choice is Spark because it supports a higher number of languages than Hadoop. All platforms support Java. With the Machine Learning tools, the best choice is Apache Spark because it supports MLlib, Mahout and H2O. Hadoop only supports Mahout.

On this platform, we can use Apache Spark or Apache Hadoop.

Table 1. – Hadoop MapReduce and Spark comparison

	Hadoop	**Spark**
Processing Model	Batch	Batch, Streaming
Data Processing	On disk (HDFS)	On disk (HDFS) or in memory
Software Requirements	JDK 1.7, SSH	JDK 1.6
Programing Languages	Java	Java, Python, R, Scala
Machine Learning Tools	Mahout	MLIB, Mahout, H2O

4 RELATED WORK

Big Data is a widely used term that has multiple definitions. In [20], a definition of Big Data based on 6V's is presented that includes the following characteristics: Volume, Velocity, Variety, Value, Variability and Veracity. In addition, [21] provides the Big Data Road Map with these phases: Data Generation, Data Acquisition, Data Storage

and Data Analysis. The number of Big Data Platforms is increasing exponentially over the next years. This creates a high number of available solutions which not only bring difficulty the choice for people wanting to select a platform for their enterprise but also create a high level of redundancy in solutions presented. Educating not only business managers but also engineering students to the potential of Big Data is crucial to guarantee the future of research and platform deployment.
In [15, 16, 20] the different technologies that can exploit the data are exposed: Parallel Computing, Distributed File System, Apache Hadoop and Data Intensive Computing. [21] also talks about the problems involved in all these new amounts of data, and provides feasible alternatives to the use of this new technology.
Currently, there are many Big Data platforms in the market and they increase daily. In [10], the authors make a comparison between the two Big Data platforms: Apache Hadoop and Apache Spark. They include a lot of interesting experiments, explaining the differences between Apache Spark's and Apache Hadoop's runtime. They executed different algorithms to obtain the results, such as Word Count, Sort, K-Means and Page Rank. In addition, they analyzed the impact in a RAM memory when these algorithms were running. In [1], the Apache Hadoop components and MapReduce model are described, and Apache Spark is presented as the future of Big Data. This paper contains only a brief description of Apache Hadoop and Spark, it does not analyze the architecture of both platforms. [8] presents the main differences between Apache Hadoop and Apache Spark, analyzing in detail the Apache Hadoop and Apache Spark platforms, explaining their architectures and how they work. In [22], the authors s describe how the MapReduce model works on Hadoop and how we can create and run small Java programs with the MapReduce model. [13] provides the knowledge necessary to start working with Apache Spark. In addition, the authors explain in detail all the libraries that we can use with Spark. To know more about the Apache Spark architecture, [23] explains how RRDs (Resilient Distributed Dataset) works, its main features and how it implements in Apache Spark. Moreover, [3] provides a good comparison between Apache Spark and Apache Hadoop. In this paper, the authors analyze many differences between the two platforms, such as the execution model, supported languages, associated machine learning tools, in-memory processing, low latency, fault tolerance and enterprise support.

5 CONCLUSIONS

With the large amount of data generated today, enterprises need Big Data Platforms to process large datasets. Nowadays, the number of platforms dealing with large volumes of data, both open source and proprietary nature, is increasing, but not all the platforms can obtain a good performance in terms of runtime and accuracy for data mining. For this reason, the developers started thinking about the idea of working with data loaded in memory instead of on disk. Because of this, coming on the scene is Apache Spark that gets very good performance with large datasets. In addition, Apache Spark is open source and ready for enterprise deployment.

In this paper, we studied and compared the architecture, ecosystem and main features of Apache Spark and Apache Hadoop. Our conclusion is that Apache Spark is faster than Apache Hadoop in all the dataset sizes. In addition, Apache Spark is more accurate than Apache Hadoop. As future work, we plan to analyze these platforms to observe how they work in academic environment and identify the advantages over others Big Data platforms.

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A Parallel Between Android and iOS Design Guidelines

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ABSTRACT

The proliferation of smartphones and the user centric design philosophy behind it makes interaction and user experience a key piece when designing mobile applications. This paper is a side-by-side analogy and comparison of design guidelines for both Android and iOS platforms. The comparison include navigation, screen size, interaction and motion, colour and backwards compatibility. This work will help students to set some of the foundations required to establish models or tools for designing user interfaces for platform convergent solutions.

Conference Key Areas: Engineering Skills; Curriculum Development

Keywords: Android, iOS, Material Design, Human Interface Guidelines

1 INTRODUCTION

Interaction and user experience are currently the main key factors for the success of an application. On the other hand, there is a worldwide market of 3,4 billion devices [1], used for a wide range of tasks from browsing the web, gaming, shopping and use services. As such, developers and designers are required to provide a match and fluid experience across devices and platforms that have audiences with a distinct culture and principles but with the same goals [2].

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Material Design and iOS Human Interface Guidelines [1] [3] exist to provide consistency and continuity, granting third party applications look and behaviour, allowing seamless integration with the operating system.

In this paper we compare design guidelines under the scope criteria concerning device resolution, navigation, interaction and interface components, in order to establish similarities between Android and iOS application design wise.

The remainder of this paper is structured as follows: Section 2 presents the evolution of smartphone interaction and user experience. Section 3 gives the main principles of mobile interface guidelines. Section 4 establishes a comparison of key points for application design and development, comprising screen size and resolution, navigation, colour schemas, usage and backwards compatibility. Finally, Section 5 presents our main conclusions and suggests some future work.

2 EVOLUTION OF SMARTPHONE INTERACTION AND USER EXPERIENCE

Launched in 2007 the first generation Apple iPhone changed the industry deeply concerning user interface and experience given that interaction was touch based without a stylus. For the first time users were prompted to touch elements on the screen aided by the familiarity of UI elements that mimic real life materials as such as metal, paper, wood or glass. Also the iPhone set apart from major competitors as it had only one main button to interact with the devices, contrary to others with physical keyboards like RIM Blackberry, or models sporting Symbian the mobile dominant OS due the need of a stylus. Until 2010 no platform would present a design language that would shape the interface and experience across multiple type of devices, and Microsoft brought that with Windows Phone and the Metro Design language (see Figure 1).

Fig. 1. Windows Phone 7

A design language is used to provide a consistent and unique look and feel as it lays out approaches and choices for design elements like colour, shapes, textures materials and others. With that purpose on Windows Phone 7, Metro Design Language opted for typography in favour of an iconographic User interface, as in Android and iOS, focusing more on content and less on the decorations, a trait that later design languages inherited.

This minimalism trend helped cement that users no longer required reality approached metaphors to interact with the system, and in a way it influenced Apple iOS 7 identities. When announced in September 2013, the iOS 7 had its elements revised, to remove lustrous decorations and its skeuomorphic elements it also introduced a deep revision of the Human Interface Guidelines itself.

3 MOBILE INTERFACE GUIDELINES

A design language is used to provide a consistent and unique look and feel, as it lays out approaches and choices for design elements like colour, shapes, textures materials and others. In next sections, iOS and Android interface guidelines are briefly described.

3.1 iOS Human Interface Guidelines

Human Interface Guidelines (HIG) is the iOS specification for building user interfaces that also serves as basis for Apple evaluation process when apps are submitted to the App Store [1].

HIG promotes the principles of deference, referring that the User Interface (UI) must never outshine the application content. This is emphasized by the translucence and blurring of elements which helps to focus on content without distracting the user. Clarity is the second principle to set apart the most important content and interaction. This is enforced by the use of colour for elements state change, and a clean typography with the sans serif Font San Francisco SF. The use of depth with blurring and translucence is the final principle enforced by HIG, helping to separate the content.

The guidelines were redesigned on iOS7, where a grid system was put in place redefining the space between elements and the fonts where made bigger. Finally, colour was introduced as a main state change to communicate with the user, ending the skeuomorphism omnipresent on prior versions of iOS (see Figure 2).

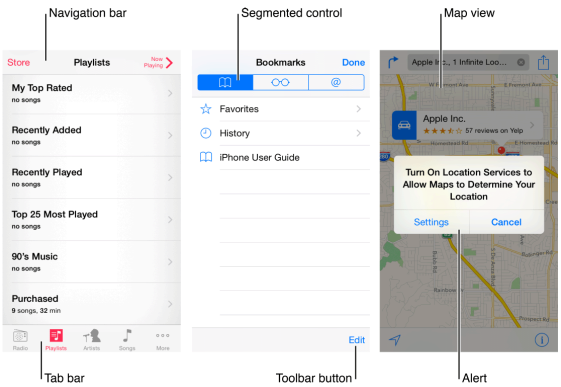

Fig. 2. iOS App Anatomy

3.2 Google Material Design

Google's Material Design is a design language introduced as visual guideline for Android 5.0 aka Lollipop [3]. It was conceived to provide design guidelines for applications that run on a wide array of devices including smartphones, tablets and personal computers. The language is a metaphor for a dynamic transformable material akin to paper that uses elevation to differentiate on hierarchy, bold colour for identity and motion and animation for feedback. It encourages the use of white space and establishes a metric relationship of elements by the adoption of a grid-based system to layout UI elements [3].

Another principle of Material Design it's the principle of motion with meaning, expressed through the use of animation in a denominated UI choreography, keeping a coordinated behaviour in transitioning elements when using path based animations and transitions. Material Design is also a language that is in constant evolution it's not a static concept as Metro, the guidelines are updated with new elements and definitions while other existing concepts are refined.

4 CONNECTING GUIDELINES

Rather than learning, developers and designers tend to introduce foreign elements to the platform. It is not uncommon to see applications on Android with iOS elements. This may be traced to company policies, user demands, trends and other factors that affect the design process of smartphone application [7-10].

On the following sections, key points to help with a convergent and consistent application design will be observed. Each section was based on a suggested approach by Google Design advocate Roman Nurik for iOS designers entering the Android design [4].

4.1 Interaction and Motion

Human Interface Guidelines (HIG) is the iOS specification for building user interfaces that also serves as basis for Apple evaluation process when apps are submitted to the App Store [1].

4.2 Screen sizes and Resolution

Mobile applications are expected to be responsive and adapt to screen density, size and device type. Both platforms implement a scale independent unit of measure that allows elements to be measured on screen and work the same way dp (density pixels) for Android and points on iOS. By providing scale and resolution independent specifications on both platforms, designers allow developers to easily implement screens since the operative system scales accordingly to the measures provided.

4.3 Navigation

Android has physical buttons that affect navigation and application states. This buttons can currently be physical on the device or emulated on screen. The back button is the one that makes the key difference here since it is omnipresent and influential to the app state changes. On iOS there is only one physical button that when pressed may put the application to a halt state and/or sent to background.

4.4 Colour

On Material Design app it is recommended to limit the applications palette to at least three colours: the primary, a darker tone of the primary, and another colour that must be complementary to the other two primary colours. HIG states that colour improves communication, and on platform it helps to indicate interactive elements and provide continuity. It also recommends to consider colour blindness by avoiding using red and green for state changes, to stick with a key colour for interactivity and state changes, and warns for cultural differences between countries and how colour should be used as communication vehicle [4].

4.5 Backwards Compatibility

Android ensures backwards compatibility with the Support Library, which allows keeping appearance and functionality back to version 2.1, reducing the impact posed by fragmentation [5].

Due to the fast rate of adoption of new versions and the way Apple pushes updates, developers may opt to drop support of previous versions of iOS with little to no impact to the application. Depending on logic and features implemented, there might be the need to alter or provide different or extra logic to support those versions.

4.6 Component Similarity

When designing an application, basic interface components are used to represent and interact with information. These blocks, buttons, tables or menus depend on the numerous use cases given our application requirements. Table 1 represents a comparison between each component, stating the analogous of an Android screen on iOS and vice versa based on work by other authors [6] and guideline documentation.

Table 1. Components with similar usage scenarios

Android	iOS
ViewGroup	UIView
TextView	UILabel
EditText	UITextField, UITextView
Button	UIButton
ImageView	UIImageView
RecyclerView	UICollectionView
ViewPager	UIPageControl
ListView, RecyclerView	UITableView
TabLayout, Tab	UITabBar, UITabBarItem
Toolbar	UINavigationBar
AlertDialogBox	AlertView
DialogFragment	UIPopOverController
Slider	UISlider
Switch, Checkbox, ToggleButton	UISwitch
ProgressBar	UIActivityIndicatorView
Popup Menu	Action Sheet
Option Menu, Action Items	UIBarButtonItem
Spinner	UIPickerView
WebView	UIWebView
ScrollView	UIScrollView
Intents	App Extensions

5 CONCLUSIONS AND FUTURE WORK

The main objective of this paper was to show the similarities of the design guidelines and application components between Android and iOS, as well as to provide a tool to help either application porting or simultaneous development.

With those guidelines, computer engineering students can test and modify the software, simulating real environments and improving their competences, for example proposing new interfaces.

As future work we propose the inclusion of an in depth comparison using eligible metrics, as well as extensive questionnaires and test-involving users of both platforms, since either are driven by user centred design.

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7.

Ethics in Engineering Education

Proposing a Comprehensive Knowledge Map of Engineering Ethics
for Engineering Education

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ABSTRACT

Engineering has been a preferred discipline in higher education in Asian countries. Approximately 1/4 of students in higher education are studying engineering in Taiwan. In recent years however, several engineering related disasters such as the Fukushima Daiichi Nuclear Disaster, the sinking of the MV Sewol ferry, and the Kaohsiung Pipeline Explosion, have left a devastating impact on Asian societies. Studying disasters can provide insights to Engineering Ethics, Engineering Ethics can then promote better engineering. This paper is grounded in a collaborative Japanese – Taiwanese effort to provide effective tools for Engineering Ethics education and proposes a conceptual framework for Engineering Ethics in the form of a 4 x 3 dimensional GRID. This GRID is illustrated using the example of the discussion around the Kaohsiung pipeline explosion.

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Keywords: engineering ethics, engineering education, knowledge map, framework for discussion

INTRODUCTION

As a response to engineering failures, Engineering Ethics has developed in the West as an important part of engineering professionalism since the turn of 20th century. Owing to the recent interests in engineering education accreditation in Asia, Engineering Ethics has been recognized as an essential part of engineering education. Engineering Ethics appeared in engineering education in Taiwan only several decades ago, even though the engineering curricula follow the western ones closely. But the big question remains within the engineering community: what is Engineering Ethics and how should one teach it? The Japanese Society of Engineering Education (JSEE) started a discussion around these big questions among domestic and international scholars and published the first version of the Learning and Educational Objectives in 2013, which is renewed annually as reported in Kobayashi & Fudano [1]. The objectives are divided into several categories, which belongs to Cognitive and Affective domains. In the Taiwanese setting, Hong & Wang 2013 [2] discussed their findings about a Science, Technology and Society (STS) approach to Engineering Ethics teaching.

Thereafter, inspired from a survey feedback with Taiwan's engineering ethics educators on the JSEE's Objectives, we constructed a knowledge map, which we hope will be helpful for engineering educators to discuss Engineering Ethics. This knowledge map is represented as a 4x3 GRID of Engineering Ethics, with 4 levels of concern and 3 areas of focus. The levels of concern are micro, meso, macro and meta as proposed in Li [3] and Fudano [4], and they refer to respectively as individual acts, institutional issues, society and engineering issues and the nature of engineering in a general sense. The 3 categories of focus are Educating Engineering (teach and learn), Practicing Engineering (do and make) and Creating Engineering (research and innovate). As an example, we use the GRID to analyse the investigation taking place in the aftermath of the 2014 Kaohsiung pipeline explosion. It is clear that the actions following the disaster focused more on the micro and meso levels whilst reflections about engineering education and discussions about innovative solutions were not explored.

1 ENGINEERING ETHICS IN ENGINEERING EDUCATION

1.1 General Background

Engineering Ethics has been an important part of engineering professionalism since the turn of the 20th century as a response to engineering failures in the West. Moral values, personal conducts and professional practices are incorporated as part of the Engineering Ethics education in many western engineering educations.

Gardelle [5] discussed that European countries and countries receiving European influences, have made changes in and adaptations to higher education, engineering education and training for engineers as the Lisbon Strategy, the Bologna Process and the project INNOV'ING 2020 took shape. Froyd *et al.* [6] reviewed how Engineering education has gone through several transformations in the 20th century. Ethical education can be included in engineering education and training as discussed in

Monteiro *et al.* [7]; challenges and expectations are different in two subsystems in the Portugal cases.

In Taiwan and Japan, Engineering Ethics appeared in engineering education just several decades ago even though their engineering curricula follow the western ones closely. The long-standing segregation between the aspect of the social/humanity and the aspect of science/technology in education makes it difficult for Engineering Ethics to take roots in engineering education. It is therefore often regarded as an "additional" or "required but trivial" subject.

1.2 Engineering accreditation

As countries with a high number of engineers in training in higher education per capita, Japan and Taiwan have joined the leagues of engineering education accreditation efforts since late 20th century. The Japanese Accreditation Board of Engineering Education (JABEE) and the Institute of Engineering Education Taiwan (IEET) were established respectively in 1999 and 2003 as accreditation organizations in these countries. More than 500 departments in Taiwan have been accredited by IEET criteria since 2003.

1.3 Criteria of Engineering Ethics

Because of the interests of engineering education accreditation in Asia, Engineering Ethics has been recognised as an essential part of engineering education. As required in IEET, *Criterion 3 Graduate Attributes and Assessment*, a program seeking accreditation must demonstrate that students have attended the following outcome upon graduation: "3.7 knowledge of contemporary issues; an understanding of the impact of engineering solutions in an environmental, societal, and global context; and the ability and habit to engage in life-long learning" and "3.8 apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice, and a sense of respect for diversity". In other words, these criteria task engineering faculties with the imperative to teach integrated ethical ability in their departments.

1.4 Number of Engineering Ethics courses

Traditionally, Taiwanese curricula do not include ethics, social or other integrated courses. Therefore, many departments either started offering "Engineering Ethics" courses or sought help from humanity scholars. *Fig. 1* and *Fig. 2* show an increase in the number of courses, and in the number of students approximately after 2005. This corresponds to the take-off of the accreditation trend in Taiwan. But the big question remains within the engineering community: what is Engineering Ethics and how should one teach it?

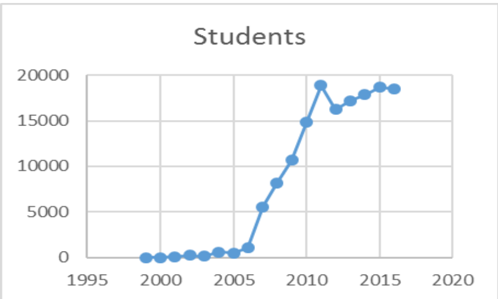

Fig. 1. Number of students have enrolled in Engineering Ethics courses

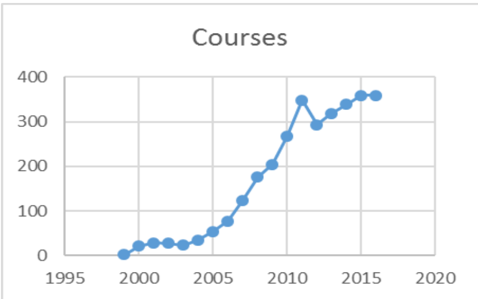

Fig. 2. Number of Engineering Ethcis Courses offered

2 APPROACHES TO ENGINEERING ETHICS TEACHING

2.1 JSEE's teaching and learning Objectives

The Japanese Society of Engineering Education (JSEE) started discussing the big questions among domestics and international scholars and published the first version of Learning and Educational Objectives in 2013, renewed annually thereafter as in Kabayashi & Fudano [1]. The objectives are divided into 2 domains (Cognitive and Affective) and 4 categories. The 4 categories are: (1) Comprehension of the relation between science/technology and society/environment, (2) Comprehension of the role, commitments and responsibilities of engineers, (3) Ability to make ethical judgments and solve problems, and (4) Attitudes required of engineers and values shared by engineers. The first three are in cognitive domain.

2.2 Taiwan's Engineering Ethics educator's responses

Hong and Wang have been studying an STS approach to Engineering Ethics teaching in Taiwan since 2007. In late 2015, they conducted a survey with domestic Engineering Ethics educators asking them about their opinions to the JSEE objectives. Ten percent of 363 instructors who have taught Engineering Ethics courses during 2013~2014 responded to the questionnaire. We asked the educators about how important they regard the JSEE objectives and how important the role is which these issues play in their course work. From the respondents' who gave feedback through this preliminary survey, the educators asked for teaching material based on solid research, especially material which supports interactive teaching. Helping engineering students to develop concerns about social issues and reflective thinking about ethical issues is crucial and challenging. Moreover, there were diverse views about the qualification of the educators of Engineering Ethics. In Taiwan, an estimated more than 80% of the educators are engineering scholars. This situation is very different from Japan, where Engineering Ethics educators mostly comprise social science scholars, including historians of science, philosophers of science and ethics scholars.

3 KNOWLEDGE MAPS FOR ENGINEERING ETHCIS

3.1 The Engineering Ethics GRID

Through this review process and the survey on the Objectives, we constructed a knowledge map which we hope will be helpful for discussing Engineering Ethics with engineering educators. We now propose a 4x3 GRID of Engineering Ethics as a framework for engineering education, as shown in Table 1. There are 4 levels of concerns: micro, meso, macro and meta as in Fudano [4], concerning the individual acts, the institutional issues, society and engineering to the nature of engineering. There are 3 categories of focuses: Educating Engineering (teach and learn), Practicing Engineering (do and make) and Creating Engineering (research and innovate).

Table 1. GRID of Engineering Ethics

Category	Engineering Education	Engineering Practices	Engineering Creation
Level / Action	teach and learn	do and make	research and innovate
Meta The nature of engineering	Engineering Philosophy, ultimate Objectives	Practicing engineering, the nature of industry	Sustainability, for the future / heal the past

Macro Relationship between society and engineering	Engineering teaching in the context of society	Good (real) CSR	Innovation for the needs of society
Meso Institutional issues related to engineering and engineers/organizations	Support for good engineering education, good evaluation strategies and nimble to necessary transformation	Certification and support for establishing good institution practices	Discussion and support to resolve/avoid Issues (research ethics)
Micro Acts of individual engineers/organizations	Curriculum / instruction; pedagogy	Practical skills in industrial setting	Research, design, innovate in the lab/company

3.2 Expected advantages

This GRID can serve as a reference for teaching issues concerning Engineering Ethics as it includes levels from personal to societal in areas of education, industry and academia; allowing the focus to start at any cell and remain aware of the others for discussion of Engineering Ethics under various contexts. Making these issues explicitly visible and unpacking the inter-relationships, this GRID can promote a more sophisticated discussion about dimensions that are often overlooked. It can also be used to track the progress of developments of issues and concerns, and/or benchmark the aftermath of disastrous events. Educators can remind students to pay attention to those unattended perspectives, which may need innovative ideas to resolve.

Although the GRID is laid out as a table, users should note that the division between cells is not definite or rigid, the various factors can interact and affect each other. Also the 3 categories are interconnected as for instance creation has a strong influence on education. We apply the GRID to a study of a recent engineering disaster in the next section, as an example.

3.3 Kaohsiung Pipeline Explosion

Near midnight on July 31st, 2014, sections of main roads in densely populated residential and business neighbourhoods in Kaohsiung city centre exploded, as shown in *Fig. 3*. Thirty-two people were killed and 321 were wounded. Many of the victims were emergency response personnel. Based on the indictment of Kaohsiung District Prosecutors Office, the direct cause of the explosion was a leaky propene pipeline, which was wrongfully exposed in a rainwater culvert box. The erosion caused by the moisture in the culvert box may have weaken the wall of the pipeline, which carried the propene pumped to a petrochemical factory. During the 4 hours between the first reporting of the foul smell around 8pm to the explosion at midnight, an estimated 10 tons of propene leaked into the rainwater culvert boxes beneath the roads before it finally exploded. Emergency response teams and the city government were scrambling and not able to identify what was leaking and they also did not know about the exact location of pipelines going through the city's underground. Citizens were shocked by this apparent lack of information about the pipelines and the chemical as such, as well as the chaotic emergency response about the leak from the first moment the foul smell was noticed up to the moment of the actual explosion.

Fig. 3. Street affected in the Kaohsiung explosion (photo by Syuan Shih Sheng)

What can an engineering disaster of this magnitude teach us? Human beings learn from disasters and failures and then create better regulations, theorems and practices. In Hong and Wang [8], we took an STS approach to the technical characteristics along with ethical reflections. This case revealed that there is a void between the knowledge *about* and the practices *of* civil engineering and petrochemical engineering, especially when it comes to proper documentation and management. It appears that conventional construction work can be very different from the theories taught about this in class and the approved drawings of the work-plans. Many spontaneous decisions were often made on site, and were left out from the documentation. Furthermore, whilst, the petrochemical factory takes safety very seriously within/inside the walls of the factory land. The pipelines running under-ground throughout the city, from the factory to another industrial establishment, are usually not included in their focus on safety procedures. Furthermore, some steps in the highly regulated standard operating procedures (SOP) were set up under assumptions regarding the operation conditions. Since a pipeline leak had never happened before, such an occurrence was therefore not given high priority in the SOP. The public may have had a blind trust in the expertise of the petrochemical industry and City's technological governance. It is very difficult to pursue an understanding about the risk of living in an industrialised city, when knowledge about the industry and its operations are not part of the public domain..

Hong and Wang's research team has been following the court process pertaining to the Kaohsiung pipeline explosion since the companies and the city government were prosecuted with criminal charges in late 2014. We use the GRID to show the aftermath of the explosion in *Table 2*. It can be seen that the efforts after the event focused more on the micro and meso levels about practicing engineering.

When we use the GRID to evaluate Kaohsiung pipeline explosion, it is clear that the investigation focused more on the micro and meso level practices; the core values and the directions regarding a better engineering for society are still to be discussed. It can be seen clearly that reflections on engineering education and discussions about innovative solutions to the problems remained unexplored.

Table 2. Kaohsiung Propene Explosion explained in Engineering Ethics GRID

Category	Engineering Education	Engineering Practices	Engineering Creation
Action	teach and learn	do and make	research and innovate
Meta The nature of engineering	Understand risk in modern techno-society, (Propose transparent policy on pipeline location and chemicals)	Petrochemical Industry adjusts their presumptions and value (Petrochemical industry cares about underground pipeline maintenances and holds conferences)	Create new energy /infrastructure/chemical industry solutions for sustainable society (Continuous dialogues between industry, government and academia)
Macro Relationship between society and engineering	Discuss Petro-chemical policy and transitional measures, (teach students with the case study)	Look at the relationship between petrochemical industry and local community, do progressive CSR (Judge expressed doubts about petrochemical company's CSR statement and policy)	Create new kind of petro-chemical industry, city, and citizen participation processes in public affair management (Industrial pipelines safety issues gain domestic recognition, technical discussion started)
Meso Institutional issues related to engineering and engineers/ organizations	Professional societies and education bodies discuss and include systematic causes into education (Chemical Engineering association offered workshop on pipeline safety)	Investigate the systematic problems in management, look into improvements in laws and regulations	Government and related agencies create new technologies or new institutes, operations (City government made information of the pipeline location open, established public roads construction information central office)
Micro Acts of individual engineers/ organizations	Professional societies and education bodies investigate the causes and teach the missing knowledge/abilities (teach students professional abilities, responsibilities, ethics with the case study)	Individual responses while on duty (The responsible person, engineers and technicians were prosecuted with criminal charges, trials are taking place currently)	Engineers and researchers act in developing and designing new technologies (Engineers and companies develop new surveying and monitoring technologies and tools)

*the level of shades represent the degree of attentions paid, darker means more discussion and more work was done.

4 SUMMARY AND ACKNOWLEDGMENTS

This paper proposes a 4x3 GRID of Engineering Ethics as a framework for engineering ethics education. This comprehensive GRID includes levels from personal to societal in areas of education, industry and academia and allows the focus to start at any cell and stay aware of the others for discussion of Engineering Ethics in various contexts. The GRID helps to point out that the investigations and ongoing court processes around the Kaohsiung pipeline explosion tend to focus on technical issues and miss out on the systematic and deeper causes of the problem. Possible changes in responsible engineering practices can therefore not be explored.

We will continue to research on engineering ethics, engineering education and controversies in engineering, aiming to develop directions on education transformation in a risk-based society. We hope to bring the attention of education government agency, higher education institutes, and industries to the existing gap between education, practice and creation of engineering.

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Articulation of Civil Engineering Ethics.
What is the specific purpose of the profession?

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ABSTRACT

This paper justifies the need for the articulation of civil engineering ethics. The professionals can adapt this ethic, to allow them to guide their work towards achieving the internal goods in their profession.

The text establishes the importance of the civil engineering and reviews the role of professional associations as custodians of "*good and correct work*" of its members both technically and ethically. The paper argues the reasons why codes of conduct, ethical codes or deontology are insufficient.

The article suggests the necessary steps to achieve a consensus on the universal ethics of civil engineering, in the current context of engineering practice in a globalized world. The text remarks the need to initiate a dialogue involving the maximum participation of all the civil engineering areas, with professionals and external agents to define the ethical code of the profession, understanding the ethical code as a conduct to which civil engineering achieves its meaning and social legitimacy.

This will be the beginning of the articulation of ethics of the civil engineering world.

Conference Key Areas: Ethics in Engineering Education, Engineering Skills, Curriculum Development.

Keywords: Civil Engineering Ethics, Professional Responsibility, Internal Goods.

INTRODUCTION

Civil Engineering responds to the needs of society and nature and, based on theories and tools of science and technology, creates products and gives benefits to the society. The current world, in crisis, needs practical solutions and needs engineering to solve current problems, such as the generation of renewable energy, access to potable water, waste water treatment and pollution control, the improvement of global communications and transport systems, achieving the millennium goals for sustainable development, mitigating the effects of greenhouse gases or adapting to climate change [1], [2].

To be able to face these challenges, the engineers receive training during their studies at the University. And then, day by day in the course of their professional life, must complete and expand. This causes competent professionals with solid technical knowledge that allows them to find (technical) solution for any problems that is outlined. But engineering often lacks humanistic training that allows them to contextualize the projects that they develop, or raise questions about the effect of their work on future generations.

In the following section, the author points the corruption problem in Spain and how to stop it. Then she suggests the model of the Professor A. Cortina to be applied to the civil engineering ethics and finally ends with the conclusions.

1 PROBLEMS ABOUT CIVIL ENGINEERING IN SPAIN

1.1 The spread of corruption virus and how to stop it

Either by the training or the evolution of modern society, in recent times (at least in Spain) the profession of civil engineering has been linked in too many cases of corruption. Corruption can range from diverting funds to enrich some professional personally, to the construction of unnecessary infrastructures that the State finances with public money. All too often we read headlines in the press where the engineers seem to feel no responsibility for their projects.

Various codes of ethics/codes of conduct have been developed to try to establish the proper behaviour of these professionals [3], [4], but corruption cases surrounding civil engineering are still very frequent. John Ladd has argued against the uncritical acceptance of codes of ethics as authoritative ethical guides [5]. His main point is that ethical principles cannot be established by organizations or their members. On the other hand, only those belonging to a particular profession, know the purpose and the means they have to do a certain job (they are custodians of the body of knowledge of that profession), and on this is based the claim that professions must be autonomous, must be self-governing [6]. If the members of the profession do not regularly comply with their obligations, it should be the society that demands greater regulation in the profession.

For this reason, in this text, a model of ethics is provided that will predictably contribute to improve the training of these professionals and to guide their work to achieve the internal good of their profession.

Therefore, we believe it is fully justified the need to incorporate the teaching of ethics to civil engineering students, as a way to provide them with the necessary tools to act as correctly as possible, taking into account all aspects presents and futures that will affect their decision making.

In our view, it would be a mistake to introduce subjects of ethics in the curriculum that will treat the subject in a general way, without differentiating the context in which the studies are conducted and with a few variations on the content received by secondary students. It would be more about articulating an applied ethics and, from that, to study real cases and to arrive at a conscious decision making and argued on the way to act.

In order to arrive at that moment, the first step will be to articulate a civil engineering ethics. It would be advisable for the professionals to know this ethic in the moment of exercising their profession. And we think that the model of applied ethics proposed by Professor A. Cortina [7] would be applicable.

2 THE PROPOSAL

According to Professor Cortina, to design the applied ethics of civil engineering would be necessary to follow the following steps.

2.1 Determine the specific purpose, the civil engineering internal good, by which civil engineering acquires its sense and social legitimacy.

It is essential that future civil engineering professionals know the internal good of their profession. Let us remember that the internal good of practice is what gives sense and legitimacy to a profession, in the words of Professor A. Cortina [7]. We have to define what the internal goods of the civil engineering profession will be, and for this we must not forget that the practice of engineering seeks the welfare of the people and communities in which they live.

Many of the internal goods of this activity will be associated with technical excellence and could be among others; the imaginative and practical use of science and mathematics, deep knowledge of the subjects necessary to develop the activity and in short would be to have the necessary training to develop the activity in an excellent way. Other internal goods would be related to safety, social and environmental sustainability of the projects planned, and to the profitability of the projects. It would try to give the best possible service to society.

If we want to go a little further in the definition, we could also consider the promotion of human rights and the search for peace as internal goods to the civil engineering profession. And for many engineers the greatest internal good will be the satisfaction of contributing to the flowering of people through the pursuit of technical excellence.

In any case, a debate is needed between civil engineering professionals to define the internal goods of the profession, since although they can be intuited, there is still no consensus about them.

As external goods, professor Cortina [7] mentions money, prestige and power. And as it says, we have to work to obtain internal goods and with this we will get external goods, but these should never be the end of our work.

Engineer Meredith Thring [8], one of the pioneers in thinking about engineering ethics, said: "*The subjective qualities of human life, such as personal fulfilment, happiness, freedom and love, are much more important In the long term for people affected by a (for their) engineering work, that the possession of goods and status symbols beyond those necessary for a full life*."

2.2 Find out what is the appropriate means to produce the internals goods in a modern society.

Of course the right way to produce the internal good in civil engineering practice is to perform this practice in an excellent way, taking into account all the actors affected by the intervention, and studying the short and long term effects of the intervention in the environment.

The only way to ensure that it is done properly is to continually review the training that students receive in engineering schools and examine professional practice. In addition, in engineering schools, students should be encouraged to work as a team and with professionals who are not civil engineers. Only then they will be prepared to form multidisciplinary teams, which are likely to be the ones that obtain the internal goods of the civil engineering profession.

In our opinion, ethics committees (so-called in the case of Spanish Association of Civil Engineers), the Professional Conduct Committees (in the case of the ASCE (American Society of Civil Engineers)) or similar, should be empowered, exercising in a serious and rigorous way their role. In order to do this, it will be necessary to address all complaints of professional malpractice, studying each case and sanctioning if it is concluded that there is a bad practice. This, in addition to giving visibility and importance to the ethical behaviour of the profession, will be used to rearrange and revise the existing codes, in addition to ensuring compliance. It will be a way of granting social legitimacy to the profession.

The search for the external goods of the profession cannot be allowed to be accepted and encouraged socially.

In most cases, major civil engineering works contain a large number of technical, social and environmental aspects that interact with each other and sometimes change the environment in an irreversible way. So it will be necessary to create ethics committees that study all the variables affected by the action. These ethics committees will be multidisciplinary and through dialogue and being aware of the responsibility for the execution of civil works, will ultimately decide the need for the action.

2.3 To inquire what virtues and values need to be incorporated to achieve the internal good of the profession.

MacIntyre's definition of virtue in After Virtue is: "*A virtue is an acquired human quality that enables us to acquire the internal good to a practice and the absence of which prevents us from achieving such goods*" [9].

This definition establishes a causal relationship between the exercise and possession of virtues, and the achievement of internal goods by practice. For MacIntyre among the desirable virtues (it would be advisable that the civil engineer also possessed them) would be justice, truth and courage. We can also identify certain desirable and appropriate human qualities in engineering practice. The Royal Academy of Engineering of Great Britain has identified four elements as "fundamental principles" that should guide engineers in achieving professional excellence: "*Accuracy and rigor; Honesty and integrity; Respect for life, law and the public good; Responsible leadership, listening and informing* " [10].

These principles can be applied at any time in the work of the engineer, but some of them are particularly relevant in different aspects of their work. Thus, *accuracy and rigor* are especially relevant to the technical aspects of their work; application of mathematics, physics, scientific knowledge and practical knowledge. We would be highlighting professional technical competence. The requirement of *honesty and integrity* will be especially relevant when negotiating the commission of a particular project. We must keep in mind that current engineering is an international activity and acceptable business standards can vary greatly between different cultures. For this reason it is necessary that the civil engineers be honest and complete and only accept those projects that are able to perform for an adequate cost.

Respect for life, law and the public good is an essential recognition taking into account the deep effects that engineering can have on the flourishing of the individuals and communities in which they live. The proper expression of this respect requires us to be very careful, because the effects of the engineering activities can have a very large impact on the territory and time.

For all this, and because of the confidence that the citizens have in their engineers, which arises from their training and acquired knowledge, it is necessary that they take the reins and behave as *responsible leaders*, who listen and inform all the actors involved in a given project. Engineers possess the knowledge and skills that enable them to solve problems and realize opportunities, and also have the ability to identify these problems and opportunities.

2.4 To discover what are the values of the civil moral of the society in which it is inscribed and what rights does that society recognize to people.

For Professor A. Cortina, civil ethics is the set of values that citizens of a pluralistic society already share, whatever their conceptions of good life. The fact that they already share the values, allows them to build their lives together [11]. In this set of values should be equality, freedom, solidarity, active respect and attitude to dialogue.

When performing an engineering work such as the construction of a dam, we are obliged to respect the rights of all agents involved in the intervention. We will have to study if it is morally acceptable for society to destroy the environment in which the dam is to be located.

As Adela Cortina says "*in order to obtain social legitimacy an activity must, at the same time, produce the goods expected of it and respect the rights recognized by that society and the values that such society already shares*" [12].

In the current scenario where the work of an engineer can be done in any country of the world, it is the professional's obligation to study and to know the cosmovision of the territory in which a project will be carried out, to know the values of civic morality and the rights that society recognizes for people.

2.5 To ascertain what values of justice demand the principle of the discourse ethics, related to a universal critical moral, which allows us to put in question existing standards.

Normally in most western countries the existing standards protect citizens and all are treated as equal before the law. But in the current scenario of the practice of civil engineering in the globalized world, where it is usual to develop the activity in developing countries and in societies where existing morale is unacceptable under the magnifying glass of the inhabitants of the first world, It is necessary to establish a universal critical morality that, from the moral criteria of justice, may call under consideration and condemn existing norms [13].

The scope of a critical moral is broader than positive law. Therefore, engineering companies or engineers who work in companies with laws that do not adequately protect their citizens, must comply with current legislation, but do not settle to it, but must resort to the principles of a critical moral.

Therefore, when the civil engineer must intervene in the territory, in order to make fair decisions, they will have to (in the words of A. Cortina) "*attend to the prevailing law, to the prevailing moral convictions, but also to find out what values and rights be rationally respected* " [14].

The procedure that we consider valid to ascertain which norms are morally correct will be the discursive ethics of K.O. Apel and J. Habermas. The most important feature of this procedure will be that we will not have a rule like correct, if the rule has not decided by everyone affected by it, after a dialogue held in conditions of symmetry.

2.6 Leave the decision-making to the citizens concerned, with the help of advisory instruments, they will weigh the consequences using criteria drawn from different ethical traditions.

This last step would derive directly from the previous one. In order to make any decision to intervene in the territory, it will be necessary for all those affected to intervene in conditions of symmetry, providing each of the persons involved with the same importance.

All those affected will have all the information available, much of it provided by the technicians who, in an honest and truthful manner, will explain the scope and consequences of the action. A dialogue will be established in which different criteria can be interpolated from different ethical traditions, contextualized for the moment and the specific area in which we find ourselves (hermeneutical way). Since, as Professor Cortina says, "*a single model of ethics is powerless to guide the decisions of the political and economic worlds, medical, ecological or simply, civic coexistence*" [12].

Therefore, we are forced to take into account the different models at the right time, although the coordinating element will be the discourse ethics, because it has its roots in communicative action and subsequent argumentation, which constitute the means of coordination, although not the substance of other human activities [12], [15].

3 CONCLUSION

It is very difficult to apply the scientific method and draw conclusions from a paper like the one presented here. This is because many dimensions of human life do not need a method to be understood, and this can be applied to the field of ethics. It is possible to say that in this field the important thing is the arguments more than the method. Despite these limitations we dare to conclude:

The model of applied ethics, proposed by Professor Adela Cortina, is applicable and can serve as a frame of reference in the ethical training of civil engineering professionals.

Being a good professional, a good engineer, implies an excellent behaviour not only in the workplace, but also requires similar behaviour in the social field. The ethical obligations, to be useful, must cover all activities and all the members of society. It is very important to provide individuals with sufficient training and experience to understand the importance of making ethical decisions. And allow them to develop their work being aware of the responsibility acquired and the consequences of their works.

The concept of responsibility that is handled in the field of civil engineering is insufficient. The meaning of the term should be broadened and legal responsibility should not be mentioned as the only obligation to be fulfilled by civil engineers.

We think that critical hermeneutics with a dialogical character and under the protection of the ethics of responsibility, is a good a method of articulating an ethics of civil engineering.

To do this, one of the first steps will be open a dialogue at the international level, to define the internal goods of the profession. This dialogue which should have the maximum representation of all actors related to the practice of civil engineering, with all professionals and all people Involved.

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Ethics as a skill of a software engineer?

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ABSTRACT

One problem of the increasing intelligence of the systems is that the number of decisions having an ethical component is increasing, too. Traditionally, the designers of the system seldom made ethical decisions; the ethics was left for the user. However, when the system itself makes decisions, the ethical consequences have to be solved when the system is made. Since these decisions are mostly implemented by software, it is often the programmers that have to make these decisions.

Another problem is, if a programmer is asked to make illegal or unethical software. The well-known example of emission faking by car manufactures is an example of such software, but this seems to be far more common than this.

We have several ethic codes as the ethical guidelines for engineering. They give full ethical responsibility to engineers on the design and implementation of systems. The specific problem with software is that the programmers do not necessarily realise the ethical nature of the system; either they do not understand the application area enough to see it, or they do not know the full context of the piece of software they are implementing.

The conclusion discusses how to embed the awareness of ethical questions in software engineering education.

Conference Key Areas: ethics in engineering education, engineering skills

Keywords: software engineering education, ethics

1 INTRODUCTION

This paper is motivated from two phenomena that have recently become more evident. The first one is the increasing intelligence of the systems, and the second is that programmers have been told to make if not illegal, at least unethical systems.

The problem of the increasing intelligence of the systems is that the system makes bigger and bigger decisions autonomously. This has the consequence that the number of decisions having some ethical component is increasing, too. In traditional technology, the designers or manufacturers of the system seldom have to make ethical decisions; the ethics of product's usage is left to the user. The situation changes when the system itself makes a decision, and the ethical consequences have to be solved when the system is made. Since these decisions are mostly implemented by software, it is often the programmers that have to make them. From the viewpoint of this paper, one of the main problems is if the ethical aspect has not been noticed during the specification phase of the system, and the decision is left on the programmer, who might face difficulties in taking the responsibility of the decision that could be hard to answer even by experts on the application area. There is also the additional problem that even the programmer implementing the software might be unaware that there are some ethical questions involved.

The other problem of unethical software is that the programmers being asked to make illegal or unethical code more and more often. This has been discussed in network publications like Business Insider Nordic [1] and Freecodecamp [2].

The overall finding is that it is very difficult to see the possible ethical consequences of a technical decision. Hence, the studies of software engineering should embed ethics to allow students better recognise possible ethical questions.

The paper is organised as follows: First, some ethical codes are introduced in Section2. In Section 3, the problem of unethical code is discussed. Section 4 discusses the problems raised by the increased intelligence. The paper ends in conclusions.

2 ETHICAL CODES

There is a number of ethical codes intended to be used in engineering or software development. Archimedean Oath [3] originates from Lausanne (1990), and it is intended as a general guideline for all engineers. ACM and IEEE have provided ethical codes for their members, but also these are general in nature [4], [5]. These codes emphasise personal responsibility of the engineer. In Archimedean Oath, this is expressed as follows:

"I shall recognize the responsibility for my actions, after informing myself to the best of my abilities, and shall in no case discharge my responsibilities on another person."

In the case of software, it is sometimes hard to recognise if the code has any ethical consequences. The person writing the code may not know the circumstances it will be executed, and even the description of the required code might be written in a way that this is impossible to find out. Furthermore, more and more software is built on existing frameworks, components, libraries etc., and the developers of the framework can hardly be responsible for applications that use the framework or the library. Hence, this strong emphasis on personal responsibility is sometimes too hard and the limits are hard to set. This also requires that the programmers and developers are aware of these ethical questions in general to better recognise ethical questions when they arise.

3 ILLEGAL AND UNETHICAL SOFTWARE

The first question is what is illegal or unethical software. Probably there is no definite answer to this question, since the same code or software is intended to be used in clearly legal purposes, but in some cases, it can be used for illegal or at least unethical situations. In this paper, illegal and unethical software are defined to be software that do not have legal use or they have properties that are unethical from the very beginning - or they can be judged as such, depending on the ethical code of the observer. From this on, unethical systems is used to mean both illegal and unethical systems.

It is clear that any software made to break into systems or to cause harm to the target system or the host computer fall in unethical class. The programmers of these kind of systems are probably well aware of their nature and have made their choice when joined the project. The more interesting cases are cases, where the product itself as a whole is not unethical, but its makers are asked to implement some properties that are not ethical.

3.1 Case Volkswagen emission scandal

In the case of Volkswagen emission scandal, many cars with a Diesel engine had software that was able to decrease emissions when measured in a laboratory. This is probably the most well-known case where unethical software has been made on purpose as a part of legal software. The case is described in more detail in e.g. [6].

The case has an interesting side point, where the software engineers alone were accused for the emission scandal [7]. Later on, this claim was shown false, but even then, this case raises the question if the software engineers should have refused to program such software. According to all of the ethical codes referred in Section 2, they should have done so.

The Volkswagen case is here as a well-known example. It is not known, how much this kind of code exists in general, but it is probably more common than we expect. For instance, there have been several cases when software is suspected to violate the privacy of its users by gathering information of their computer use.

3.2 Code I'm still ashamed of

In 2016, programmers were discussing in Freecodecamp about cases where they have been asked to write unethical code. Results were published in Business Insider (Nordic) [1]. The discussion is still (as spring 2017) online, and can be found in freecodecamp.com, but directly to this discussion it is easier to use reference [8].

One of the main articles on the topic was published by Bill Sourour [2] with a title "Code I'm still ashamed of". In his article, Sourour describes how he as a young professional ended up making a piece of software that - as he feels - caused at least one death. The nature of the software was marketing a drug, and part of it was a quiz, whose results were not used except in the case of allergy, otherwise it suggested the same drug of the client. Only later on, after reading a piece of news where one of the users had made a suicide, the programmer learned that the drug has side effects causing depression and suicidal thoughts. He felt responsible, and concludes:

"As developers, we are often one of the last lines of defence against potentially dangerous and unethical practices."

Other examples in the discussion include a request to use emergency frequencies to make a wireless device work faster, hence endangering emergency messaging if the programmer had not refused. In on other example, a web page had a possibility for the customer opt-out of company newsletters. The company did not honour this, but prepared to send these customers specially edited messages. One of the themes seems to be that when one programmer refused, another one did not.

Anyway, the discussion shows that there are many cases where software professionals are asked to write unethical code. Some of the cases in the discussion are experiences where refusal to write unethical code has succeeded, but a lot of the cases are descriptions where the programmer or somebody else ended to write the code; in many cases, they left the company later on because of these kinds of requests. As in the Sourours article, there are also cases where ethical aspect becomes clear only when it is too late.

3.3 Discussion

There is not much data what would happen, if the programmer refused to write unethical code - in the Freecodecamp's discussion many of the programmers quit the job themselves. It can be asked if they will lose their jobs, but even if not losing their jobs, the refusal to write the code may affect their career, make salary raises smaller or non-existent - things that are hard to show that they originate from the refusal. The problem is that even if there were no consequences, fearing them may affect the programmer. Further, if programmers have a feeling that somebody will do it anyway, this might lower their ethical standard.

In the context of this paper, the cases where ethical implications are found later on are of the most interest. If one was not aware of the ethical point of the view when writing the software, does it free the programmer of the personal responsibility? If it does, does this form an easy excuse? To solve this easy excuse problem, there should be more awareness of ethical questions among software professionals.

4 INCREASING INTELLIGENCE OF THE SYSTEMS

There is a huge number of potential problems that arise with intelligent systems. First of all, who is responsible for the decisions made by the system? Our codes of ethics give responsibility to the engineer, but if the device makes the decision autonomously - especially after a learning process - is the programmer still responsible?

Even if the manufacturer or the vendor is the responsible one, what if the system has been used against the manual, or it has not updated as requested, or something like that falling clearly on the users' or owners' responsibility? Anyway, the owner or user cannot be responsible for decisions they did not have possibility to affect - the manufacturer should be responsible for them. On the other hand, a system that is capable of learning should itself be responsible for the decision - but still, it is a machine. This is one of the main questions to answer before widely used autonomous systems like cars can be taken in a large-scale use.

The responsibility is not the only problem. There are problems especially in cases where there are several possibilities that are almost equal (by some metrics) or all alternatives are bad.

4.1 Biased decisions

When programming a system there are cases where the behaviour is not neutral, like in the example above where the quiz ended up recommending only one drug - the customer expected to get a neutral answer, but actually got a very biased one. In these kind of questions, the decisions may favour e.g. the customer, vendor, or manufacturer of a product. The customer expects the system work as their benefit prioritised, but the reality may be something else.

4.2 All alternatives are bad

Cases where there are no good alternatives at all are more problematic. Whatever is selected, something bad will take place. If there is acceptable metrics to compare the alternatives, it can be used. Unfortunately, the metrics in these cases is often ethical in nature and may even differ culturally or from the points of view of individuals.

4.2.1 Example of a drowning man and a child

This example come from movie "I, Robot". A detective and a girl are in a danger of drowning. The robot rescued the detective, since he had much better probability to survive compared with the girl who had only 11 percent. This case introduces perfectly logical metrics for selection who to rescue, but the detective himself thought that the robot should have rescued the girl. The scene can be found on Youtube with title "11% Is More Than Enough: Save The Girl".

Computers can handle logical reasoning as in this case. Adding cultural, emotional, or social aspects make decision hard to understand and implement. What is the ethical reasoning that could end up rescuing the girl? Should there be emphasis on the age or sex? Actually, many ethics codes like Archimedean Oath tell us not to let things like age, sex, race or religion affect our decisions.

4.2.2 Example of an autonomous car

Examples of this kind can be found easily from the internet. Consider a case where a completely automatic car is driving on the street and a child runs to the road just ahead of the car. At the same time, a car is approaching on the left line (assuming right-hand traffic), and on the right side there are parked cars.

In any case, the car should try to stop, so the system hits the brakes. Breaking is not enough and three cases can be identified:

1. Avoid collision using the left line.
2. Avoid collision yielding to the right
3. Continue straight.

The first alternative would cause a head-on collision with the approaching car. This alternative endangers passengers in both cars, but saves the child assuming that she will not continue the left line. If the metrics is how many humans are potentially harmed, this may be the worst alternative.

The second alternative would cause a collision with one (or more) of the parked cars. This will endanger the passengers of the car, but saves the passengers of the approaching car and the child - assuming the car will not bounce from the parked car and hit the child anyway. If the autonomous car is empty, and the metrics is the number of potential injuries, this is the best alternative. On the other hand, there may be humans in the parked cars and the autonomous car is not aware of them.

The third alternative is to continue straight and hit the child. Depending on the speed, this potentially kills her, but saves the passengers of the cars.

So, what is the metrics to be used? Does it make any difference if the human is not a child but an adult? What about an animal (a dog or a cat)? In general, if the car has alternatives to save the pedestrian or the passenger of the car, which one it should select? Further, how many people would like to buy a car that does not prioritise the safety of its passengers? Should we make the software ethically configurable so the owner may decide on the metrics?

After all these unanswered questions, a quick look at the possible algorithm may be in place. The algorithm may be something like the following:

1. Something blocks the road.
2. Break!
3. Avoid the obstacle, try left.
4. Left is blocked, too. Try right.
5. Right is blocked, too.
6. Nothing can be done, just try to stop.

As can be seen, the implementer may not be aware any of the ethical questions arising. Even the code making the decision may not indicate the consequences in any way.

5 CONCLUSIONS

For ethical questions, there are no easy answers. In the light of the examples of this paper, one of the problems is to recognise whether the decision has ethical consequences or not. Although not a real case, the case of an autonomous car shows that it is possible to write decision-making software without noticing its ethical consequences. Even in real-world cases this viewpoint was not always seen until later on. Together with strong personal responsibility on the developer of the system, this forms a dire problem.

Particularly in software, where the same piece of code can be reused again and again, and the software is produced as components, the decisions should be identified on the early phases of development. They should not be left for later phases since their nature may not be recognisable. This means the ethical aspects should be evaluated as the software project is started.

In many cases, there are no separate ethical courses for engineers. Having such a course in the beginning of the studies might the waste of time - the students may not be ready to accept that ethical questions are part engineering skills until they understand more about the technology itself. However, ethical aspects should be highlighted in some part of the studies. The best places could be in connection with practical studies like assignments and project courses. For instance, we could require that each assignment or project work in studies include a statement that evaluates if the system have potential ethical questions or not. This way, eventually, the habit would reach the companies, too. As it appears that the answers of ethical questions may be culturally dependent, should we allow the customer to select the underlying ethical principle? If so, the programmers should be even given broader education in ethics.

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The Engineer; The Oblivious Prostitute?

Collins Dictionary, 3rd sense of the word

Bill Kinlough

A philosophical View of Engineering Thinking and curricula

> *"Now I am become death, the destroyer of worlds"*
>
> *Oppenheimer's words after completion of the project"*
>
> *Whether one considers this diligence of Oppenheimer's to be evidence of moral weakness or of admirable strength largely defines one's view of the moral responsibility of scientists and political men*
>
> Editor *The New Atlantis*

My conscience and lack of sleep will no longer allow me to be quiet and so, the charade must come to an end. I am here to challenge the assumptions and justifications made and offered in the field of engineering schools and engineering schooling. To discuss the dogma that determines our thinking and whether we are justified in carrying on regardless of the arguments that I shall raise in this paper

I shall endeavor to introduce a number of themes in this Philosophical/Engineering paper that are all connected to engineers and engineering awareness. If we look at Epistemology, Ontology and Axiology as the foundation for engineering we shall see a completely different engineer coming out the other side of the equation. Oregon state University has the following statement regarding teaching 'There are three major branches of Philosophy. Each branch focusses on a different aspect and is central to your teaching' The website mentions the three main branches of my paper and why they are so important to teaching; 'Your educational philosophy is your beliefs about why, what and how you teach, whom you teach, and about the nature of learning. It is a set of principles that guides professional action through the events and issues teachers face daily'. That is understanding what your role is as a teacher and as a professional, led by your profession, and not by a subject.

Without using these perspectives to observe and think about the engineer, teaching, the professional, the university and the role of the teacher, I will show that all we're doing is just shooting in the dark without understanding what we are really, actually doing. I shall look at the Engineering environment that a young engineer enters and what the culture of engineering involves, what it means for a young man's future if we continue doing what we do in this manner (I refrain from using the term 'teaching' here). I will show that it is hollow and without insight, it is harmful and undermining for the young engineer and his true role in society. It is detrimental to the environment and lacking in the basics that are seldom addressed. I will finish with a simple argument about how professional we truly are by introducing the professional area and autonomous thinking. Before you refute what I am saying, I should like to quote Aristotle who says 'It is the mark of an educated mind to be able to entertain a thought without accepting it.'

If we teach knowledge, we should have a solid grounding in Epistemology, We should understand what justification and evidence is, and introduce the concept of evidential defeat. Truth and its true meaning, skepticism and empiricism. The Knowing of Knowing has to be an essential part of engineering, because we apply concepts and models constantly to what we are doing without first examining how clean our lenses really are to help us truly see things. We can have knowledge of mathematics, but this knowledge is totally different to the knowledge needed to tackle a complex engineering problem. **Epistemology** is the study of knowledge and how we gain knowledge. If I look at engineering schools, I see that over 70% of all questions in engineering never get beyond the third level of Bloom's taxonomy, which means our students are compelled by us to think in the same way throughout their education. Can we then say that we understand that what we are 'teaching' is true knowledge. Heidegger tells us the following:

> *"This flight-from-thought is the ground of thoughtlessness. But part of the flight is that man will neither see nor admit it. Man today will even flatly deny this flight from reasoning." (***Heidegger***)*

Thoughtlessness, why? Because our students are not challenged to think reflectively or in any other way except in a calculative manner. This raises the following questions: In what professional environment will our students enter? Will that be purely calculative? If a complex problem has 20 sub-questions are all the sub-questions then calculative questions? When we think about knowledge we think about the following questions also; what is knowledge? Are we teaching real knowledge?. Is a multiple-choice exam a test of pure knowledge? Aren't our questions just a reflection of what happens in the classroom and if we seldom rise above the 3rd level of Bloom's taxonomy, what are we really doing? There are several distinct forms of knowledge; factual, conceptual, procedural and meta-cognitive knowledge and we teach mainly just one. What are the consequences of our actions and are we aware of them?

Heidegger, tells us that we have the potential for thought, but he says

> Just as we can grow deaf only because we hear, just as we can grow old only because we were young; so we can grow thought-poor or even thought-less only because man at the core of his being has the capacity to think; has "spirit and reason" and is destined to think.**(Heidegger)**

Man, of course, has to become aware of the potential of his thinking faculty, and the many shades of thinking that he is capable of. Is this what we awaken in our students? Do we make them aware of this potential that they have naturally? When did we explain the different forms of thinking to them last? Where is epistemology in our curriculum? What are the consequences of it not being there? An important question that you should also address is the following; where they in your curriculum when you were a student? If not, isn't there something dreadfully wrong if thinking as an engineer is not an integral part of the engineer's curriculum?

I think the picture is clear. I think there are very few engineering schools that have even thought about these questions and even fewer that have answered them. The victim is the student and can only be the student. Totally unused potential that will never be completely taken advantage of except maybe by their future bosses. Do these bosses represent society? Is a company's success the same as society success? Finally, I wonder are engineers the type that will 'flatly deny this flight from reasoning'?

I would now like to move onto **Ontology**, this part of philosophy deals with 'being', I need to discuss the reason for the existence of engineering students. We shall start with the student's learning. Freire states that 'When a person is truly educated, she or he will reflect on the world she or he lives in. This is where liberation comes in.' **(Freire).** Kant believes that understanding who we are and what we are to become needs a special type of thinking; 'Enlightenment is man's release from his self-incurred tutelage. Tutelage is man's inability to make use of his understanding without direction from another. Self-incurred is this tutelage when its cause lies not in lack of reason but in lack of resolution and courage to use it without direction from another.' Students should be independent thinkers at the end of their engineering schooling according to Kant. Are our students thinkers or doers? Can they think autonomously? Are they being directed in their thinking by their company or by their own power of thought? Does the engineering environment demand sound, logical and reflective thinking or will it be o.k. just to teach our students calculative thinking? Isn't this why an engineer exists?

Normally, the tyranny of the majority determines what a decent curriculum is. By determining the make-up of the curriculum they directly influence what is good for an engineer, but what is it based on? Experience? Work? Technology? None of these aspects can give you the answer because we are measuring minds. Minds that can deal with the true engineering environment which can be one of real complexity, a complexity that can never be tackled by calculative thinking alone. It is the reasoning of an engineer that we should be measuring, reasoning based on his insights into complex problems, reasoning to examine the scope and depth of the problem he is faced with. Reasoning that will always give us the best possible answer. Isn't this the true engineering environment? Is this what we should be aiming for? An engineer that does not need anyone to hold his hand, an engineer that Kant himself would be proud of.

Gordon Redding states 'The implication is that the more a society contains individuals who can think for themselves, so as to reach informed judgments and persuade others of them, the greater is the society's capacity to handle the difficult work of adjusting to changing and increasing complexity' A complexity in which our students should be comfortable; my experiences in reading final-year reports show they are not just incapable, but extremely incompetent at understanding the true complexity of the problem they are confronted with. Only through our understanding of who we truly are (**Ontology**) can we get to the truth of what engineering is and what engineering teaching is all about. It has absolutely nothing to do with the product, which is the consequence of what we should be measuring. The analogy of the man who buys a fish and shows his wife what she believes he's caught, although he hasn't the slightest idea of how to fish. It's not about the final product, it is all about knowledge employed along the way.

The seriously tough questions we have to ask if we want to have any value in teaching engineers are the following; Do students become prisoners of their own thinking? Have they been given the tools to escape their calculative thinking? Which classes have given them these tools? If we hardly ever exceed Bloom's 3rd level in our teaching, when does this higher level of thinking and knowledge become the students own? Can they, through their manner of thinking, ever come to realise the real truth and value of engineering?; What value do these students have for engineering and for society? Can students ever reach anywhere near their true potential through our teaching or are we supplying slaves for the bosses?

We need students who can think autonomously, that we can develop and they can themselves decide where and for whom they want to work. It will always be their choice, but we can rest assured that their choice will be the right one, if they become autonomous thinkers. We should not look at companies or regional tastes to determine what a student learns. Then the following questions arise: If a student is autonomous in his thinking won't he always make the correct choice? Do we measure the autonomy of a student's thinking in the final year at this moment? Or do we measure if the company is happy with the result? Aren't we doing society a great service by creating engineers that have reached their cognitive potential and aren't we creating something special for society? If we answer this question correctly; what is the nature of engineering? Then I think we have a huge duty to answer all the others ones I have posed

The **Ontology of Universities and professionals** is my following point. Redding writes 'Academic freedom is the main expression of openness to understanding relevant external change. At the heart of any such process in most societies is the institution of the university, whose function is to facilitate these processes of continued human and societal evolution **(Redding)** In other words it is the work of universities to interpret the environment's signals and to ensure that our students act in accordance with what is deemed necessary by society. Not to take onboard blindly everything that comes down from a government who cannot possibly have the knowledge of our universities. Should utility be the dominant criteria for our curricula? What values are linked to our criteria? Should corporate values determine what an engineer should look like? Is giving information teaching? Can you create an engineer based on regional preferences? . The word 'teach' implies not only an action but also an achievement, if we only see it as a task, does it matter how we teach as long as we complete our task?

A professional cannot not listen to managers if they believe that they are damaging the teaching or engineering profession. It is our responsibility as professionals and as engineers to protect our professional area. The questions that arise here are the following; Isn't this our duty to determine the forces and dynamics of society and interpret these for our students? Isn't this what defines us as teachers of engineers to determine and protect the environment that the engineer enters so that he can have a complete understanding of his responsibilities in that environment? Can he reach that understanding through his calculative thinking? Don't we as teachers of engineers have to be autonomous thinkers in our function and our roles as teachers of the youth of society? Isn't that our main responsibility? Isn't our job, as professionals, to question our institutes and be critical of any dynamics that will affect or influence our engineering students? Here's a question for you; when did you last have a conflict with your colleagues about the direction of the school curriculum? Can we call ourselves professionals if we sit quietly while our institutes and managers determine what is best for the engineer and the teacher? Should we accept all that comes at us and not even discuss the merits of anything that influences our students? Isn't that our role and our function as both teaching professionals and as Engineers? Or should we ignore everything except the technical aspect? If the answer is yes, then aren't we just secondary-school level technical people who pass on information to young people? Can you call yourself a teacher if you do not act competently and responsibly in that role? Is it unethical to accept salary if we are being incompetent as teachers of young minds? Is it our responsibility to ensure that our curriculum is properly grounded in our schools and universities and are not based on the whim of the few or the many, but on pure reasoning!

On a different level, the questions that arise should be the following; What value do we have as universities, as centres of knowledge, if we are just doing what the man tells us to do? What value do we have as teachers of engineers who refuse the burden of the teaching profession and just play with our subject? Aren't we just as much slaves as the students we teach? Aren't we also prisoners of our own thinking? Aren't we fooling ourselves by calling ourselves teachers of young minds? When did you last really measure the thinking of a student? I don't mean by giving them multiple choice, but by challenging their thinking in all its aspects.

My third point is **Axiology,** if you want to know about the university you work in, then I suggest you look at who is teaching Ethics, if it is a communications teacher, this proves two things; 1. the engineers themselves do not understand and/or don't want to understand the ethics and morality involved in the work of engineers. Secondly, if ethics is not integrated, although it is a major part of decision making in engineering, can we really say that we understand what engineering really is? Almost every decision an engineer makes is just part of a continuous chain of decisions reaching into other peoples' lives. A student of mine Sparsh asked me a few months ago "Mr xxxxx isn't every engineering problem an ethical problem?". After thinking about it for a minute, thinking about the choices of materials, how we dispose of the material, what the consequences of more automation for society is, every single material choice that we make is at the cost of nature, I had to agree with Sparsh that real engineering in even most simple of environments demands a moral insight that is solid and based on the values of the engineer. Not on the values of the boss. The question arises; What value does a hollow engineer have who has little or no sense of morality? How steady is an engineer who does not understand his own value when it comes to big decisions? How valuable is that same engineer for us as a society? Can society trust such an engineering Cyclops? Aren't we just hollow men who don't want to be enlightened?

My next point is **values**, of course, a wonderful vague term, which most people would never look up in a dictionary; why? Because it is such an everyday word and easy to miss if you do nt think about it. Collins' English Dictionary describes values as 'the moral principles and beliefs or accepted standards of a person or social group'. Now if I pose the question 'What are the accepted standards and beliefs of engineering?' I am sure that 98% of teaching engineers have not got a clue what they are. The question then arises; What are the consequences for this ignorance? What does it mean for the young minds we teach? The following questions also have to be answered; "What are the accepted values of the teaching profession?" Is that important? If we cannot answer these two questions, how professional are we really? Can we do any damage as teachers to these young peoples' minds by not being aware of who we are and what we are? Is it really enough to just teach a technical subject? Isn't that the essence of secondary-level teaching? Can we really call this knowledge? Aren't we just fooling ourselves?

I would like to talk about Hofstede's culture theory and 'the Hollow Men' who I believe are 'engineering teachers', because they may look like teachers, talk like teachers, even do some work that teachers do but if you go to the heart of what they are doing, you will see that they are hollow men who miss the guidance of "Engineering Values" and "Teaching Values". Values tell you who you are, they guide your every decision, they are the steering wheel in your profession. Now I ask you; how can you do anything in teaching if you don't understand that? What guides you? What guides our behavior? What steers us into trouble and keeps us out of trouble?

The next point I would like to introduce is a white rectangle, which I call **the Professional area**, if we as teachers, evaluate a product instead of measuring the thinking behind a product we are dirtying this very white and clean Professional area. There are many ways in which we can soil the professional area, these are; 1. Blaming students 2. Mono-directional teaching 3. Oblivious Teaching 4. Unaware of values 4. Not being jointly responsible for the curriculum 5. Unaware of responsibility to society etc. etc. Each and every point comes from a lack of awareness of what engineering is and what teaching as a profession is. Like blind men, we soil the professional area again and again, and the following question arise; Are we then being incompetent? Do we not create the engineer as prostitute being used and abused by bosses for their own goals, selling themselves and their skills cheaply, without ever debating whether the boss is the one to be served? Do we not undermine the role and importance of engineering again and again if we know not what we do? How professional are we really?

Let us now talk about what we should be trying to achieve. Autonomous thinking, this is what we should be doing according to Horvath; discussing what students should be capable of doing; 'Reflection, self-reflection, evaluation and self-evaluation best support effective learning if their results are relevant to the learning process. Thus their success depends to a large extent on the students' metacognitive knowledge, that is, the knowledge possessed by the students about themselves as learners and the learning process.' Independent, reflective, metacognitive thinkers who we can trust in the roles we give them as a society. We can trust them because they understand what an engineer is, they understand who they are, they are aware of the consequences of their work and the importance of the decisions they make. They are responsible for their environments, they are true engineers

To conclude, there is light at the end of the tunnel. That light is indeed the light of the real world, let us leave the caves that we have been inhabiting for years, and go out into the light of awareness and by becoming aware, we truly become what we have been playing at for the past years!

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Ethical Dilemmas of a Software Engineer

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ABSTRACT

In the Information Age machines and devices are always being controlled by computers. With this, many ethical questions arise. Is a machine allowed to harm someone in favor of saving somebody else? Who is responsible for harmful actions of an autonomous car? How soft or hard should the algorithm that finds a fitting donation organ for a patient be programmed? The base of all these machines and computers is their source code, written by a human programmer. Therefore, we need to understand the ethical implications of the programmer's code. The purpose of this paper is to identify ethical implications that can result from the source-code of a program or a machine.

Conference Key Areas: Ethics in Engineering Education

Keywords: Ethics in Computing, Ethical Code, Implications of software code

1 INTRODUCTION

We live in the time of the digital revolution. We see computer-based systems wherever we go and most people cannot imagine a world without computer systems anymore. These systems are made of the actual device, known as hardware, and the source code, known as software. The software controls the hardware and makes the hardware useless without it. The base of the software is their source code, written by a human programmer, which implies that the programmer can define the possible

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actions of the hardware. The combination of software and hardware forms a usable computing system, which can range from a calculator over the airbag control unit of a car to cockpit elements of an airplane. Having this in mind, some people argue that it is the programmers fault, if the airbag did not explode during a car accident and hold the programmer responsible for the consequences. Considering the fact, that the programmer created this bug that led to the failure unintentionally, it is difficult to determine the person who is responsible for bad consequences of a software failure. The software development process involves many areas such as architecture, design, coding and testing, which results in the share of responsibility among those persons who work in one of these areas. The authors in [1] say that it is too much for a single human to be held responsible for all bad consequences in any profession. Furthermore, software systems are characterized by their complexity, which makes it difficult to predict future consequences.

This paper does not focus on the findings of the responsible person for the bad consequences of any kind of software failure, but rather focuses on the possible bad implications that can result from software failures. Besides providing an overview about general ethical coding practices that are known to help keeping bad implications to a minimum, we present more complex ethical dilemmas the software developers must face. The main contribution of this paper is to clarify ethical implications that can result from a programmer's code to alert programmers about their responsibility to keep bad consequences of their code to a minimum.

This paper is structured as follows. Section 2 overviews existing literature. Section 3 reviews general ethical coding practices a programmer should follow and section 4 and 5 discusses more complex software systems that require more insights to understand how the programmer should code to follow ethical guidelines. Finally, section 6 concludes this paper.

2 LITERATURE REVIEW

To the best of our knowledge, there is no work that focuses on the ethical implications that can result from a programmers code to clarify the importance of software engineering ethics. Despite this, several research efforts have been carried out that focus on other aspects of computing ethics.

The authors in [1] provide an insight about the ethical responsibility of the software engineer by analyzing how far software engineers can be hold responsible for bad consequences of their software products. Because of the complexity of software systems and difficultness to predict consequences, the authors reveal it inadequate to analyze the responsibility only by the occurring consequences.

In [2], general ethics in software development are discussed, which include privacy, encryption, trust, freedom of speech and intellectual property.

Software engineering deals mainly with information, so that the main values concern truth, such as fairness and sincerity, honesty and integrity and earnestness etc., which are part of the ACM software engineering code of ethics and professional practice [3]. These guidelines also describe professional practices to avoid bad practices that could result in defective products, including appropriate testing and a good documentation. Above all these professional practices stands the public interest, which is based on health, safety and welfare.

There is several literature available that focusses on ethics in computing in general [4]–[7]. These books provide insight about ethical concerns that appear in the computation technology.

3 ETHICAL DILEMMAS OF SOFTWARE ENGINEERS

Computer programmers encounter several ethical issues [4]. In this section, we review ethical dilemmas that a programmer must face every day. We are referring to all types of software developer, which have different roles in the software development process. Most of them are programming code in various languages, but having their focus on different aspects of the end-product. A code programmer focuses on the creation of a software product, whereas the test programmer wants to guarantee the correctness and robustness of the software product. Software developer receive the information about what to code in forms of software specifications, which describe the requirements for the software product. In the following, we present scenarios of ethical issues that can occur during the software development process, which include the following ethical dilemmas:

- Coding Practices
- Code Review
- Programmers and Viruses
- Programmer Security Responsibility

For each topic, we discuss common ethical issues and present ethical guidelines that can minimize immoral consequences.

3.1 Coding Practices

Programmers face a lot of ethical dilemmas during their general coding practice. Most of them result from an incomplete communication between client and developer, short knowledge of the required programming tasks, simple boringness or laziness and most often the source, a lack of time to complete the task.

Bad code is not fulfilling all requirements of the software specifications. It can result from not realizing the complexity of the specifications and therefore underestimating the whole project. It can also result from client pressure that are in great need of satisfying deadlines. Finally, bad code can be written by programmers that do not have the technical knowledge to successfully meet the required software specifications.

Consider the following example: A software development team is in the final stage of finishing a software product, but one programmer writes bad code and slows the process down. Two other programmers want to rewrite this code without notifying management to put the project back on track. On the one hand, this covers up someone else´s failings and could put future projects at risk. On the other hand, we cannot expect that everyone always succeeds and it is better for everybody to work in an environment, where everyone is supported, rather than blamed for his/her failings. To this end, supporting team members is always recommended, but instead of covering up someone else´s failings, one should seek permission from the project management to support him/her and fix the code together.

Weak code results from lazy, careless or overworked programmers. Due to unrealistic deadlines, programmers can become overworked. The ethical dilemma of doing the job versus doing the job to the best of our ability arises. Doing the job right, by investing extra hours usually pays off in the end, but could also result in the miss of a deadline. To this end, it is important to find an ethical balance between doing the best you can and doing the job just as required to satisfy any deadline.

Keeping up-to-date with the latest development practices takes a lot of time and does usually not fit in during the regular working hours. If the company does not provide extra educational seminars to provide new or upcoming technical coding practices, it is up to the programmers how to choose. Many programmers do this on the fly, because they are interested in the topic and have fun doing so. Others simply do not have the time to invest extra working hours into keeping their programming skills always up-to-date. To this end, if the job management does not provide educational seminars, it remains ethical to not acquire the latest coding practices.

3.2 Code Review

Code reviewing provides a check and balance for the created software product. A code review is performed in three different ways: by a third party, by a coworker or by an automated software. Simple code reviewing makes sure that the code has no basic vulnerabilities. More complex code reviewing is known as penetration test, which will try to penetrate the security of the program.

Doing **lazy code reviews**, because you know that everyone writes decent code could either safe time or cause a lot of damage. It is important to know the priority and complexity of the project to decide how thorough the code review should be. As a programmer, you should be able to find a feeling for the needed thoroughness of the code review. If you want to make sure to not cause any damage afterwards, you should prevent lazy reviews.

There are many tools available that can do an **automated code review**. Therefore, we can ask if it is ethical to completely rely on these tools. These tools have their weaknesses and some of their code adjustments can be irrelevant and not as optimal as suggested. It is therefore important to find a balance between the tool suggestions that can be helpful for future changes and suggestions that are not relevant or even not suitable.

3.3 Programmers and Viruses

Viruses can be introduced into software development, either intentional or unintentional, which results in ethical problems. Viruses can be propagated within the development environment due to lack of attention. Programmers can be responsible for populating them in the development environment.

Is it ethical to use your **company computer at home** or at the university to continue your studies? This puts the laptop at a higher risk to contracting a virus than within the company network. Is it appropriate to put the company laptop at such a risk, or should you keep the company laptop at the workplace? Using the company laptop outside the work place is a difficult issue and the way this is handled varies from business to business. To this end, it is necessary to discuss this matter with upper management and to be on the safe side you should avoid using company resources for private affairs.

The company allowed you to take the company laptop home and you have unknowingly **contracted a virus** while studying in the university, which then infected the whole network at work. Should you confess that you got the virus from studying in the university? Not telling how the virus was contracted will extend the process of finding and destroying the virus. This would be unethical and could cause even more damage to the corporate network than it already does. You should confess that you made a mistake and provide any details that could help eliminating the virus.

Downloading shareware involves many ethical issues. Downloading shareware can help programmers to reduce their time coding enormously. Every IT department should have strict rules concerning downloading shareware to not run into problems. Forbidding the use of shared codes will make the programmers job more difficult and subsequently less time efficient. The programmer might also lose interest, because s/he does not like programming code that is publicly available and might consider it as a waste of time. There is no standard policy available and the IT department and the programmers should find a balance for this topic.

3.4 Programmer Security Responsibility

The security of a software product involves many areas. These areas include among others security issues for API calls, temporary fixes and the use of backdoors.

If you are writing code and are using functions from other APIs, should you **assume that these APIs are already secure**? Or is it the programmer's responsibility to make sure that the API he is using is secure, by implementing security features such as error-handling routines to meet the company's security requirements? Using external APIs in your code always increases the potential security risks. The problem is that checking each external API for security vulnerabilities takes a lot of time, which is usually not available. To that end, it is up to the programmer to find a good balance between doing the job and ensuring that the product meets the required security specifications.

A **temporary fix** makes the program function correctly but it is not the optimal solution for the problem. Is it ethical to perform a temporary program fix, even though the future outcome could result in security or other problems? In the reality, temporary fixes are common practices, because companies consider it more important to meet deadlines instead of fixing every problem with the best solution. The temporary fixes are then usually improved by better solutions in future software patches or updates. As an example, Microsoft uses this technique for patches that address security weaknesses and we argue that it is a decision of upper management how to proceed with temporary fixes.

Back doors are implemented by programmers to get into the system in case something goes wrong with the application. If the program locks itself, the only way to get access to the program to free the system resources is by using a back door. Integrating back doors into a software program is a security risk. If the bad guys find out about how to access the backdoor, they can easily get access to the system. Is it ethical to implement back doors, even though you know that it would be possible to get into the system during a lockout by other means? Implementing back doors into the application involves a security risk and should be discussed with the management before implementing. Sometimes, back doors are important, because it is the only way to get into the application if a serious development problem occurs. If there are alternatives for handling those issues available, these are the better and more secure solutions.

4 CODING ETHICALLY – AUTONOMOUS VEHICLES

When programming the behavior of an autonomous car, much more difficult and complex ethical questions arise. Following precisely the ethical coding practices does not guarantee that an autonomous car will act ethically in all situations. Consider the following example: A drunken man walks along the sidewalk and falls on the street directly in front of a driverless car, which kills him instantly. The victim's family claims the vehicle manufacturer responsible for the death, because the car could have swerved around the man, crossing the double yellow line and colliding with an empty driverless car. A reconstruction of the accident by collecting the car sensors information confirms this. The vehicle manufacturer asks the chief software designer: "Why didn´t the car swerve?".

If a person would have been controlling the vehicle, s/he would not be blamed for not making the right decision. A court would never ask this person, why s/he did not act the right way in this critical moment. The person could have panicked and acted on instinct and s/he would not be considered as responsible for the drunken man's dead. When robots or machines are driving, this is a whole different story and the question, why the machine did not find the best outcome for the situation becomes valid.

While human drivers can decide how to crash in real time, an automated vehicle´s decision of how to crash was defined by a programmer a priori. The vehicle interprets the sensor data to decide how to react, but the logic of this decision has been implemented ahead of time. On the one hand, this works well if a crash can be avoided. On the other hand, if a crash cannot be avoided and people will get injured, the vehicle must decide what is the best way to crash. Consequently, this becomes an ethical decision. As an example, the programmer must decide whether the car prefers a sever one-vehicle crash over a moderate two-vehicle crash or chooses another way that has a low probability for not crashing at all, but a high probability for a severe two-vehicle crash, as shown in Figure 1 below [8].

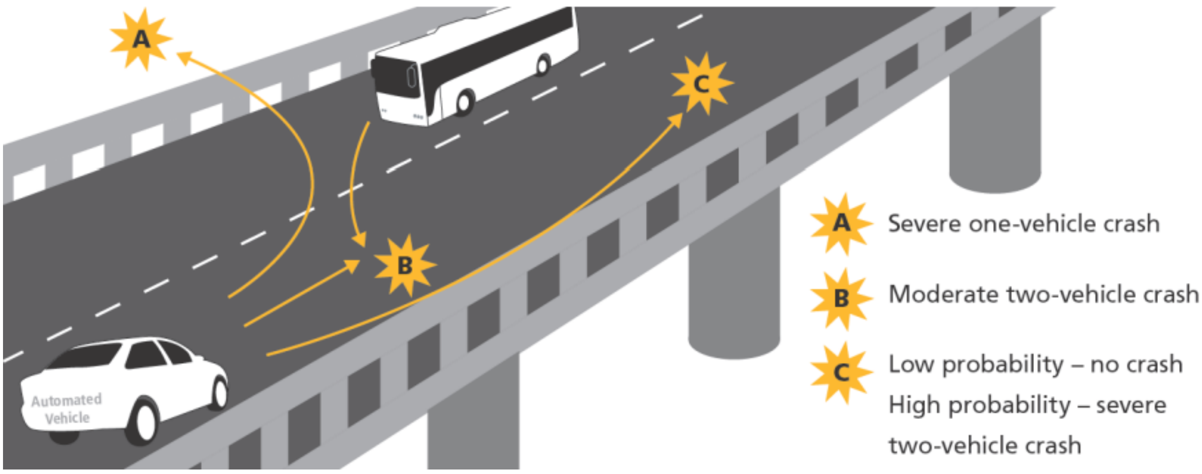

Fig. 1. Diagram of three alternative ways to crash for an autonomous vehicle when an oncoming bus suddenly enters the vehicle´s lane

This ethical problem refers to the moral experiment of the Trolley Problem, in which it is to decide whether to let five persons being killed and leave one person unharmed or to rescue five persons by actively killing one person [9]. This dilemma has been often discussed in literature and has not provided a solution and that is why there is no obvious way to effectively encode human morality in the software of autonomous vehicles [8].

A different approach to deal with this problem was provided in [10], by introducing risk management as an alternative way. Autonomous vehicles must constantly save the values of dangerous situations to compare with different objects on the road during crashes. How these values are formulated and the risks of driving are shared to other automated cars include ethical elements. Risk management techniques can be used to evaluate these possible risks. Using these techniques, it seems manageable to design ethical autonomous cars. Because these solutions might not be perfect, it is important to justify them by widely accepted ethical principles.

With the rising of autonomous cars, manufacturers and software developers will have to defend the actions of their autonomous cars in ways that are much more difficult to explain than what the normal driver would have to. The developers should therefore learn from experiences in similar areas such as industrial safety standards [11] and should continue to study the ethical implications of automated vehicles. We aimed to provide insight into the possible bad implications of autonomous vehicles that are very complex and not yet completely possible to prevent.

5 CODING ETHICALLY – HEALTH CARE ORGAN DONATION

The most difficult problem for an organ transplantation is the unavailability of a suitable donor organ. The next difficulty is the finding of a suitable donor organ at the right time. Programmers have designed algorithms for finding suitable donor organs. This is a hard combinatorial optimization problem and involves a lot of information, such as blood type, antibody information of the patient and antigen information of the donor [12]. Programming such an algorithm that involves life and death decisions implies critical and ethical decisions for the programmer. They face questions like how soft or hard should the matching algorithm be, or should younger and healthier patients be preferred over older, more unhealthy patients. Other questions concern, if the healthy-living patients should be privileged over patients that heavily drink or smoke. There are different ethical models available and in practical use that use different principles to judge which people for an organ transplantation or vaccines during a pandemic influenza get priority rights. These principles include *First-come, first-served*; *Sickest first; Prognosis* and other *instrumental values.*

In [13], the authors evaluated eight ethical principles for rare medical interventions. They state that no single principle can consider all ethical elements and it is therefore necessary to combine different principles into a multi-principle system. They quantified three existing and practical systems and provided a new system that priorities younger people, incorporates the medical prognosis and adapts the principles *save the most lives; random lottery selection; instrumental values*. For applying an ethical system like this in practice, these ethical values also need to be integrated into the algorithm by a programmer, because the selection of which person will receive the next available suitable organ will be processed by a computer.

When a software developer has the task of programming parts of such an algorithm s/he does not have to create these different ethical principles into the code by himself. The required specifications will already imply these ethical principles and the way they should be implemented. It is still important that the developers know what implications their code might have. It is a big difference if the programmer is coding the specifications for a website or for an organ donation algorithm.

For all kinds of software that is directly used to ensure the health of humans, the ethical implications that can result from software failures can be vast. Of course, it is not only the programmers task to ensure the correctness of his code in such cases.

There are other professions like quality and risk management that will thoroughly review and test the software to avoid any failures, but it is also the programmers task to understand the possible implications of his code. When programming a heart-beat control monitor the programmer should ensure that s/he is following ethical coding practices to reduce the possibility of future serious consequences for patients [14].

6 CONCLUSION

In this work, we reviewed best practices for ethical coding issues that face software engineers every day. We also provided a brief insight on other software programming topics, autonomous vehicles and organ donation, which can have very diverse and complex ethical implications. Every software program that involves humans or the environment as a user or as a part, can have ethical implications.

With this being said, we argue that it is important to teach software engineering ethics education, to teach students how to code ethically and demonstrate the possible implications of their computer programs. It is from utmost importance for every software developer to think about possible bad implications of their code. Having possible ethical implications of the developed program in mind, the developer will try to avoid them, which will result in a better software product.

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8.

Curriculum Development

Evaluation of the Implementation of New Framework Regulations for Engineering Education in Norway

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ABSTRACT

This paper reports on work to reshape the Norwegian bachelor of engineering education. It describes the process the reshaping is an important part of, several major findings of both positive and negative nature, and corresponding proposals for improvement in both the short and long run. Some of these findings are rooted in formal changes in the Norwegian educational system, while some of them arise from changes in society per se. Some of the proposals for improvement are easy to implement by individual institutions, while others require a tight cooperation between different institutions.

Conference Key Areas: Curriculum Development, Quality Assurance and Accreditation, Engineering Skills

Keywords: Engineering education, Framework regulations, Evaluation of implementation, Engineering skills

INTRODUCTION

The Norwegian Ministry of Education and Research adopted on 3rd of February 2011 new framework regulations for engineering education, composed of mandatory regulations and supporting guidelines. A national strategic academic body for the STEM-field within the Norwegian Association of Higher Educational Institutions, UHR-MNT, is mandated with an active role in relation to the guidelines and will propose revisions when needed. Based on the framework, the engineering education has been approved by FEANI (Fédération Européenne d'Associations Nationales d'Ingénieurs).

After the regulations were implemented, there have been major structural changes in the Norwegian higher educational sector. Several mergers were implemented in 2016, and as the merged institutions are working to operationalize their new structures, the aligning of study programs is crucial. The merger processes are now completed, and engineering education is offered at fewer and somewhat larger institutions. A national evaluation of these study programs has been initiated; the main goals are quality development and experience exchange.

This paper will present the background for the evaluation of the implementation of the framework regulations for engineering education in Norway, the process for the evaluation, formal and societal changes crucial to engineering education, successes and failures of implementation of the framework as well as other national tools developed to support the on-going quality development process. In the conclusion, a way forward is described.

1 BACKGROUND

1.1 A competence based framework for engineering education

Norwegian engineering education is controlled by a mandatory framework – including guidelines anchored in the regulations. The guidelines are expected to be in a process of continuous improvement. The regulations were adopted by the Norwegian Ministry of Education and Research in February 2011, based on a national development process involving different stakeholders. The description of the learning outcomes for all engineering candidates is the central and most important part of the regulations. It was implemented by universities and university colleges in 2011 and 2012. The vision of the work was “The Engineer – community committed, creative and empowered, with the ability to actively contribute to the challenges of the future”! The following topics were chosen as focus areas to improve within the education programs: ICT proficiency, corporate social responsibility, ethics and the engineer's role in society, systems thinking, integration of theory and practice, co-operation and student mobility, interdisciplinarity, innovation and entrepreneurship, research based education, environmental concern as well as transition between bachelors and masters level, which is strongly dependent on the STEM-base within the programs.

The regulations and the development of this competence based framework for engineering education is further presented in [1].

1.2 Implementation

Based on a national survey of stakeholders within universities and university colleges, theory and the objectives of the new curriculum, attributes that may be associated with quality education were suggested as part of the national guidelines. Successful implementation of the new engineering education was expected to provide an engineering education with the following characteristics:

- Integrated and holistic
- ‘Cutting edge’ by means of professional updating
- Updated and including varied learning and evaluation methods
- Research and development orientation
- Professional competence and practical skills
- International competence

- Interdisciplinarity, innovation and entrepreneurship
- Study effort and coping
- Engineering enculturation

Against this background, an evaluation process of the results from implementing the competence based framework for engineering education was initiated in 2016, by UHR-MNT.

2 PROCESS

The evaluation process is the product of a national working group, local self-evaluation groups, an on-line survey of staff and students in universities and university colleges and national workshops with institutional representatives. The local self-evaluation was carried out by a broad-based group at each institution. Both faculty management, management at the department and study program level, as well as academic staff, administrative staff and students were represented. Eight institutions have been part of the self-evaluation, most of them with several campuses – which at the time of implementation were independent institutions. 980 respondents answered a questionnaire comprising 37 questions, with partly selected questions to different respondents. Respondents were management, staff and students. The main body of questions were based on indicators of the characteristics listed in section 1. The answers from the survey were made available to the self-evaluation groups. The self-evaluation groups also answered a questionnaire with three groups of questions: overall, related to the main themes and detailed questions on selected areas. Two national meetings with 50 and 55 participants each have discussed the results from the survey and the self-evaluations carried out by the institutions, with focus on experiences and challenges identified by the national working group. The process itself has identified several good examples and experiences from which everyone will benefit. Shared experiences that can contribute to continuous improvement of the programs are part of the results from the evaluation. These will be further presented and discussed in section 5.

3 FORMAL CHANGES AND SOCIETAL CHANGES

3.1 Structural changes in the Norwegian higher education sector

During the implementation period, there have been major structural changes in the Norwegian higher educational sector. Norway must adapt to meet social changes and to ensure jobs and welfare in the future. An important goal is increased quality in higher education and research. Therefore, a report to Norway's National Parliament No. 18 (2014-2015) "Concentration for Quality – Structural Reform in the University and University College Sector", has resulted in a fundamental reorganization of the Norwegian university and university college sector. The higher educational resources are now concentrated at fewer but stronger institutions. The goal has been to establish a structure for tomorrow's knowledge society. This change has significantly affected engineering education. The evaluation results, supporting processes and the way forward that are presented in the next sections should be seen in this context.

3.2 Quality culture in higher education

Over recent years, there has been considerable attention to quality in education on both a national, political level and the institutional level. The Government has the last years been paving the way for increased quality at universities and university colleges by various means. The report to Norway's National Parliament No. 7 (2014-2015)

“Long-term plan for research and higher education”, the structural change described in section 3.1, adjustments in financial systems for universities and university colleges, simplified goal-oriented management and revised regulations for academic quality, are all examples of this.

Some important goals for the extensive work on developing a culture for quality in higher education is given in another Government white paper, the report to Norway’s National Parliament No. 16 (2016-2017) Quality Culture in Higher Education [2]:

- Demanding and engaging studies
- Students integrated in the academic community
- Clear learning goals and holistic programs
- Varied learning and assessment methods
- Collaboration with working life
- Teachers with good educational skills
- Teaching should be valued higher

NOKUT, the Norwegian Agency for Quality Assurance in Education, has in 2017 established a new regulation on supervising the education quality of higher education (the study supervisory regulation) [3]. The goal is to ensure high quality in Norwegian higher education. NOKUT’s Director explains: “With the new study supervisory regulation, we are turning our quality work even more clearly towards what happens at the level of study offerings. This is where the students meet the subject and the academic community, and the institution must facilitate the students' learning and ensure that they achieve the planned learning outcome”.

3.3 Thematic changes

In the current framework regulations there are high-level learning outcomes specified for five selected fields of engineering – civil engineering, computer engineering, electrical engineering, chemical engineering and mechanical engineering, as these had been dominant for a long time; this is no longer the case. Educational provision now combines some of these five fields, i.e. as Mechatronics or Fire Safety Engineering, and includes sub-fields, or programs not at all related to these long established fields. Hence, this has to be taken into account when the current framework is to be updated.

Since the current framework was designed, safety and security have become only increasingly important for an engineer to be aware of and able to handle. Hence, this has to be explicitly built into the framework for the future.

Further, the importance of knowledge and skills of chemistry have likewise increased alongside the environmental focus over the last years. The knowledge and skills of chemistry needed for this focus are not the same as those that were in focus just a decade ago. Once more, the framework for the future has to reflect this.

Finally, ICT knowledge and skills were of course included in the current framework. However, the corresponding learning outcomes were not sufficiently well specified – perhaps nearly taken for granted, and they have to be updated and upgraded – including an explicit coupling to safety and security.

4 SUCCESSES AND FAILURES

The self-evaluation in broad working groups has aimed to map the positive effects that can be experienced from implementing the regulations and supporting guidelines, as well as unintended effects that should be followed up with adjustments and revision of national regulations.

4.1 Sharing of good examples

The self-evaluation groups are satisfied with the high-level learning outcomes for the engineering studies. Some described the learning outcomes as somewhat over-ambitious, but after discussions in the national meetings, it was decided to retain these learning outcomes unchanged.

The framework regulations focus on an integrated and holistic education. The institutions describe it as an advantage that the guidelines also cover a description of the different paths to enter engineering education, including a vocational path via apprenticeship, and common requirements for transition from bachelor in engineering to master in technology.

To meet the society’s need for higher education, several institutions emphasize how programs are developed in close interaction with local industry. Some institutions also offer work place experience that awards academic credits.

Professional knowledge is emphasized in the new framework regulations. In the first year all programs include an introduction to professional engineering practice and working methods. For most institutions part of this is common for all engineering students (e.g. history of technology, project management, environment and society, introduction to laboratory and research methods), with another part directed towards each program or branch of study. Project based learning is common and the students are also introduced to general competences such as group dynamics and how to handle conflict.

To get a closer connection between professions and academia some of the institutions describe how the students at an early stage are introduced to academic learning activities. Analysis, critical thinking and scientific methods start being connected in the course “introduction to professional engineering practice and working methods” in one of the first semesters and ends with the bachelor thesis in the last semester.

In the 5th semester the students may choose between optional specialization, student exchange or work place experience.

4.2 Improvement areas

The current framework regulations had to include a lot of new learning outcomes compared to earlier versions – due to the extended knowledge and skills needed in general by an engineer. This may have been perceived as leaving too little room for making different study programs unique within an institution and across institutions. This should be alleviated by introducing some additional flexibility in the framework regulations.

The teaching and assessment methods used in the Norwegian engineering education have been fairly ‘traditional’. More varied teaching methods – like flipped classroom approaches, and more modern assessment methods – including digital exams, are gradually being introduced to secure the achievement of the learning outcomes on different levels. However, there is still considerable room for development.

Establishing the current framework introduced several meeting arenas for national benchmarking of the different educational provision. However, there has not been much focus on international benchmarking – like peer-to-peer evaluation of study programs between institutions in different countries. Hence, there is also a potential for improvement here.

The current framework is also structured so that it enables students to spend one out of six semesters at another institution outside Norway. To date, too few students have taken advantage of this possibility, so other measures have to be applied to increase the rate of student exchanges.

5 OTHER TOOLS

The work has resulted in concrete actions and cooperation between the institutions. Especially, there has been increased variation in learning and assessment methods. The MNT-conference was established in 2015. The conference is aimed at teachers in STEM-subjects at university-level that are close to the students, knowing what is difficult within these subjects, having experience with different teaching methods and knowing what the students struggle to master [4,5]. The conference is a meeting place where teachers within STEM-subjects can document and share experiences with each other and others active within STEM-education, including institutional managers and students. The second conference was held in 2017, and the evaluation showed it was a success.

The Nordic Journal of STEM Education has also been established. This is a peer-reviewed, open-access journal publishing in the broad field of Science, Technology, Engineering, and Mathematics Education. Contributions that address pedagogical, educational, and academic developments or studies are invited. The journal is planning for two main sections: one for contributions based in the Scholarship of Teaching and Learning (SoTL) and in empirical observation and theoretical frameworks, and one that reports and reflects on the use of “good practice”. Experience, reflection and scholarly studies can be shared in support of the development of higher education. After the MNT-conference the authors are invited to further develop their contributions into full papers for peer-review and publication in the Nordic Journal of STEM Education. The journal will be classified on level 1 in the Norwegian two-tier scientific classification system.

6 THE WAY FORWARD

In the last few years the framework for education in Norway has changed a lot. There has been an increased focus on educational competence. For example, all universities and university colleges shall by 2019 have a pedagogical merit system. It is also expected that peer-review and peer monitoring of teaching will be implemented. The Government has also built a competence-based arena for quality in education, i.e. the Centres for Excellence in Education Initiative. The framework for Engineering Education aims to follow up and strengthen these changes.

In the future, a web site for engineering education will be established with the current framework and the corresponding regulatory descriptions. This should open up for a more continuous development of different study programs and other related educational provision. This change will also be accompanied by an extended use of professional forums where teachers and researchers meet to discuss, propose and facilitate enhancement of programs and provision.

Already now, there is a need to change the framework regulations’ minimum subject size, some exemption provisions and the scope of the bachelor thesis. There are also challenges with the division into subject groups, topics, subjects, specialization topics and electives, in terms of size, content and naming.

As already indicated in section 4.1, some institutions have reported that the learning outcome descriptions may be too ambitious. Compared with overall expectations of the higher educational sector, the level and extent should still be appropriate. However, concepts such as ‘insight into’ versus ‘knowledge’ and ‘skills’ are important in this context, and clarifications are needed here.

After implementing the current framework regulations, it has not been possible to see any clear effect in some designated areas – e.g. drop out or gender distribution. Further, it has been difficult to decide whether other perceived effects – like more research based focus, are the outcome of the current framework or other changes – like the ones discussed in section 3. Both these aspects need to be further checked with the proposed changes of the framework.

7 SUMMARY AND ACKNOWLEDGMENTS

Some findings are:

- The common engineering base that is fundamental in the curriculum has been difficult to implement, but there are also many examples of good solutions. These will be used by the different institutions to improve their own programs and provision.
- Appropriate digital and environmental skills along with different aspects of engineering enculturation have not been integrated as well as they should. This has to get a clear focus in the future.
- A minimum course size of 10 ECTS is found to be too rigid. This should be changed to a smaller minimum amount, but at the same time limiting the maximum number of course exams to be taken each semester.

We need to thank a lot of actors in preparing this paper:

- The members of the national working group
- The members of all the local self-evaluation groups
- The respondents of the large on-line survey
- The participants of both the national meetings

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MINT^{grün} - Fluid Mechanics Project Laboratory

Supporting and preparing students for their courses of study

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ABSTRACT

A survey from 2015, presented an analysis of the study situation and student's orientation success in Germany, has indicated a knowledge gap between schools' content of teaching and required engineering skills at the university. This paper presents an example on developing a new orientation program to bridge the gap of knowledge for the students with interests on fluid mechanics. The paper is divided into two main parts: The first one introduces the MINT^{grün} orientation program at the TU Berlin and gives the latest numbers and trends. The second part focuses on the development of the Fluid Mechanics Project Laboratory of the department Fluid System Dynamic. A deeper insight on the structure and the teaching concept are given. This concept takes the mentioned survey into account.

Conference Key Areas: Sustainability, Skills and Engineering Education

Keywords: STEMgreen, Fluid Mechanics Project Laboratory, TU Berlin, Thamsen

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INTRODUCTION

Since 2012, the Technische Universität Berlin offers a special orientation program in the subjects of mathematics, informatics, science and technologies (MINT^{grün}; English: STEM^{green}[2]). The department of Fluid System Dynamics at the TU Berlin contributes to the orientation of young students by offering a laboratory dealing with fluid mechanics in applied mechanical engineering. The project laboratory provides useful engineering skills by teaching the students all the basics of using engineering software (such as Excel, SolidWorks, VBA) and guides them through advanced usage. It also imparts structured working methods while teaching the importance of sustainable engineering. Students achieve basic and advanced engineering skills (software and working methods) as well as exploring the multifaceted nature and the importance of sustainable engineering at the example of fluid machines. Since launching the project, it has been continuously evaluated by the students. The results show a very good rating for the teaching approach and a first analysis reveals that more than half of the students participating in the orientation program choose a STEM topic for their later studies.

1 BRIEF OVERVIEW OF MINT^{GRÜN} (ENGLISH: STEM^{GREEN})

1.1 Structure, numbers and trends

After graduating from high school, young people have to decide what they want to do professionally. Some choose to take an apprenticeship for about 3 years, whereas others choose an academic career and study at universities. The German universities offer a wide range of possible study courses. Most pupils feel overwhelmed by the countless possibilities and are unsure which course to take. They are expected to decide on “the right” study course which they will be practicing for the rest of their lives. This causes a lot of pressure and makes the decision even harder. Young people feel the need to be guided and orientated. Therefore, the Technische Universität Berlin launched an orientation program in 2012 called MINT^{grün} (English: STEM^{green}) to show graduated pupils the countless possibilities in the fields of science, technology, engineering and mathematics.

The orientation program of STEM^{green} lasts two semesters and consists of different modules as shown in *Fig. 1*. The “Scientific Window” and the “Study Program Decision” are obligate courses, where students gain all necessary information on how to orientate themselves. The other modules are facultative and consist of basic lectures (i.e. engineering mathematics) and so-called Project Laboratories. Whilst lectures mostly use frontal teaching methods, the Project Laboratories focus on practical tasks and give the students the possibility to create a STEM-related object on their own. After taking the two-semester program, most of the courses can be transferred to the student’s chosen course of study.

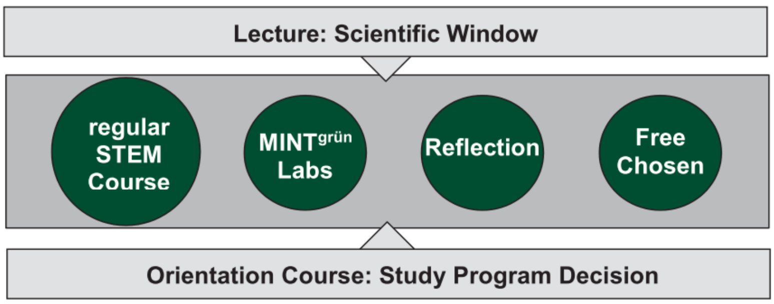


Fig. 1: Structure if the orientation program MINT^{grün}

[2] STEM: Science, Technology, Engineering, Mathematics

1.2 Project Laboratories

One characteristic feature of the orientation program MINT[grün] are the above-mentioned Project Laboratories which were specifically designed for STEM[green] students. Especially in the earlier stages of a course of study, subjects are more theoretical. For a successful orientation, it is mandatory that students discover their practical and project related potentials. Therefore, the orientation program offers a wide variety of laboratories, which cover the fields of construction, chemistry, mechanics, physics, history, robotics, fluid mechanics and many more.

The department of Fluid System Dynamic at the TU Berlin contributes to the orientation of young students by offering a laboratory dealing with fluid mechanics in applied mechanical engineering.

2 STRUCTURE OF THE FLUID MECHANICS PROJECT LABORATORY

To introduce and explain the structure of the Fluid Mechanics Project Laboratory (FMPL) it is necessary to refer to a German survey from 2015 which analyses current study states and student's orientation success. The conclusions of this survey build the basis for the FMPL's structure. This survey [1, pp. 21-30] shows that students wish for a better support regarding the achievement of engineering skills (which were not taught in school) and handling of common engineering software such as MS Excel. A majority of the students mentioned a knowledge gap between the schools' content of teaching and required engineering skills at the university. Finally yet importantly, students criticise the lack of support for achieving scientific writing skills regarding their homework and their bachelor theses. The laboratory is designed to satisfy those needs.

Another significant part of STEM[green] is a successful orientation of the students. Therefore, it shows them the importance of sustainable and responsible engineering, while exploring the diversity of STEM-related subjects. Consequently, current topics like "green energy" and "energy revolution" are discussed and an insight is provided. Students gain a deeper understanding of the fact that the "energy revolution" is not just generating electricity through renewable energy sources, but also improving the consumers (i.e. pumps[3]).

To show both sides to the students, the FMPL is divided into two parts, a lecture and a tutorial, as shown in *Fig. 2*. The next two subchapters provide a deeper insight on the lecture's and the tutorial's contents.

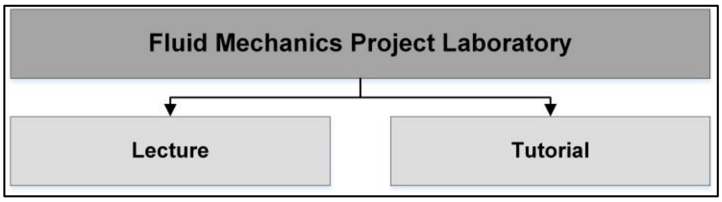


Fig. 2: Structure of the Fluid Mechanics Project Laboratory

2.1 Lecture

A weekly lecture, held by the professor, gives the students theoretical concepts of fluid system dynamics and their general fields of application. The focus is put on driven machines (pumps) and their sustainable construction. Different types of impellers and their fields of application are explained. In addition, drinking water and

3 About 30% of Europe's electricity is used to power pumps. [2]

wastewater networks are presented and today's challenging phenomena are highlighted. The expansion of the students' knowledge in the field of fluid machines is encouraged by many examples with a practical orientation.

The discussed topics are complemented with a practical exercise, where students do measurements on fresh water pumps or a sewage pumps running in a fluid system.

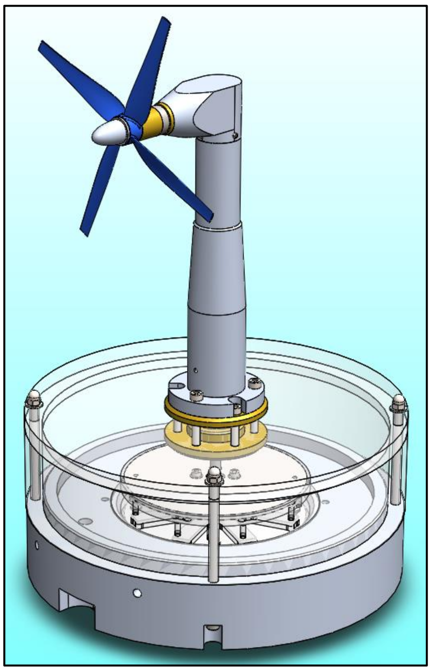
The main goal of the lecture is to show the students the many possibilities on fluid mechanic related topics. It contributes mainly to the student's orientation.

2.2 Tutorial

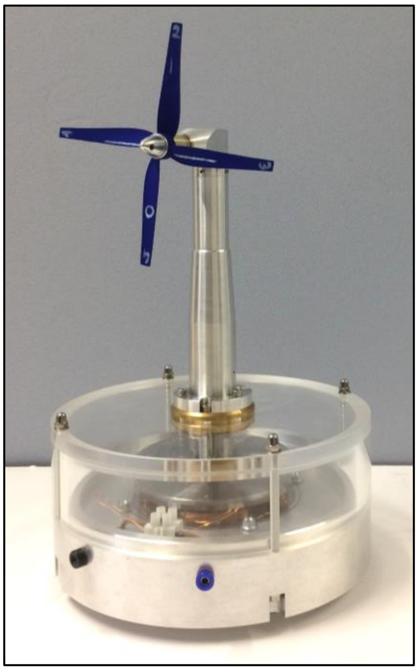
The tutorial has a practical character and provides insight on how to do group projects in study courses. One Tutorial has space for 20 to 22 students and is accompanied by 1 research fellow and 1 research assistant. Two separate appointments are offered and therefore a total of 40 to 44 students are mentored. One of the main goals of the tutorial is to close the gaps mentioned in the survey [1] and prepare the students for their daily studying and engineering life. This includes the following topics and skills:

- Project management
- Group work and social competences
- Safe handling of calculation software (i.e. MS Excel)
- Safe handling of computer aided design software (CAD, i.e. SolidWorks)
- Measurements, sensors and characteristic curves
- Scientific writing (i.e. with MS word)
- Presenting project results (i.e. with MS PowerPoint)

To impart this knowledge, the rotor of a wind turbine model is designed within this tutorial. Many parameters (i.e. rotor diameter, blade number) are assigned by the group members. Therefore, every group owns their personal unique rotor. A rotor designed by the students is shown in *Fig. 3*. Consequently, the tutorial shows the producers side of sustainable engineering and renewable energy, whereas the lecture deals with the consumer's side.



(a) CAD model



(b) actual model

Fig. 3: Example of a rotor for a wind turbine model designed by the students

Fig. 4 summarises the FMPL tutorial's structure and which topics are discussed at a certain point.

Phase	Duration	Contents	Achieved skills
1	*2 weeks*	Organisation and project management	Organising group project Time management Creating project schedules with MS Excel
2	*3 weeks*	Fluid mechanics and wind energy	Basic calculations in MS Excel Handcrafting and testing airfoils Advanced usage of MS Excel (links, functions, variables) Complete rotor calculation
3	*2 weeks*	Computer aided design (CAD)	Introduction into 3D modeling Basic usage of CAD software Advanced usage of CAD tools (scripts & macros) Manufacturing of the student's rotor
4	*3 weeks*	Measurement techniques and test stands	Purpose of test stands Usage of sensors Measurement of each group's rotor Advanced usage of MS Excel (graphs, functions)
5	*3 weeks*	Writing and presenting skills	Creating templates for MS Word Basic usage of MS PowerPoint Scientific writing recommendations

Fig. 4: Structure of the Fluid Mechanics Project Laboratory's tutorial

As shown in *Fig. 4*, the first two weeks are allocated to organisation and project management. In this phase students get support for their general study-related questions. Furthermore, working groups are assigned and basic project management skills are taught using MS Excel. This allows the students to acquire new skills and knowledge on teamwork and time management. Students are supported with useful tips and personal experiences to end their project successfully.

The following three weeks are spent on providing basic physical knowledge about fluid mechanics and wind energy. Simple calculations are first done in MS Excel to show the fundamental features of calculation software. It is followed by advanced usage of MS Excel, i.e. using links, functions and assigning variables. The main goal of those three weeks is to teach the students smart usage of engineering tools to make their life easier. Furthermore, students get a first idea on how airfoils work by crafting airfoils and testing them on a small wind tunnel. After this period, the first milestone is reached. Students have their personal rotor calculated with MS Excel.

The next two weeks are dedicated to the design of their calculated rotor with CAD software. At first, basics are taught to ensure the safe handling of the CAD software. Later, advanced skills are provided (i.e. scripts and macros) to speed up the students design process and teach smart usage of engineering tools. At the end of this phase, students have their personal rotor as a 3D model and it is ready for manufacturing. The second milestone is thus reached.

Three more weeks are allocated for describing measurement methods and test stands as well as for the actual measurement of the student's rotor model. Students gain a deeper understanding on sensors and how to acquire measurement data. Furthermore, data evaluation and visualisation using the MS Excel is also introduced.

The last three weeks are used to impart scientific writing and presentation skills. Under supervision, students design a template for scientific papers with MS Word, which they can use throughout their study courses and even for their bachelor thesis. Practical exercises are used to achieve more detailed knowledge of using MS Word. A similar strategy is used to impart presentation skills. First, the basic usage of MS PowerPoint is taught and subsequently practical examples and personal experiences are given to the students.

3 RESULTS AND TEACHING APPROACH

Every student is unique. Every student uses different ways to learn and consequently it is mandatory to use different ways to teach. We attach great importance to address every learning type (auditory, visual, communicative, and motoric [3]) by the use of different media, such as exhibits, pictures/graphics, slides and presentations, experiments, group work and topic related examples. Since launching the project, it has been continuously evaluated by the students. The results show a very good rating for the teaching approach and good response for the concept (*Fig. 5*).

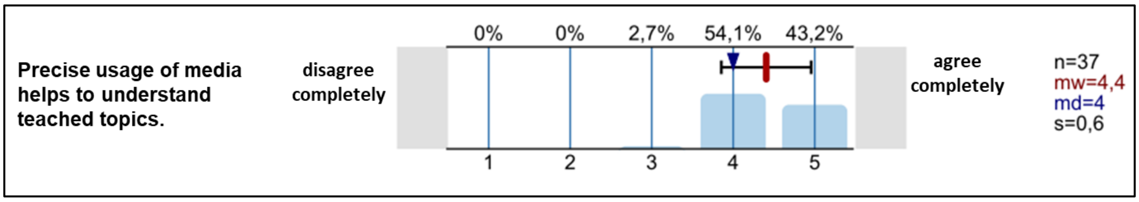


Fig. 5: Survey results regarding media usage

A first analysis reveals that more than half of the students participating in the orientation program choose a STEM topic for their later studies. Even people, who leave the university and start an apprenticeship, consider the contents of the FMPL as useful for their later jobs. The Fluid Mechanics Project Laboratory as a whole was rated last semester with “very good” (*Fig. 6*).

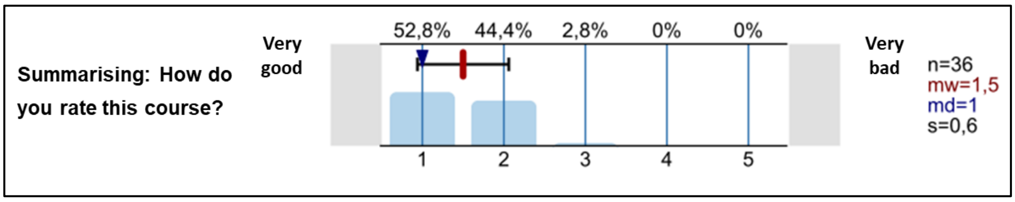


Fig. 6: Student’s summarised rating of the Fluid Mechanics Project Laboratory

4 SUMMARY AND ACKNOWLEDGEMENTS

The teaching concept of this Fluid Dynamics Project Laboratory contributes highly to the orientation of our students. The lecture and the tutorial complement each other in a way that a huge field of fluid mechanical engineering is covered. Students gain a diversified insight on fluid mechanic related topics and their field of appliance. Due to the practical concept of the tutorial, students achieve various engineering skills and working methods, which can be used in many study courses or even in apprenticeships. Due to the teaching of basic and advanced skills regarding engineering software (MS Excel, MS Word, MS PowerPoint, SolidWorks), students are well prepared for their course of study. In this program, the students get supported in general studying related aspects as well as fluid mechanic related topics.

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Confidence in and beliefs about first-year engineering student success

Case study from KU Leuven, TU Delft, and TU Graz

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ABSTRACT

This paper explores the confidence freshman engineering students have in being successful in the first study year and which study-related behaviour they believe to be important to this end. Additionally, this paper studies which feedback these students would like to receive and compares it with the experiences of second-year students regarding feedback. To this end, two questionnaires were administered: one with freshman engineering students to measure their expectations regarding study success and expected feedback and one with second-year engineering students to evaluate their first year feedback experience.

The results show that starting first-year engineering students are confident regarding their study success. This confidence is however higher than the observed first-year students success. Not surprisingly, first-year students have good intentions and believe that most academic activities are important for student success. When second-year students look back on their first year, their beliefs in the importance of these activities have strongly decreased, especially regarding the importance of preparing classes and following communication through email and the virtual learning environment. First-year students expect feedback regarding their academic performance and engagement. They expect that this feedback primarily focuses on the impact on their future study pathway rather than on comparison to peer students. Second-year students indicate that the amount of feedback they receive could be improved, but agree with the first-year students that comparative feedback is less important.

Conference Key Areas: Engineering Education Research, Attractiveness of Engineering Education, Gender and Diversity

Keywords: academic self-confidence, feedback, reasons for students success, student beliefs

1 GENERAL

The transition from secondary to higher education is challenging both from the academic and social perspective [1]. Students have to adapt their study and learning strategies to the new context of higher education, but , a priori it is often not clear for students how and to what extend they have to adapt. The social-comparison theory [2] states that people evaluate their abilities through comparison to others when they are lacking objective means of comparison. As students enter a new social group when starting in higher education, they lack a comparison framework, which induces uncertainty about their abilities.

This paper explores the self-reported confidence of starting first-year engineering students in being successful in the first study year of higher education. Additionally, the paper explores what students belief to be important study-related behaviours to obtain study success. Finally, as feedback is considered a powerful tool for improving student achievement [3], the paper explores what feedback students would like to receive during their first year in higher education.

Self-efficacy, or the expectation to be successful for a specific task, can be considered as a situation-specific self-confidence [4], as such academic self-confidence can be

viewed as self-efficacy in an academic context [5]. A person's self-confidence in the context of academic achievement is different from general self-confidence.
Earlier research showed that self-efficacy is significantly related to academic performance [6] but that the effect depends on the timing of the self-efficacy measurement [7] and might only be important for students with high intelligence [7]. The impact of students' academic self-confidence on student performance also exists for engineering students [5].
Feedback has been a proven powerful tool for improving student achievement, but its effectiveness depends on the type of feedback and the circumstances under which feedback is given [3]. During the transition from secondary to higher education this feedback is considered pivotal regarding student motivation, confidence, retention, and success [8], [9].

2 DATA COLLECTION AND METHODOLOGY

2.1 Data collection

In the academic year 2016-2017 data was collected from **first-year** engineering science students at three higher education institutes: KU Leuven, Delft University of Technology (TU Delft) and Graz (TU Graz). The survey contained 16 questions regarding confidence in and beliefs about first-year student success, expectations regarding feedback, and experiences regarding feedback in the transition from secondary to higher education. At KU Leuven a paper-and-pencil questionnaire (in Dutch) was administered in the first weeks of the academic year. TU Delft performed an online questionnaire (in Dutch) in the first weeks of the academic year, in which four of the 16 questions of the survey were included. TU Graz organized a paper-and-pencil questionnaire (in German) during the welcome days within the first study week.
2,127 students completed the questionnaire (KU Leuven n=409 from Engineering Science bachelor, TU Delft n=777 from 12 Bachelor of Science programs, all with a technological focus (e.g. Computer Science, Mathematics, etc.,) TU Graz n=941 from all Engineering Science bachelors).
In the academic year of 2016-2017 data was collected from **second-year** engineering science students at the KU Leuven using a Dutch paper-and-pencil questionnaire during a lecture in the first week of the academic year. The survey contained 41 questions regarding the activities and behaviours students believed to be important for first-year student success, and their experiences regarding feedback in the first year. 271 students completed the questionnaire.
The two questionnaires used a five-point Likert scale ranging from not at all typical, over not typical, somewhat typical, typical, to very typical.

2.2 Methodology

This paper uses descriptive statistics visualized using diverging stacked bar charts to present the survey results [10]. To assess the significance of the differences between the different institutes a two-step analysis was performed. First, a Kruskal-Wallis rank sum test was used to test the overall significance of differences between groups. Second, a pairwise Wilcoxon test was used to test the significance between different groups. For the pairwise Wilcoxon test a correction was used to accommodate for multiple testing [11].

3 RESULTS

3.1 Confidence in and beliefs about first-year student success

On the question "I feel very confident to successfully complete the first year.", 71% of the **first-year students** reply this is typical or very typical for them, while 7% of the students indicate this is not typical or not at all typical for them.
Fig. 1 shows the responses for the different institutes. The Kruskal-Wallis test indicated statistically significant differences between the responses on the survey question by the students in the different institutes (chi-squared=477.81, df=2, p-value < 2.2e-16).
The pairwise Wilcoxon-test showed significant differences between all three institutes.
The survey questions regarding the reasons for success was formulated as a main question "To be successful in the first year it is important that I will" with four subquestions: "study hard, attend classes, prepare classes, and meticulously follow the communication of teachers and faculty staff through email and the virtual learning environment.". Overall 93% of the students believe that studying hard is important for study success. For attending classes this is 91%, for preparing classes this is 80%, and for meticulously following the communication of teachers and faculty staff through email and the virtual learning environment this drops to 50%.

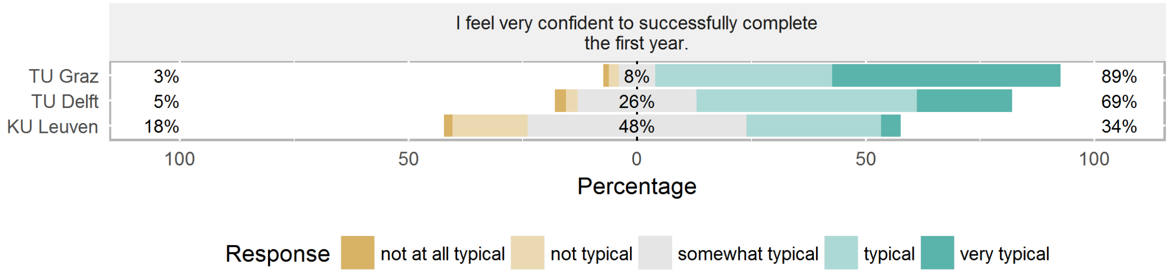

Fig. 1. Stacked boxplot for first-year student responses on "I feel very confident to successfully complete the first year." for different institutes.

The Kruskal-Wallis test indicated statistically significant differences between the responses in the different institutes on all above subquestions (Table 1).

Table 1. Table showing the statistically significant differences between institutes for on the first-year student responses regarding the question for reasons for study success. Institutes sharing a letter are not significantly different (Wilcoxon test, p-value threshold 0.05).

To be successful in the first year it is important that I will …	KU Leuven	TU Delft	TU Graz	Kruskal-Wallis
study hard	a	a	b	χ^2=17.9, df=2, p=1.31e-4
attend classes	a	b	c	χ^2=264, df=2, p < 2.2e-16
prepare classes	a	b	a	χ^2=331, df=2, p < 2.2e-16
meticulously follow the communication of teachers and faculty staff through email and the virtual learning environment.	a	-	b	χ^2=81.6, df=1, p < 2.2e-16

For all questioned reasons regarding activities underlying first-year success the differences between the institutes are significant. KU Leuven and TU Delft students believe "studying hard" is more essential than TU Graz students. KU Leuven students agree most that attending class is important for study success, with the TU Delft

students on the other end. KU Leuven and TU Graz students believe preparing classes is more important for study success than TU Delft students. Finally, KU Leuven students believe that following the communication through email and the virtual learning environment is more important for study success than TU Graz students (TU Delft students did not receive this question).
The survey questions regarding the activities and behaviours **second-year students** believe to be important for first-year student success was formulated as a main question "To be successful in the first year it was important in my opinion to " with seven subquestions: “use good study techniques, study hard, attend classes, prepare classes, meticulously follow student email, regularly checking the virtual learning environment for new messages and content, and feel well in my studies (academic well-being)”. Overall students agreed most that using good study techniques (82%), feeling well in the studies (76%) and studying hard (76%) was important (Fig. 2). Attending classes (45%) and regularly checking the virtual learning environment (38%) was considered important by less than half of the students. Preparing classes (22%) and meticulously following student email (15%) were considered least important.

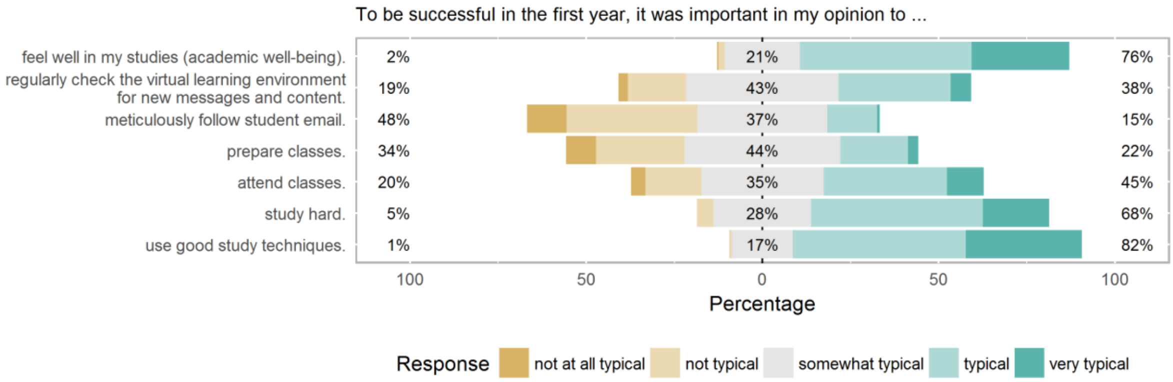

Fig. 2. Stacked boxplot for second-year student responses on possible reasons for first-year student success.

Discussion

Overall starting first-year engineering students are confident regarding their first-year student success. However, large differences exist between KU Leuven, TU Delft, and TU Graz. While cultural differences definitely impacts students’ answers, the different university contexts including admission requirements also impact student confidence. Surprisingly this confidence does not correlate with the percentage of successful students in the first year (drop-out bachelor around: KU Leuven: 42%, TU Delft 24%, TU Graz 60%). A small elaboration is needed to explain the higher confidence of TU Graz students, despite the high drop-out rate. 40% of the beginners at TU Graz are coming from dedicated colleges providing them with a prior knowledge in the specific field of studies. While these beginners have strong domain knowledge, experience shows that they are often not successful in higher education as the difference between secondary and higher education is quite big and is often underestimated by those beginners. Another effect is that a lot of Austrian students are recruited by companies before obtaining a bachelor degree, so these students are dropping out, while they might have been successful.
Not surprisingly, first-year students initially have good intentions and believe that most academic activities are important for first-year student success (while some initial doubt is already observed concerning the importance of preparing classes and meticulously following communication). When student look back on their first year their beliefs in the importance of these activities and behaviours have strongly decreased.

While studying hard is still considered important by most students, attending and preparing classes and meticulously following communications are not considered essential.

3.2 Feedback

When asked which feedback **first-year students** would like to receive during the first year 87% agrees they want to receive feedback on their academic performance and 69% agrees with feedback concerning their academic engagement and activities (Fig. 3). Very few students respond negative on these questions (3% and 7%). 79% of the first-year students want to receive feedback showing the expected impact of their current academic performance and behaviour on their future study pathway or study success (Fig. 4). The demand for comparative feedback (position with respect to fellow students) is lower (58%) and more student do not agree they want to receive such comparative feedback (19%).

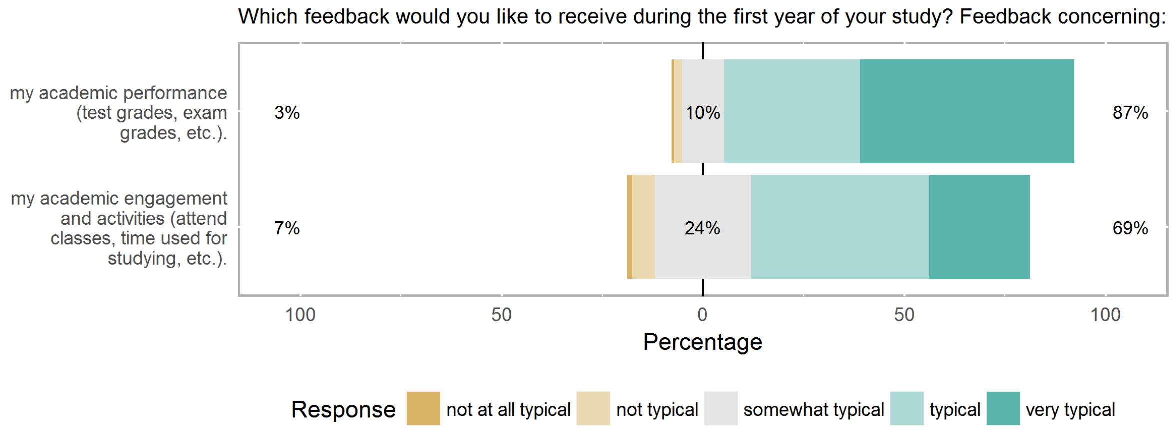

Fig. 3. Stacked boxplot for first-year student responses on expectations regarding topics of first-year feedback.

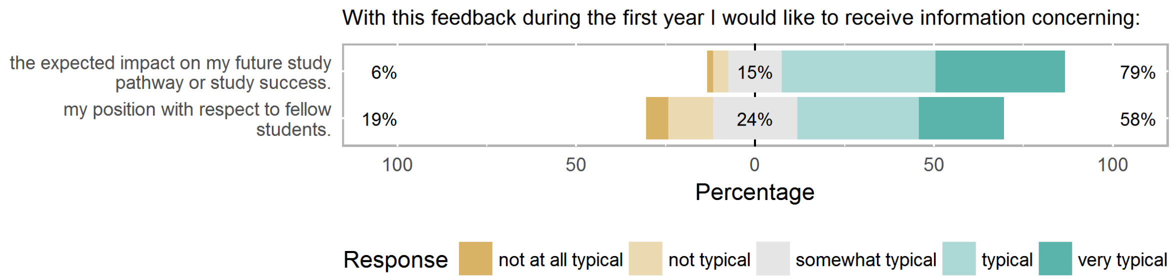

Fig. 4. Stacked boxplot for first-year student responses on expectations regarding content of first-year feedback.

When **second-year students** are asked whether they received sufficient feedback in their first year, 61% agrees for feedback regarding academic achievement, while only 38% agrees for feedback on study efforts, and even less 20% regarding feedback on academic well-being (Fig. 5).

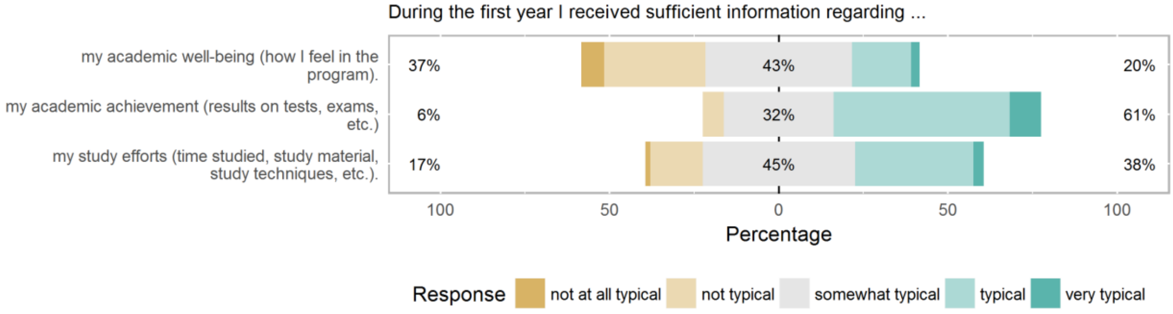

Fig. 5. Stacked boxplot for second-year student responses on experiences regarding content of first-year feedback.

When asked about the format of feedback 55% of second-year students agrees it showed the possible impact of their activities and achievements on their future study pathway way, few students (23%) agree it helped them to position themselves with respect to peer students (Fig. 6). On a positive note, students find the feedback useful (57%) and indicate that it made clear what was expected from them (54%), that it helped to make study-related decisions (44%), or even made them reflect on their studies (38%) or adapt their study behaviour (31%).

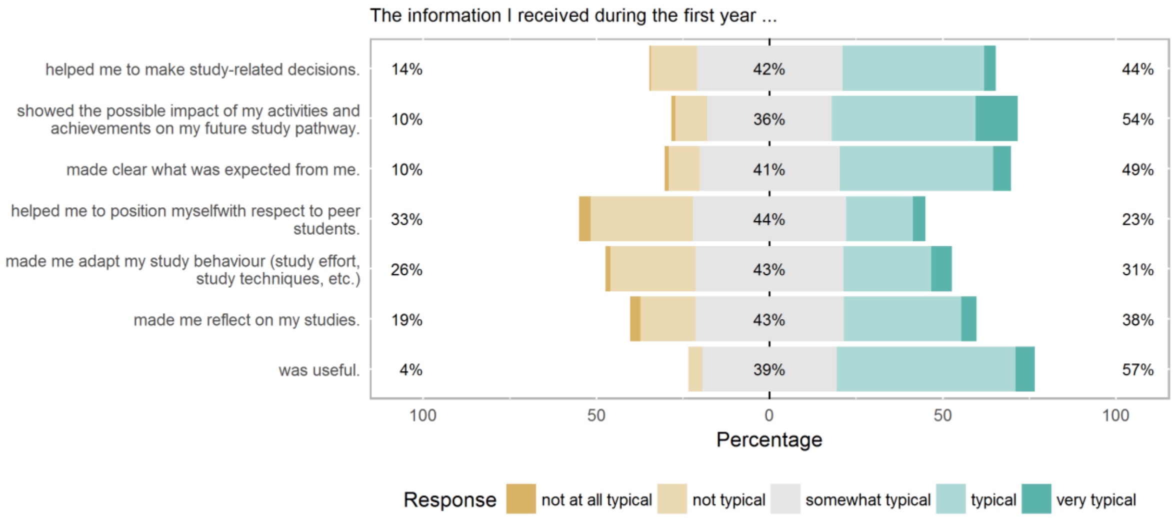

Fig. 6. Stacked boxplot for second-year student responses on experiences regarding format and effect of first-year feedback.

Discussion

A big difference exists regarding first-year student expectations on feedback and experiences of second-year students regarding the feedback they received during the first year. While 69% of the first-year students explicitly agreed they would like to receive feedback on their academic engagement only 38% of the second-year students agreed they received sufficient feedback on this topic. Similarly 79% of first-year students expect feedback on the impact on their future study pathway while 54% of second-year students agrees to have received such feedback sufficiently. Only 23% of the second-year students indicate that they could use the feedback to compare to peers (23%), but this was also believed to be less important by first-year students (58%).

4 CONCLUSION AND FUTURE WORK

The results show that starting first-year engineering students are confident regarding their success. This confidence is however higher than the observed first-year students success. Not surprisingly, the students have good intentions and believe that most academic activities are important for student success. When second-year student look back on their first year their beliefs in the importance of these activities and behaviours have strongly decreased, especially concerning the importance of preparing classes and following communication through email and the virtual learning environment. First-year students are expecting feedback regarding their academic performance and engagement. They expect that this feedback primarily focuses on the impact on their future study pathway rather than on comparison to peer students. Second-year students indicate that the amount of feedback could be improved, but agree with the first-year students that comparative feedback is less important.

With regards to future work, first of all, the results will be used to improve and shape feedback towards first-year students. Future feedback should rather focus on the impact on study pathway than on comparison to peers. Second-year students indicate the importance of academic well-being for student success. Therefore, this is another point of focus of feedback during the first-year. The results show that big differences exist between institutes, therefore feedback should always take into account the local context. As future work, the influence of gender and other background variables on the first-year experience will be studied. Finally, the obtained results will be used as a baseline measurement for studying the impact of newly designed feedback.

5 ACKNOWLEDGMENTS

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Addressing retention at an English-medium Engineering College:
A case study of Freshman students in the Middle East

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ABSTRACT

The low student retention rate in an English medium engineering college in the Middle East has been attributed to the students' lack of readiness in language and sciences, lack of motivation, and issues regarding adjusting to university life. To address this, a new freshman course called Introduction to Engineering, ENGR110 was introduced in 2015. The course, incorporated into the First Year Experience (FYE) program, was designed to introduce students to the different majors offered, soft skills such as team work, time management, goal setting, problem-solving, and to establish a learning community on campus. It includes hands-on activities, problem-solving sessions, seminars/workshops, field trips as well as presentations by alumni. A particular emphasis on having students make informed decisions early about their choice of major was seen as critical in getting students focused and motivated. This paper

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describes the impact that the course has had on student retention based on students' to two consecutive surveys.

Conference Key Areas: Engineering Skills, Curriculum Development, Attractiveness of Engineering Education

Keywords: first-year experience (FYE), retention, learner-centered teaching

INTRODUCTION

Success in student retention reflects the effectiveness of education students seek to acquire [1] and figures have implications on both the finances and the reputation of colleges and universities [1, 2]. Since the 1980's, in engineering colleges "difficulty of the subject and the mismatching of student and academic expectations, have resulted in higher dropout rates than for many other subjects" [3]. Providing students with additional support and applying teaching strategies in the first year of engineering are solutions provided by engineering colleges, as traditionally taught courses have been criticised for being overly academic and not providing enough knowledge of engineering as a career [1]. In the Arabian Gulf region where the current study has been initiated, the higher education (HE) system was primarily established in the 1990's and early 2000's.

Due to the relatively young age of the system, attention to student retention has thus become of more relevance in recent years. Also, there is evidence of students frequently requesting to change majors during their course, often multiple times. According to Freedman [4] this is not uncommon, but high rates result in a considerable waste of resources and time, for faculty, students and institution. This paper describes the initial phase of a longitudinal study on the effects of a new, introductory course Introduction to Engineering (ENGR110), which aims at both decreasing the rate of changes in majors and at improving student retention. The course was implemented for a cohort of approximately 150 female and 60 male first-year undergraduate students. The course outcomes were then evaluated via two student surveys and through the assessment of Student Learning Outcomes (SLO's).

1 MAIN FACTORS AFFECTING STUDENT RETENTION

The two principal aspects affecting student retention are the students' approaches to HE and approaches implemented by HE institutes to improve retention. Students' approaches to HE are affected by their school experiences, their family background, by the way in which education is viewed in their culture and by the students' prior knowledge regarding HE [5, 6]. A review of the literature pertaining specifically to engineering students' retention [1, 2, 6, 7, 8, 9] showed that engineering colleges and institutes of HE have attempted to responded to the students' needs mentioned above. According to the research, the following five approaches are the most common ones intended to improve retention; high entry criteria [1, 2], providing support mechanisms, including helping students to improve their study skills, instructor and peer mentoring and advising, as well as "preparation, transition programming [and] first year experience (FYE) programming," [2 p.2].

Another way is to keep students in cohorts throughout their freshman year [7]. Activities which students appreciated, according to Willis [6], were interactive learning experiences, including field trips, laboratory work, site visits and design projects, as well as work placement, which help students to adjust and integrate into HE. These involve active learning and group work, important motivators to engineering students [7]. Such active learning and problem-based learning (PBL) methods also promote the general criteria for learning outcomes provided by the Accreditation Board of Engineering and Technology (ABET) [10]. Furthermore, actual first year engineering courses help students to "feel more confident in their engineering skills and more deeply integrated into their engineering careers and therefore more likely to remain in engineering," [1 p.10].

1.1 Retention issues pertinent to the current study

In the current study, which took place in the United Arab Emirates (UAE), some young men and women face specific hurdles in secondary and higher education. These include parental disinterest, poor academic preparation for higher education [11], poor English language skills obtained at school and a lack of career counselling in high school [12]. Over 70% of students in HE in the UAE are women [12], perhaps because they are already performing better than male students in secondary education [13], as well as at tertiary level [14].

Moreover, males have the advantage of joining the military, police or government jobs as alternatives to pursuing higher education [12]. The engineering college where the current takes place is sponsored by a major Emirati oil company, and its international partners and all undergraduate students have signed an agreement to work for the company. Therefore, students are guaranteed a job on entry to HE. Currently, 1547 undergraduate and 650 graduate students are enrolled at the college.

1.2 Existing support system: The first year experience

The First Year Experience (FYE) was designed to help students transition into university life, enhance their participation in student life, boost academic performance, and, increase student retention rates. The program centres on three S's: success, skills, and socialising, all providing a supportive and structured environment in the first year at college. Activities include new student orientation, developmental/college success courses, student academic advising/mentoring, peer-mentoring, workshops [9], student experience enhancing activities [8], academic trips [15] and FYE Graduation.

Students are formed into living/learning communities in which they take the same classes [7] and are assigned their own FYE advisor who meets with advisees regularly. In the student dormitory, the communities are assigned to one floor with an upper-level student serving as their resident assistant. In 2016 a new course called ENGR110 was introduced to further assist students in their transition to college.

1.3 An overview of the ENGR110 course

ENGR110 is a first-year course designed to help first-semester engineering students decide which major within the college is best for them, and prepare them for success at the college and beyond by teaching them important skills including engineering problem solving, ethical decision-making, and teamwork using active learning methods. This course enables students to gain a broad understanding and appreciation of the engineering profession, to become members of a learning community, and to become practised at the pathways to academic success in engineering studies.

The ENGR110 curriculum also incorporates structured departmental visits at all the engineering disciplines offered by the College of Engineering. These visits include a short introductory lecture followed by laboratory tours and hands-on activities to provide the students with practical examples of what they could expect should they decide to pursue that particular major. Additionally, each department provides alumni to speak to interested students and to answer questions and concerns.

The learning outcomes for the course include:

(1) a basic understanding of engineering problem-solving process and skills;
(2) a broad understanding of the impacts of engineering and the petroleum industry in a global and societal context;
(3) effective communication through reading, writing, listening and speaking;
(4) encourage students to make an early and informed choice of major; and
(5) an awareness of, and engagement in, independent study and life-long learning.

2 METHODOLOGY

Two surveys were conducted as part of this study. The first one (N=183) was a general questionnaire, with the aim of collecting background information about students' choices regarding majors, as well as contextual data on the students' soft-skills, including time management, setting academic goals, team-working skills, use of campus resources, and motivation for studying engineering. A follow-up survey was conducted on the same cohort five months later (N=153) to evaluate any variances in choices of majors and soft-skill improvements. Some specific questions from the first survey were discreetly repeated as part of the follow-up survey to equate results. The results of the course outcomes assessment done at the end of the course are also included.

3 RESULTS AND DISCUSSION

Historically it has been found that approximately 30% of students attending the engineering college where the current study takes place formally changed their engineering major at least once during their studies. Figure 1 shows that in 2012 almost a quarter of the students changed their major. By 2015 this figure increased to almost one-third of the student body with little sign of any improvement in the situation.

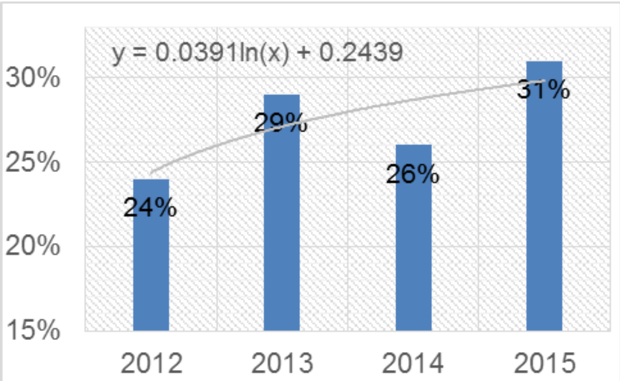

Fig. 1. Students who changed their major after three semesters (Source: Office of the Registrar, PI)

Anecdotal evidence reveals that the most common reason was due to the student's limited knowledge of the true nature and the academic requirements needed in their chosen engineering major [6]. They had very likely made their initial choices mainly based on the advice, or pressure from an 'influencer' in their lives, be that a relative, friend or teacher. Addressing this issue, as well as the problem of student retention was the main driver for introducing the ENGR110 course described above.

3.1 Choosing a major

The authors are of the opinion that a lack-of-knowledge [6], lack-of-(soft)skills [9, 15], and/or lack-of-belonging within a specific discipline [2] may be contributing factors for switching majors (or even drop out) at a later stage. It appears that the data from the survey (Figure 2) support this, as double the amount of students (13.7%) queried their original decision compared to only 6.7% prior to starting the course. This notion of uncertainty is viewed as a significant positive, suggesting that introducing the students to the different engineering disciplines as part of their first-year experience might indeed result in making major-switching decisions during this period, instead of at a later date.

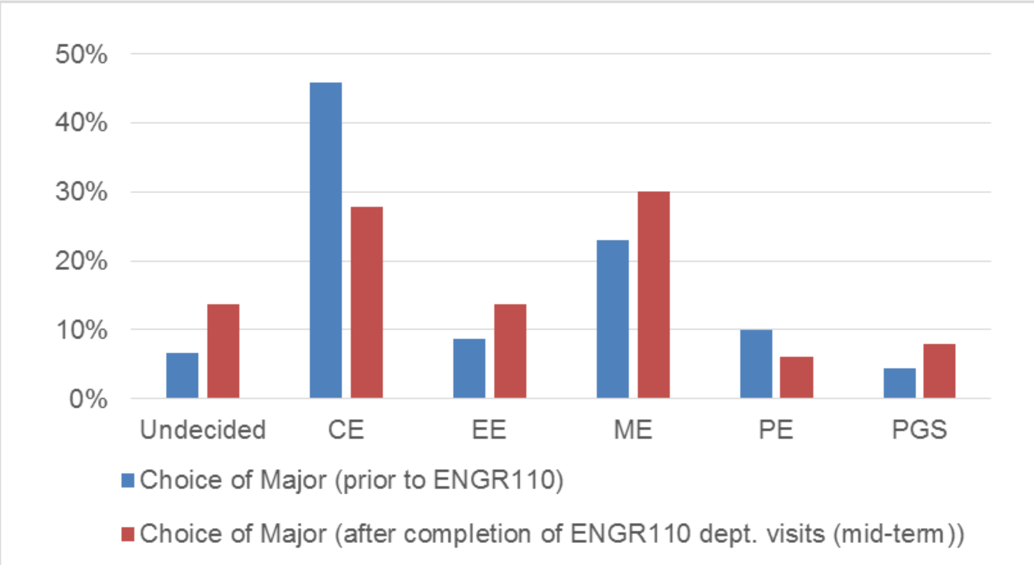

Fig. 2. Choice of majors prior to ENGR110 vs. choice of majors after introducing students to the different engineering disciplines (CE denotes Chemical; EE: Electrical; ME: Mechanical; PE: Petroleum and PGS: Petroleum Geosciences)

As the ENGR110 course is designed with hands-on engineering problem-solving skills, it aims to show students how technical problem-solving applies in practice. It also lets them demonstrate it through activities. It is essential that students develop the ability to identify with their specific engineering discipline at an early stage to secure a sense that they belong to that undergraduate peer group, a key ingredient of retention. It is why we also consider that the introduction to the Engineering disciplines plays an integral part in the efficacious declaration of their majors.

3.2 Course elements assisting in learning

Figure 3 below shows the student responses of the different course elements/activities that they felt assisted them most in their ENGR110 learning experience. It is evident that students consider the Introduction to Engineering disciplines (including the departmental visits) as most helpful, where most students (94%) ‘agree’ or ‘strongly agree’ with the concept, as this is most likely to assist them in their choice of majors, as discussed above. It is followed by field trips (75%), the studio/LAB sessions (71%), course lectures (68%) and lastly teamwork and class discussions (68%).

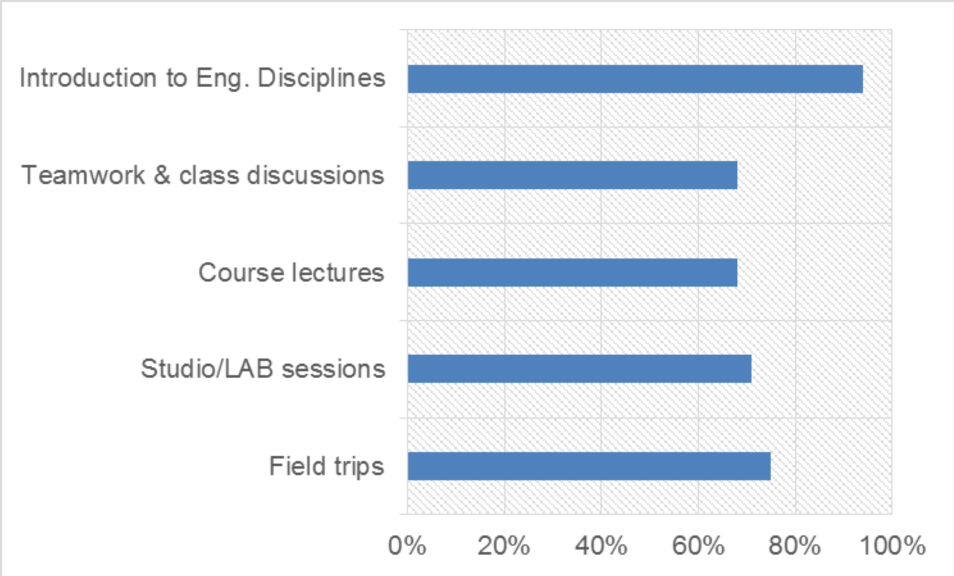

Fig. 3. Course elements/activities that students *agreed* or *strongly agreed* assisted most in ENGR110

Compulsory field trips in the curriculum for ENGR110 are intended to provide for more ‘student centred’ and ‘active learning’ activities and also to provide students with a realistic industry-related experience that is external to the classroom and university campus. Through direct experiential learning, it is hoped that the students will begin to ‘feel’ and ‘think’ like engineers and that they will observe that the topics and issues that are discussed in the classroom are also being applied and addressed in the professional world.

As an example, the initial group of ENGR110 students spent a full day at an oil industry conference and exhibition, one of the largest held annually in the world. They were assigned into small teams prior to the trip and were tasked on the day with taking a journalistic approach to the visit by interviewing many of the representative companies in the exhibition to gauge a feeling for “where the jobs are, and what are the desired skills for graduates today and in the future”. Assessment of the exercise required that each team later discuss and compare the results of their interviews and to submit a report summarising the main points while highlighting any emerging trends, similarities and anomalies between companies that they picked up on. Other field trips planned for the course includes visits to various engineering company’s manufacturing centres, research lab’s and technical offices in the area. Field trips form an essential element in the overall course objectives by reinforcing for students the themes of the course learning outcomes listed above.

3.3 Review of skills gained at the end of the course

The follow-up survey, five months later, was done to determine the effectiveness and longevity of FYE/ENGR110 programs and activities. Figure 4 below shows the results. It is evident from Figure 4 that students continued to reflect well on the personal and study skills gained, with very similar responses for key skills as when first surveyed at the start of the ENGR110 course.

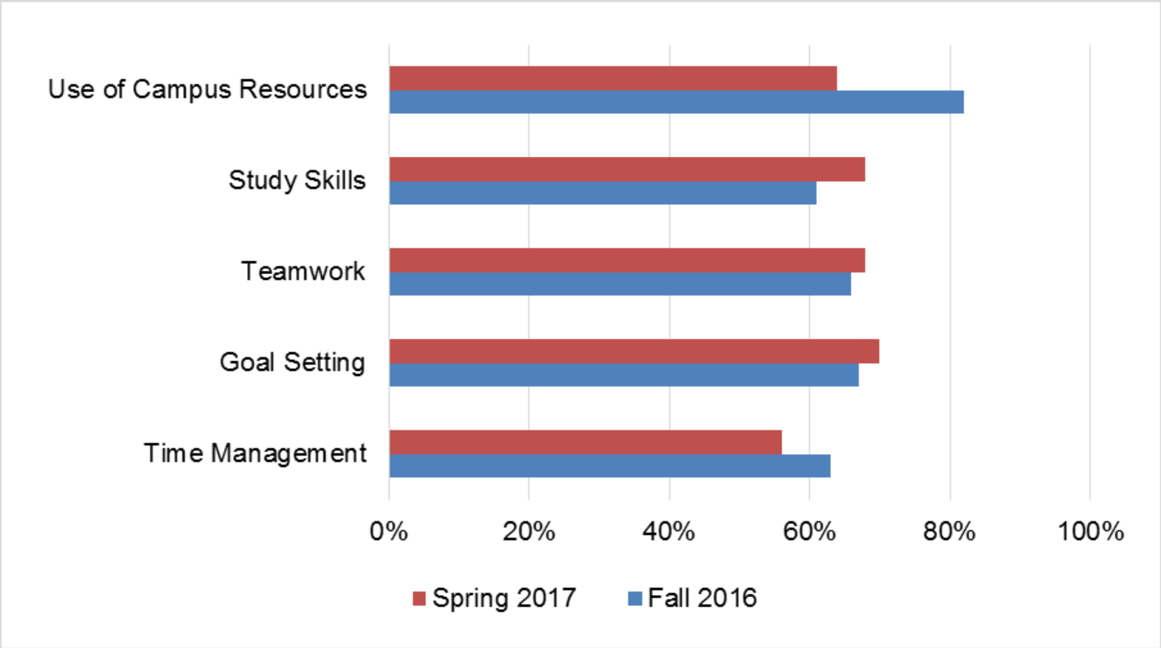

Fig. 4. A comparison of responses at the start and the end of the course about usefulness of skills gained

3.4 Assessment of course outcomes

A standard survey regarding the success of the course outcomes showed that the instruction and assessment methods overall have been effective. However, the lowest achievement level was scored for the second Performance Indicator. This may indicate that the time that students spend on their individual department visits might not be adequate. One suggested improvement for this SLO might be the inclusion of an additional assignment relating to each of the engineering majors, instead of just using a short-answer or multiple-choice quiz.

4 CONCLUSION

Even with an improved and a more tailored course (e.g. ENGR110), careful attention needs to be paid early on to those students with an inability to identify with a specific engineering discipline. Despite evidence of a value-added curriculum (including academic advising), more can be done to enhance the undergraduate engineering experience in ways to ensure that students make informed and confident selections of majors early on in their course so that major-switching decisions occur during the first semester, rather than a few semesters down the line. The findings of this study must be considered as preliminary, and we recommend that the cohort is surveyed after each academic semester to confirm the effectiveness of the First Year Experience program and the ENGR110 course.

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Evaluating the flipped classroom approach in engineering education:

Students' attitudes, engagement and performance in an undergraduate sustainability course

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ABSTRACT

This paper describes the implementation and evaluation of the flipped classroom approach in a sustainability course for undergraduate engineering students. Using a mixed methods approach, the evaluation focused on student engagement, performance as well as students' attitudes and beliefs about the flipped classroom. A novel aspect of this work compared to previous studies on the flipped classroom is the tracking of student attitudes and engagement during the course. The results indicate that while student attitudes grew more neutral during the middle of the course, student engagement as well as performance on the final written exam increased significantly compared to previous years. Pedagogical implications for instructors wanting to implement the flipped classroom approach are briefly discussed.

Conference Key Areas: Open and Online Engineering Education; Sustainability and Engineering Education; Engineering Education Research

Keywords: flipped classroom, attitudes, engagement, performance

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INTRODUCTION

It is often argued that teacher-centered approaches, particularly the sole reliance on lectures, give students insufficient opportunity to actively engage in learning activities and reflect on their progress and performance [1]. ICT is increasingly being used in higher education to activate students and move to a more student-centered approach to teaching. One approach that is becoming increasingly popular is *blended learning* [2], which utilizes multimedia in face-to-face and online teaching [3].

As a particular form of blended learning, the *flipped classroom* approach [4] has received substantial attention in recent years. The basic idea of the flipped classroom is that students prepare before class using, for example, video lectures and online quizzes, and are engaged in individual or group-based activities in the classroom. Studies show that the flipped classroom can increase student creativity and facilitate the development of higher-order thinking skills [5]. Moreover, there is emerging evidence of improved student learning compared to traditional teaching [6]. This is in line with previous research, showing that active learning generally increases student performance [7]. However, "flipping" a course requires a change from a *transmission* view to a *constructivist* view on teaching and learning, and it often requires a substantial time investment [3]. Non-traditional teaching methods may involve challenges for the teacher, such as how to support student learning in a format that is new to them and how to face students who may be reluctant to actively engage in class.

This paper contributes to the growing body of research on flipped classroom by describing the implementation and evaluation of the flipped classroom approach in a sustainability course for undergraduate engineering students. A novel aspect of this work compared to previous studies on the flipped classroom is the tracking of student attitudes and engagement during the course. More specifically, the following research questions are addressed in this paper:

1. What attitudes towards and beliefs about the flipped classroom do students have and how do these change during the course?
2. Does flipping a course increase student engagement?
3. Does flipping a course increase student performance?

Consequently, this work should be of interest to teachers who are considering flipping their courses.

1. BACKGROUND AND OVERVIEW OF COURSE REDESIGN

The course studied here, a course on mathematical modelling of environmental issues (7.5 ECTS), is offered to third-year engineering students and about 40 students enroll in this course each year. Prior to the course reform, the course suffered from low attendance (around 30%) and low passing rates (around 60%), which was thought to be related to strong competition from the final half of the bachelor's thesis course which is given in parallel to the studied course.

To improve student engagement and performance, about half of the course activities were flipped (11 of the 18 lectures). Since the flipped classroom has previously been shown to be popular among students [6], the implementation of this blended learning format was seen as a way to better compete for the students' attention.The course also consisted of six computer exercises which were adjusted in the course reform by adding reflective discussions about the assignments, to better align with the overall active learning approach. Another change made was that a bonus-point system was introduced to increase engagement. In order for students to give the new teaching format a fair chance, the flipped sessions were made semi-mandatory, where students had to take part in at least eight out of the total eleven sessions. The flipped sessions were designed as follows.

1.1 Pre-class activities

As preparation for the seminars, the students were asked to follow an online "learning sequence" consisting of a combination of videos, texts, quizzes and discussions. On average the learning sequences were assumed to take 1 hour. The learning sequences were made available in the online platform EdX Edge [8]. The videos introduced key concepts, the quizzes were used in order for students to test whether they had understood the key concepts. Occasional open-ended questions and discussion forums were used in order to provide the teachers with various input from the students and for the students to see how other students reason.

1.2 In-class activities

In class, a brief repetition of the key concepts was given. The rest of the time was spent on exercises and discussions to help the students acquire a deeper understanding and develop skills according to the intended learning outcomes. During group exercises the students typically worked for 15-25 minutes on a task or small set of tasks in groups of 2-4 in which they applied and explored the concepts and content knowledge introduced in the preparatory material. Activities were usually wrapped up by inviting students to share their thoughts with the rest of the class.

2. STUDY DESIGN

To evaluate the flipped classroom approach, a mixed methods approach was used. Data was collected through surveys, observations and interviews, both during and after the course (including some data from previous years course versions).

Students' attitudes towards and beliefs about the flipped classroom (RQ 1) were probed using three surveys. The first survey was answered by 32 out of 37 students, while the second and third surveys had 26 and 22 respondents respectively. The surveys were distributed during the first and the fifth week of the course, as well as after the course, to capture the change in attitudes during and after their experience of the course. The decrease in respondents where expected as the attendance is always highest at the course start and completion of course evaluation surveys seldom get high completion rates. In addition to these surveys, ten semi-structured interviews were conducted with volunteering students (convenience sampling). During these interviews the students were asked questions to clarify the reason for their attitude to some of the course components and the flipped classroom format.

Student engagement (RQ 2) was measured in four ways. Firstly, attendance was taken at the course sessions. Secondly, data was collected using the online learning platform on students' preparation before the seminars. Thirdly, teachers were asked about the students' engagement in the course sessions. Fourthly, an estimate of the fraction of in class time with active student engagement was made by the teachers. All of the measures except the second were compared with observations and estimates from previous years.

Student performance (RQ 3) was assessed by collecting the students' grades on the exam. This data was compared with the grades from previous years.

3. RESULTS

The results are structured following the three main questions of the study.

3.1 Student attitudes and beliefs about the flipped classroom

Only 1 in 32 students reported having previous experience of the flipped classroom. In the initial survey (first week of class), the students were positive with an average value of 3.8 out of 5 (see Figure 1). In the second survey (middle of course), students answered, on average, that they were more neutral towards the flipped classroom (3.4 out of 5). However the fraction of students that reported that they were very positive increased (see Figure 1). The distribution of answers suggests a certain divide between a group of students who were very positive towards the format and the majority of the class which seemed to be normally distributed around the neutral attitude alternative. In the third survey (not shown in the figure), after the course, the students were asked a slightly different question: ”When the flipped classroom format worked at its best in the course, what was your attitude towards the format then?”. The answers to this question showed a clearly positive attitude towards the format when it worked well, averaging 3.73 with a median value of 4.

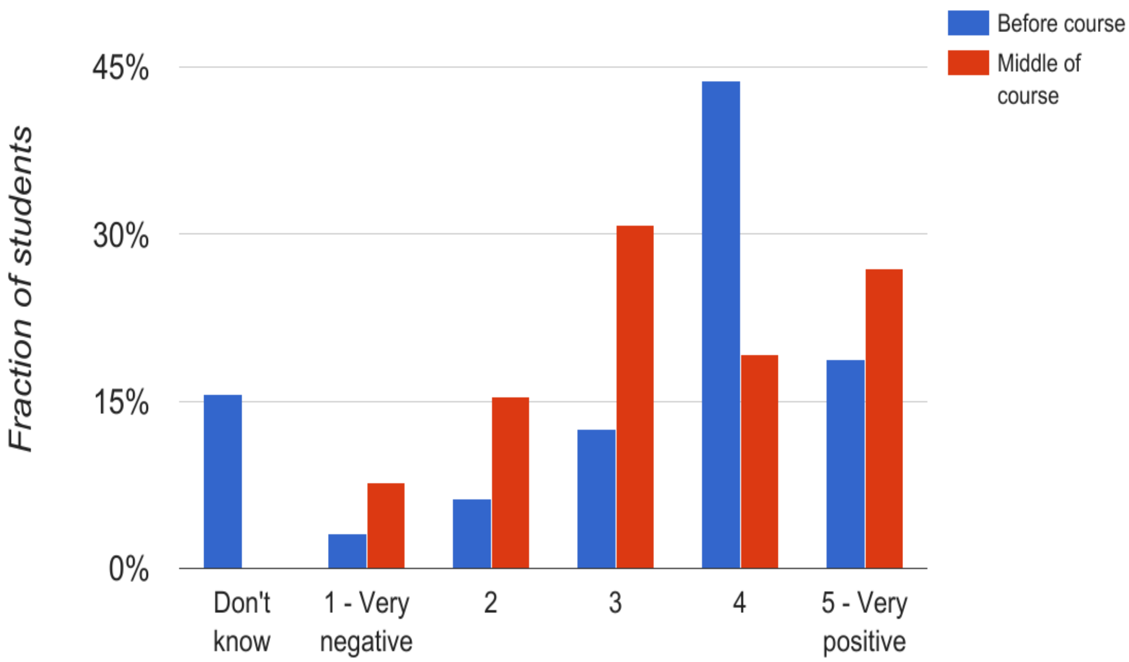

Fig. 1. Attitudes before and in the middle of the course. The question answered was “What is your attitude towards using the flipped classroom in this course?”.

Students' perceptions of their relative learning from using the two main components of the flipped classroom format, the videos and collaborative learning activities in class, in contrast to traditional lectures, was studied in the second and third survey. Figure 2 shows the answers to a question regarding whether the students perceived that they learned better by actively participating as opposed to passive listening. The answer to a similar question regarding whether the students learned better by watching videos instead of attending lectures gave similar results. Both of these questions had answers that were fairly inconclusive but there seems to exist an opinion that favors active participation over passive in the classroom sessions. The slightly positive view on active participation and on utilizing videos was more evident from the answers to the survey distributed after the course, when it got an average of 3.5 with more students answering that the learning was "much better".

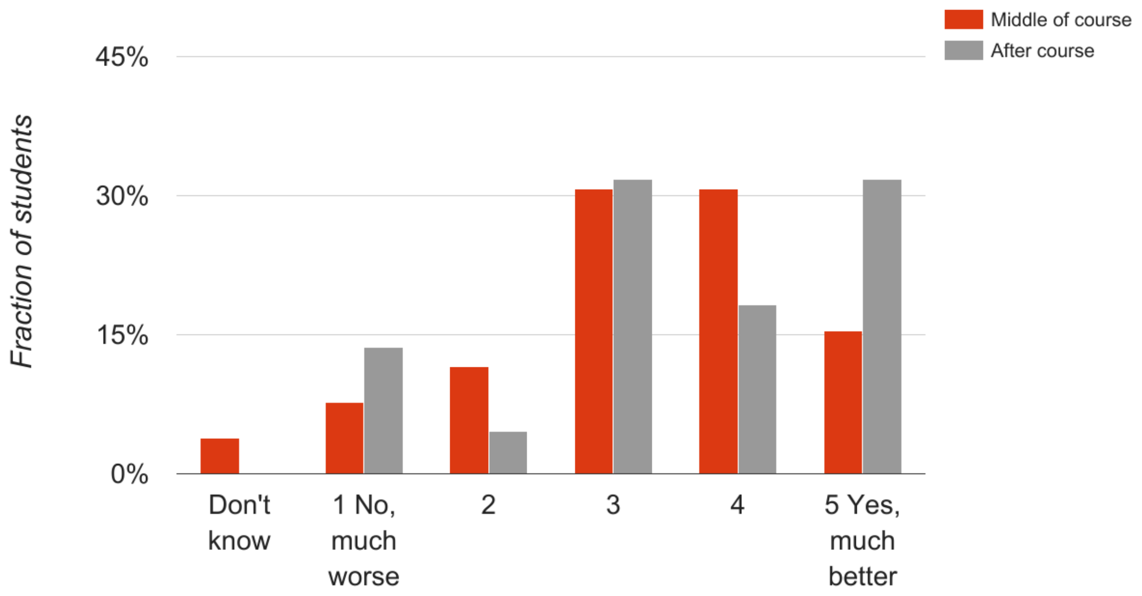

Fig. 2. Attitudes to learning effectiveness in the middle of and after the course. The question answered is "Based on yourself, do you believe active participation is a better way of learning during a lecture rather than (only) listening?".

The Interviews and answers to open questions in the survey during week 5 indicate that students perceived that the flipped classroom format was suitable for this sustainability course (for example in discussing different perspectives, which is typical for the sustainability discourse) and that it supported their learning. As an example, one student answered: "*I have an easier time appreciating material if I get to take part in discussing it and it feels like this is a course that actually can use the flipped classroom".*

It became clear, however, that the students felt that the preparatory material was more rewarding than the seminars. Being able to access preparatory material in video format and using quizzes for automatic feedback was appreciated, however students did not appreciate in-class sessions as much. For example, students stated being uneasy with having to share their thoughts and answers in front of the whole class, and others felt the difficulty level of the seminars was too low. As an example, one students commented on the seminars: *"Remake them* [the seminars] *so that one learns new things, building on the preparatory material, not only repeating them"*.

3.2 Student engagement

On average, student in-class participation doubled in comparison with estimates from previous years (except for the first two weeks which have had high attendance in earlier years as well). This can partly be accredited to the inclusion of semi-mandatory sessions. However, the attendance for all sessions increased dramatically, including all non-mandatory sessions, particularly the computer lab sessions. Both teacher observations and student interviews described the student participation in the seminars to be highly active during the regular smaller group exercises but notably passive in whole class-exercises or during units of lecturing. A couple of students remarked on the positive aspect of getting to know your classmates due to the use of the flipped classroom. When asked to compare with previous years, the teachers experienced the students' engagement to be markedly higher. The course team estimated that the students were active during 75% of the seminar class time and that the degree of preparation before class was increased substantially compared to previous years. Logs from the digital learning platform showed that the majority of the students had looked at the preparatory material before class. The students assessed the course workload to be higher: 3.6 (scale: 1- "too low" 5- "too high") relative to on average 2.8 the two years prior to this.

3.3 Student performance

Student grades on the final exam in 2016, i.e. after flipping the course, were used as an overall assessment of student performance, and student grades on the final exam for 2013-2016 are shown in Figure 3.

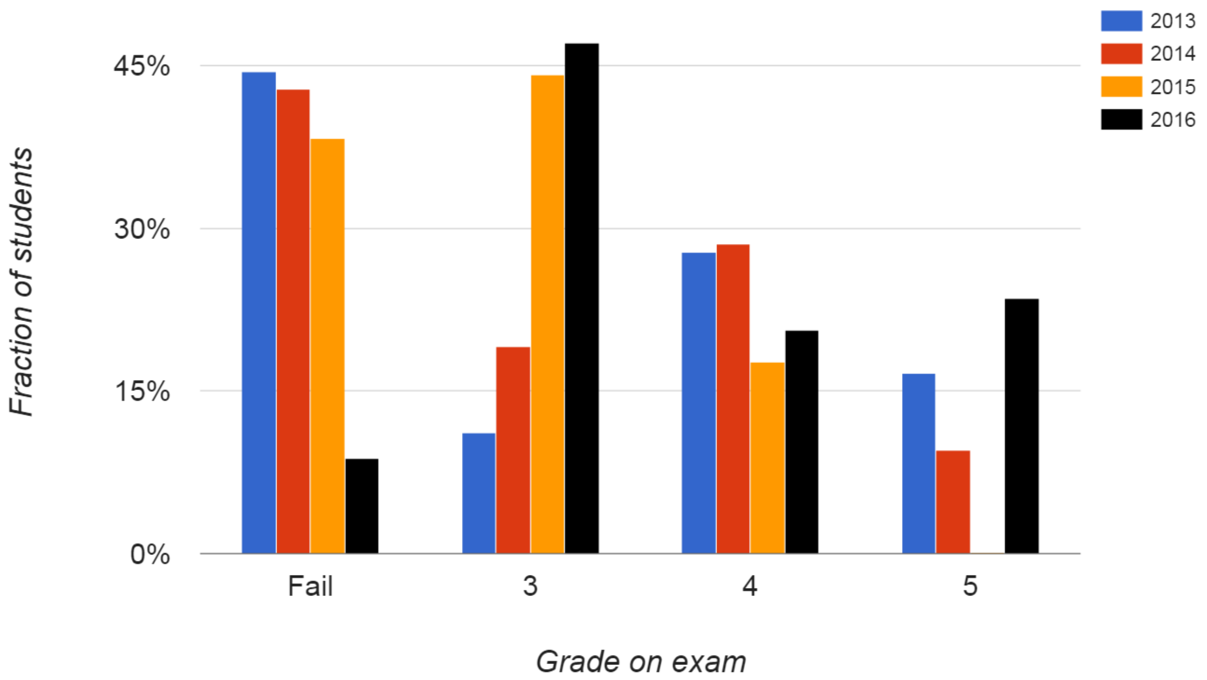

Fig. 3. Grades on the final exam in the time period 2013 to 2016. The total number of students taking the main exam these years were 18, 21, 34 and 34 respectively.

The fraction of students passing the main exam (with grades 3-5) increased from about 60% to more than 90%, for those who took the main exam. The highest grade was also achieved much more frequently, from on average 7% to 24%.

4. DISCUSSION AND CONCLUSIONS

The results regarding student attitudes towards the flipped classroom are in line with previous research, showing that the flipped classroom is appreciated by students [6]. An interesting finding was that student attitudes towards the flipped classroom changed during the course. In the first survey, students were positive towards the introduction of the flipped classroom, which changed to a more neutral stance in the middle, but after the course the attitudes were again positive. An aspect that influenced the students, and most likely their perception of the flipped classroom, was that the course ran in parallel with the second half of the bachelor's thesis course. How this parallel course influences the results should be investigated in a follow-up study.

Relative to previous years, student engagement was significantly higher according to the four different measures studied. A doubling in attendance for most sessions, more class hours spent on active learning and more student preparation before, and participation during, seminars clearly indicate a higher student engagement and effort. The student course evaluation survey also confirmed a higher perceived work load. Besides the introduction of the flipped classroom format the newly introduced bonus-point system in which students were rewarded for doing well on the assignments and presentations, may also have affected the student engagement.

Potentially related to increased engagement during the course, student performance on the final exam also increased significantly. It is difficult from one study to accredit this to the flipped classroom format in itself; however, it seems possible to conclude that the format is suitable for the course studied, as a facilitator of active learning and student engagement. Apart from the exam grades, further analysis of student examination could delve deeper into whether the introduction of the flipped classroom affected student performance in other aspects.

It takes time to adapt teaching to the flipped classroom format and to get comfortable in the new role as a teacher. For example, the seminars suffered from some deficiencies regarding the level of difficulty, and were criticized by many students. This will be fine-tuned for the second iteration of the reformed course and discussions on what learning is and what course activities which promote what type of learning will be introduced. In order to evaluate the flipped classroom format further, we believe it should be evaluated when it has been thoroughly established in a "typical course" placed with an "average timing" in the program.

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How to foster a High-Tech entrepreneurial mind-set – A multidisciplinary engineering course for Bachelor students

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ABSTRACT

It is becoming clearer that the era of digitalisation is reshaping many of the circumstances in world today in a high pace. In order to prepare the graduates in engineering for a future in a labour market which is hard to predict the content and the core competences engineering students develop during their education need to be reconsidered to meet new requests. Today there is a growing interest to develop entrepreneurial competences among students. This paper describes the Bachelor of Science in engineering course “High-Tech Entrepreneurship” developed within an external funded project at the Technical University of Denmark, Copenhagen. The course aims to foster an entrepreneurial mind-set among the students and a deeper understanding of high-technological start-ups. It’s a 5 ECTS course which is open to students from all engineering programmes. In order to measure the students’ progression towards an entrepreneurial mind-set the questionnaire “Entrepreneurial Mind-Set Assessment” is used. The questionnaire consists of 28 statement and the students rate themselves in the beginning of the course and in the end of the course. The results from two cohorts of students, indicates that the course design fulfil its purpose to enhance an entrepreneurial mind-set among the students.

Conference Key Areas: Curriculum development, Skills and Engineering Education, Attractiveness of Engineering Education

Keywords: Entrepreneurial minds-set, multidisciplinary teams, preparing professionals

INTRODUCTION

Engineering Education needs to provide students with a broad mind-set including both a solid foundation of disciplinary knowledge as well as a set of general skills in order to prepare them for their future professional working life as engineers [1]. Here, they will be increasingly met with demands toward atomisation, as well as needs for new technological and sustainable solutions, in terms of not only effective technology but also environmental issues and human development and welfare. In order to prepare the students to be more flexible on the labour market, innovation and entrepreneurship is regarded as some of the new key competences among academics. One example is the work of World Economic Forum which indicates that the fourth industrial revolution will create new conditions for labour in a near future [2]. Graduates from university must in the future to a higher extent be able to take initiative in co-creating work opportunities for themselves and for others, and this in cooperation with colleagues, maybe from other disciplines. They need to learn entrepreneurship in the broader sense which includes an idea and opportunity seeking mindset [3]. At the Technical University of Denmark (DTU), there is a growing awareness about this societal development. In parallel with this, a more systematic approach evolves about the importance of develop a set of general competences among the students that will be necessary for them in order to be well prepared for their future as professional engineers. Competences like learn to learn, information literacy, ethics, design thinking, and entrepreneurship, slowly but steady find its way into the curriculum of the education programmes at DTU. In addition, the physical learning environment are under reconstruction to meet a new way of teaching characterised of digitalised methods, active learning and innovation. The start of DTU Skylab, a student hub for innovation, contributed to enhance the student activities at DTU towards innovation and entrepreneurship. Due to the establishment of DTU Skylab a concrete place exists where students can work on develop their own ideas, building prototypes in professional workshops and gain support if they want to take their ideas further and start their own business. In 2016, DTU Skylab estimated 44 student start-ups. Through different activities for educators at DTU, they get the opportunity to be brought in contact with DTU Skylab. Some educators get inspiration to make the transition from auditory to laboratory in their way of teach. Within an external project funded by The Danish Industry-Foundation [4] and by the lead of DTU Skylab the course “High-Tech Innovation” was developed. The project aimed to promote a growth mind-set among DTU students. The course described in this paper was the work-package 2 in the project. The course was developed in cooperation between different departments at DTU involving educators and relevant staff members from DTU administration.

1 TRAING BACHELOR OF SCIENCE IN ENGINEERING STUDENTS IN “HIGH-TECH INNOVATION”

The course “High-Tech Innovation” has a novel design in order to foster an entrepreneurial mind-set among the students, paired with a deeper understanding for the processes involved in high-technological start-ups, which often demand involvement and collaboration. It’s a 5 ECTS course which spans over a three-week full time study period and is open to students from all education programmes, giving a multidisciplinary engineering approach.

1.1 Overall aims and central elements in the course

The aims of the course have a much wider perspective than inspire students to start their own businesses. The students should also be able to create own technological ideas during the course and understand the perquisites for grow of high technological ideas into products or solutions. The students learn about the mechanisms underlying growth and upscaling.

A very important underlying idea in the course is to bring metacognitive knowledge to students about what it means to be an entrepreneurial person and how to use an entrepreneurial mind-set in a wider sense. Metacognitive knowledge refers to knowledge about general strategies, in which tasks and when and how to use them, their effectiveness and also to know oneself and develop a greater awareness of personal strengths and weaknesses [5]. In this case the metacognitive level includes preparing the students for what can be waiting when they as engineers wish to promote development and idea generation in a technological content.

Central elements in the course are i) self-efficacy in a multidisciplinary undertaking ii) capture the bachelor students’ spark to become engineers with the ability for idea generation and creative solutions; and iii) prerequisites for innovation and business growth in a high-technological context. According to the work of Bandura the most central for people to be able to develop, learn and fulfil their potential is their own believes about their capabilities to have control over own actions and the circumstance that effects their lives [6]. That’s the reason why self-efficacy is a central element in this course and the overall aim in the work with the students following “High-tech Entrepreneurship”. Self-efficacy can be supposed to play a central role to unleash entrepreneurial potential [7]. Another study has showed that specifically formal learning in courses and learning from successful role-models are factors that enhance entrepreneurial self-efficacy [8].

1.2 Course Design

The key teaching methods in the course are meetings between experienced high-technological entrepreneurs and the bachelor students in sessions with a narrative approach to teaching [9] and the students' own high-tech idea generation and idea growth process. The narrative teaching approach is overall method in the course. It is not 'just' the experienced entrepreneurs that deliver narratives but the students also develop their ideas by a succession of narratives in the format of continuous pitches as a method for formative assessment. The intension is that this forms a basis from which the students can develop entrepreneurial self-efficacy [8].

The students' learning process in this course is designed following the "Double Diamond" design-model [10]. The model is building on the four phases i) discover (divergent process), ii) define (convergent process), iii) develop (divergent process) and iv) deliver (convergent process), with the divergent and convergent phases comprising of explorative and synthesis work, respectively. The model is introduced to the students in the very beginning of the course and play the role as a guideline through a very open-ended learning process where the students themselves are in charge of their learning. Active learning teaching methods and students working independently are two corner stones in teaching for innovation and entrepreneurship [11].

This first iteration in the Double Diamond is worked through during the first two days in the course during which the students generate individual ideas, form their teams around those ideas and decide what ideas to continue with for the rest of the course. Hence, after this process the students have defined an idea to work on during the rest of the course. After this process, a new divergent period follows where the student teams develop their ideas, and formulate suggestion to how the processes and products they came up with can be grown and up-scaled. The students continually work with a "Realisation Plan" during the course. This tool is important for the progression in the course and helps the students keep on track and enter the last convergent phase in order to produce a concrete solution. Throughout this work by the students they apply the input they receive by the narratives from the high-tech entrepreneurs participating as guest speakers. The students mirror themselves and their own work in the guest speakers and in their entrepreneurial stories. Gradually during the course the students start to act with more and more confidence and show a more professional behaviour in their entrepreneurial work.

During the first course day the students learn how to pitch. Student pitches is an important learning tool in the course and it also has the role as formative assessment. Every Friday the students pitch their work with growing and develop their ideas and receive feedback.

The last convergent phase starts during the last days of the course when the students prepare the finalisation of their "Realisation Plan" for their ideas. The students hand in their work for peer-review by another team. After the process of peer-review the "Realisation Plans" for each team will be handed in for the final assessment. In the summative assessment, the students present their solution during a final pitch at the last day in the course. The course is a non-grading course and the students can pass or fail.

1.3 Use of Intellectual Property Rights

"Intellectual Property Rights" (IPR) is used in "High-tech Innovation" to create an effective driving force for the students' idea growing process. One of the foundations in the course is to show the students the framework for High Technological innovation. It's very central in the course that the disciplinary technological knowledge is actively used and in focus. During the third course day after the students have formulated their own technological idea, the students get an introduction to IPR and relevant databases. A read thread in the course is that the students continually have to check if components they need or technical solutions they consider to come further in their idea-grow process already have a patent. IPR used in this way has shown to be an effective method for the students to learn about IPR but also as a method for them to develop their ideas further as well as their technological knowledge.

2 MEHTOD FOR INVESTIGATE DEVLOPMENT OF ENTREPRENUERIAL MIND-SET

The main purpose with the external funded project that made the development of this course possible was to develop initiatives at DTU that provide engineering students at with possibilities to learn about innovation and entrepreneurship in a technological context. There are many small start-ups in Denmark and the challenge is to create start-ups with grow potential that can generate workplaces and have a positive impact for the employment in society. For that reason this project also had a special focus on creating a grow mind-set among engineers students and graduates. Generally, engineers are seen as key actors in order to find new solutions to global challenges and to create more job-opportunities through new products and solutions that can be commercialised. Those circumstances also have an impact on how to design engineering education [12]. The task for work-package 2 in the project was to develop a course for bachelor students which resulted in the course described in this paper. The project was aiming for a prof-off concept and we needed to find a way to investigate how well the course fulfilled it purposes to promote knowledge about and a mind-set towards high technological innovation, growth and entrepreneurship among the bachelor students following the course.

2.1 Investigation design and evaluations of the course

During the project period the course was held as a pilot try-out three times. In the 3-week study period in January 2017 the course was established as an ordinary electable course for bachelor students from all study lines at DTU. In order to learn how the course designed work, and if the learning and assessment activities chosen were suitable for the course aims several evaluations were conducted during the piloting phase. In the first course pilot August 2015 only six students participated in the course. The course was evaluated by a focus group interview directly after the final assessment. In the second pilot in January 2016 there were 32 students participating. Also this time a focus group was conducted with a representative from each student team. The third time the course was to be piloted in August 2016 it was cancelled due to too few participants. The first time the course was held after the project period in January 2017, there where again many students in the course, 33 participants. This time no focus group interview was held, but the ordinary course evaluation for all courses at DTU was done. In all those qualitative evaluations the students have reported that the course fulfils its purpose with regards to the course design and the learning process established in the course.

2.2 Student survey

The survey “Entrepreneurial Mindset Self-Assement” was used in the second pilot of the course and the first time the course was held as an ordinary course in order to investigate deeper how well the course meets its objectives with respect to development of an entrepreneurial mind-set among the students. In the survey the students rate themselves on 28 statements on a Likert scale 1 – 5 about traits central in an entrepreneurial mind-set [13]. The students in “High-Tech Innovation” rate themselves in the very beginning of the course, pre-test, and in the very end of the course right after the final assessment, post-test.

3 RESULTS OF THE SURVEY

In this section the result of the survey and a statistical analyses are presented. The pre-test is referred to as pre16 or 17 and the post-test is referred to as post 16 or 17.

3.1 Data from student learning outcome

Data are collected from two years - 2016 and 2017 - where we have asked the students to fill out the questionnaire before and after attending the course (pre and post). This gives us 4 batches of answers named pre16, post16, pre17 and post17. Data consists of 32 observations from pre16, 33 observations from post16, 24 observations from pre17, and 26 observations from post17. For all questions the answers were given on a 5 point Likert scale where 1 indicates "Strongly disagree" and 5 indicates "Strongly agree". For pre17 we found 5 cases where the cross was placed in between to possibilities on the scale. In these cases the lowest number was used. We found one question with no answer indicated. Here the answer was coded as 3. For post17 we found 7 cases where the cross was placed in between to possibilities on the scale. In these cases the lowest number was used. 1 questionnaire had only answers on the first page (the first 7 questions). This questionnaire was not included in the analysis. 3 questionnaires had 5 as an answer for all questions. These were kept in the analysis. The data were collected on paper to ensure that the answers were given in an anonymous way. This means that we do not have paired observations (we do not know which pre and post questionnaires come from the same student). Having had that information would have made us able to make a more powerful statistical analysis and it is worthwhile to consider whether it will be possible to get that information in future studies. As a part of filling out the questionnaire the students are asked to state their study direction. Unfortunately, this was not done by many of the students so we have not been able to use this information in our analysis. Future studies will focus on getting this information right as it will be interesting to see if there are differences between different study directions or groups of study directions.

3.2 Statistical analysis

The mean scores show a tendency that the scores after having attended the course are higher than before attending the course. The 28 questions in the questionnaire are grouped into four groups concerning "Problem solving and critical thinking" (8 questions), "Teamwork" (7 questions), "Business acumen" (8 questions) and "Societal issues" (5 questions) - here called the P, T, B and S group.

We have fitted a linear model to the average response for each of the four groups with two explanatory variables and their interaction. The first explanatory variable indicated whether it was a pre or a post score, and the second one whether the score was from 2016 or 2017. The last explanatory variable is the interaction between the two main factors. The interaction gives the possibility of having different pre-post effects for the two years. For all four groups we found that the interaction was not significant (p-values between 0.06 and 0.39). Moreover the effect of year was not significant (p-values between 0.11 and 0.77). For all four groups we found a significant difference between the scores before taking the course and after (p-values < 0.005). The strongest effect was seen in the group S where it was estimated to be 2.1. For the rest of the groups it was estimated to 0.61 (P), 0.69 (T) and 0.66 (B). We also checked the assumptions (e.g. normally distributed residuals) which was OK. We also tried out the corresponding models for the individual questions in the questionnaire instead of the average of the four groups. These analysis showed the same tendencies but because of the mass significance problem (when you make many statistical tests in average 5% of them will show significance by chance) we stick to the results concerning the groups. A visual presentation of the results for all the questions is shown in fig. 1. The figure shows the mean results for all the questions (for both years as the analysis did not see a difference between years) for pre and for post.

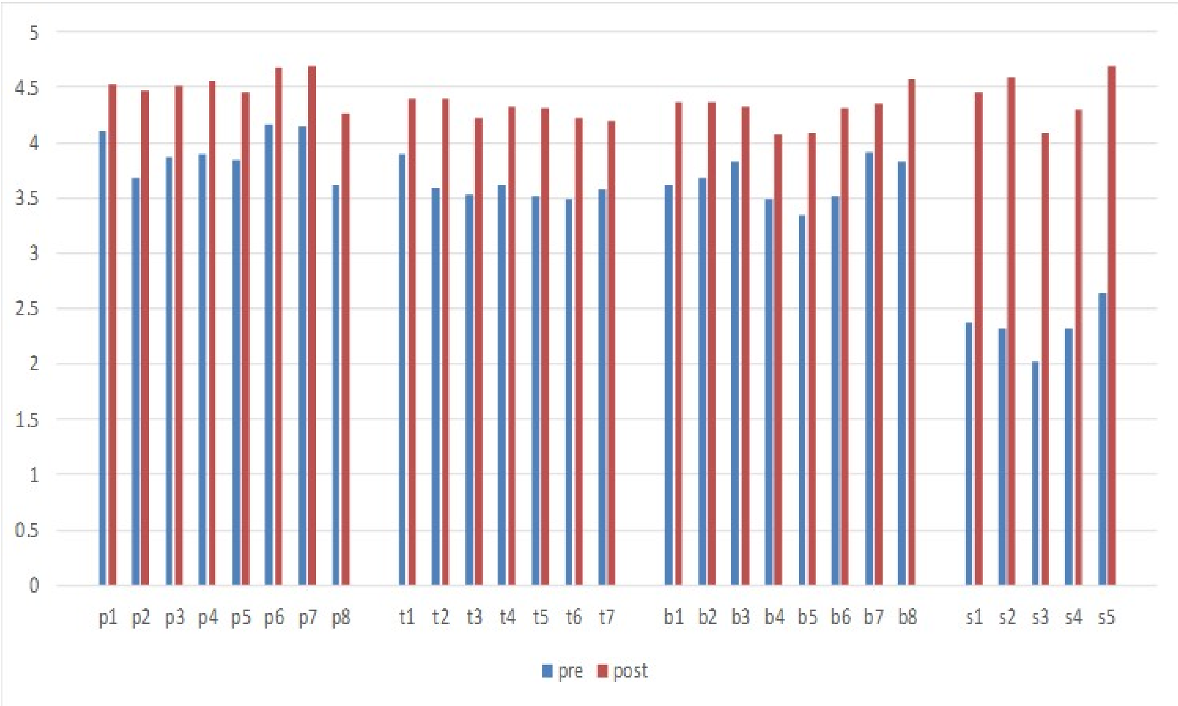

Fig. 1: A visual presentation of the results for all the questions. The figure shows the mean results for all the questions (for both years as the analysis did not see a difference between years) for pre and for post.

4 SUMMARY

The results show that the students move in a positive direction in the all groups of questions and the conclusion is that they learn from the process in the course. What is interesting is the difference in pre- and post for Business Acumen is not as big as for the societal issues. We expected a bigger difference regarding Business Acumen because we do not consider that a core topic in undergraduate course. The results shows that Problem Solving and Team Work are rated quite equal by the students which indicates that the students independent on engineering programme are quite used to work in that way. The biggest difference in the students' rating is on Societal Issues. Reasons for this can be that the students during the course see the relevance of the multidisciplinary aspect in socially relevant problems, not only through their own discipline but from the multidisciplinary engineering undertaking. That is probably something new for many engineering undergraduate students and an important experience in order to understand how, and become motivating for doing a difference through innovation in a high technological context.

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Team-based Learning: A Novel Approach to Teaching Engineering Subjects

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ABSTRACT

Team-based learning (TBL) is a pedagogical strategy similar to the flipped classroom model which promotes the benefits of small-group teaching in a large group setting, thereby enhancing students' engagement by increasing their accountability within peer group, and encouraging peer-to-peer learning. Although initially developed for a business school environment, TBL has recently been increasingly used within medical education. Reports on its implementation in engineering and science education are much scarcer. The aim of this work is to discuss the experience and impact of implementation of the TBL in a large group setting within year-one engineering module in Engineering Department at Lancaster.

Conference Key Areas: Engineering Education Research, Attractiveness of Engineering Education

Keywords: TBL; Active Learning; Engineering Education; Student engagement

1 INTRODUCTION

In recent years, both Europe and USA experience an increase number of students in engineering fields. At the institutional level, this is usually not accompanied by the increases in teaching resources, thus challenging student-teacher relationships as well as the way of teaching and learning, resulting in teaching engineering subjects by presenting a large amount of information to large numbers of students, which in turn promotes passive learning. Pedagogical strategies to overcome passive learning and enhance student engagement include collaborative learning [1],[2], problem-based learning [3] and enquiry based learning [4].

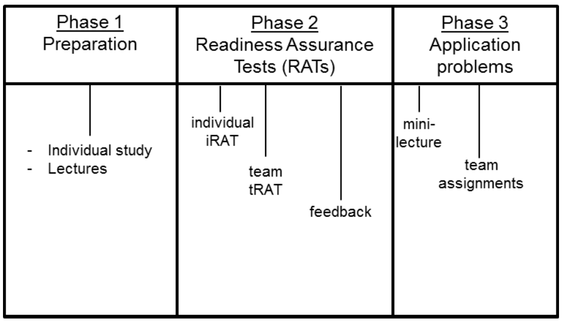
Evidence suggests that problem-based learning (PBL) is the most widely used alternative strategy offering various benefits such as increased retention of information, an integrated knowledge base, the development of lifelong learning skills, an exposure to real-life experience at an earlier stage in the curriculum, increased student-faculty interactions, and an increase in overall motivation [5]. However, the effective implementation of the PBL in large classes, such as first-year introductory modules with typically more than one hundred students, is challenging because one tutor supervises only one group of six to ten students.

In recent years, team-based learning (TBL) has emerged as a pedagogical strategy which promotes the benefits of small-group teaching in a large group setting, thereby enhancing students' engagement by increasing their accountability within their peer group, and encouraging peer-to-peer learning [6]. On the contrary to the traditional approach of teaching engineering subjects by presenting a large amount of information to large number of students, TBL focuses on student learning using course concepts to solve problems. TBL was originally developed for a business school environment has since been progressively used within medical and pharmaceutical education.

Despite its potential, reports on its implementation in engineering education are very scarce. Increased in-class discussion, peer-learning and attendance, as well as improved course effectiveness and students' perception based on student evaluation was evidenced for the mechanical design elements module [7], [8]. Also, report from Monash University [9] showed that carefully engineered team-based learning was used to develop team work, collaboration, lateral thinking and problem solving as well as, the often necessary, conflict resolution. Two recent studies [10], [11] demonstrated a clear advantage of team-based learning in engineering course over informal active learning strategy. Furthermore, discussion of the experience, evaluation and lessons learned from the implementation of the TBL within module on Fundamentals of Process Engineering was discussed lately.

Team-based learning consists of four essential practices [6]: 1) permanent teams (5-7 members), 2) Readiness Assurance Process, 3) In-class activities and assignments, and, 4) peer assessment and feedback system.

A typical module is organized into few major units and for each of them the sequence of activities is implemented as shown in Fig.1. In the first phase, students are given pre-class individual assignments (e.g. readings) and lectures that are designed to familiarize students with the key concepts. Based on this preparation, in phase 2 students are expected to perform an Individual Readiness Assurance Test. After, students re-take the exact same Readiness Assurance Test as a team by coming to consensus on their answers. The final step is Phase 3 which includes a mini-lecture with explanations about key aspects and team application assignments designed for students to use course content to solve problems in teams. In addition, peer



assessment is essential elements of TBL aiming to avoid potential "free-riders", enhance ability to work together effectively and motivate students to help each other.

Fig. 1. TBL – Implementation phases

1.1 Permanent teams

In TBL, one instructor simultaneously facilitates many small teams, typically 20 or more. Teams need to be large enough (typically 5 – 7 members) in order to guarantee sufficient intellectual resources to solve complex problems. It is important that instructor creates teams to get balanced and diverse teams with wide range of skills. Due to the fact that team cohesion is enhanced by time, it is essential to have permanent groups which can become high-performance learning teams.

1.2 Readiness assurance process

Readiness assurance process (RAP) is designed to motivate students and guarantee their preparation for the application problems. RAP consists of an individual and team readiness assurance tests (iRAT and tRAT). These tests are usually a multiple choice questions testing students' understanding of the main concepts, addressing the lower Bloom's levels of learning (knowledge, comprehension and application). iRAT might be organised as online out-of-class quiz. After, students re-take the exact same test as a team (tRAT) by coming to consensus on their answers, which assures mutual transfer of knowledge between teammates and motivation through competition with other teams.

1.3 In class application assignments

Application assignments are designed for students to put course content to use by working in teams on progressively more difficult questions, addressing higher Bloom's levels of learning (abilities to analyse, evaluate and create) according to the so-called '4S' strategy created by Michaelsen et al. [6]:
1) Significant problem – The application exercise should be meaningful and complex enough to motivate student to generate fruitful discussions within teams.
2) Same problem – All teams should work on the exact same problem which allows teams to compare their answers with answers of other teams.
3) Specific choice – Specific answer simulates a read world situation in professional environment.
4) Simultaneous reporting – Teams should report their answers simultaneously in order to encourage accountability and prevent answer drift.

1.4 Peer assessment

Peer assessment aims to hold team members accountable to their teams and to lessen the likelihood of social loafing. This is an essential element of TBL aiming to avoid potential "free-riders" which is typical for group work and enhance motivation and ability to work together effectively. Thus, the team score is adjusted for each member of a team by peer evaluation.

2 IMPLEMENTATION AND DATA COLLECTION

2.1 Implementation

Process Engineering Fundamentals is a first-year module compulsory for all engineering student (courses: chemical, nuclear, mechanical and electrical and electronics engineering), delivered at Lancaster, enrolling approximately 152 students in 2017. It an eight credit module comprising two 50-minute lectures each week in an amphitheatre and one two-hour practical session in computer room (for ten weeks). During 2016/17, students were divided into 24 teams of 6-7 members. The module was divided in three units: 1) process variables; 2) mass balances for processes without and with chemical reactions; and 3) single and multiple phase systems. The sequence of activities shown in Fig. 1 was followed for each unit. One or two traditional lectures were delivered to explain the main concepts and students were directed to individual study using previously prepared reading material which was accessible via Moodle. Next, students were asked to do online out-of-class multiple choice individual readiness assurance test in order to guarantee their preparation and understanding of main concepts. Subsequent in-class session was dedicated to Team Readiness Assurance Test which is the same test as iRAT with different numbers for students to solve within teams sharing knowledge. The resolution of test was divulgated immediately after and “mini-lecture” was given to emphasize the most difficult points. During the following sessions of the same unit, student teams were working on progressively more demanding application tasks. Thus, the same problem is distributed to all teams and responses from them are received simultaneously using active (real-time) quiz activities set in Moodle.
Assessment was performed according to following distribution:
- Exam 60%;
- Average of three iRATs 20%;
- Average of three tRATs 10%;
- Average of in-class application exercises 10%.

Both scores for team activities (tRAT and application exercises) were adjusted for each member of a team according to peer assessment using the so-called Fink method [6].

2.2 Data collection

Total of 107 students (48.6%) responded to the anonymous questionnaire comprising nine statements shown in Table 1 with Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). In addition, two open-ended questions on positive and negative aspects of their experiences were included.

Table 1. Statements on the questionnaire.

	Statement
S1	The pre-session reading was useful in preparing for team activities.
S2	I found individual readiness assurance tests (iRAT) useful to prepare for application exercises.
S3	I found team readiness assurance tests (tRAT) useful to prepare for application exercises.
S4	Application exercises allowed me to apply concepts learned in pre-session readings and RAT process.
S5	I learn better engineering subjects from TBL than from traditional lectures.
S6	I would prefer traditional lecturing for Process Engineering Fundamentals module
S7	Team work as a method of learning is an effective method to acquire knowledge.
S8	The team discussions allowed me to correct my mistakes and improve understanding of concepts.
S9	I enhanced my learning due to interactions with my teammates.

2.3 Results and discussion

Nine statements were divided into three categories: i) Readiness assurance process (statements S1 to S4); ii) Perception of TBL vs. traditional teaching (statements S5 and S6); and, iii) Perception of significance of team work (statements S7, S8 and S9). The obtained results for each category are presented in Figures 2, 3 and 4. It can be observed that the students' attitudes were reasonably good.

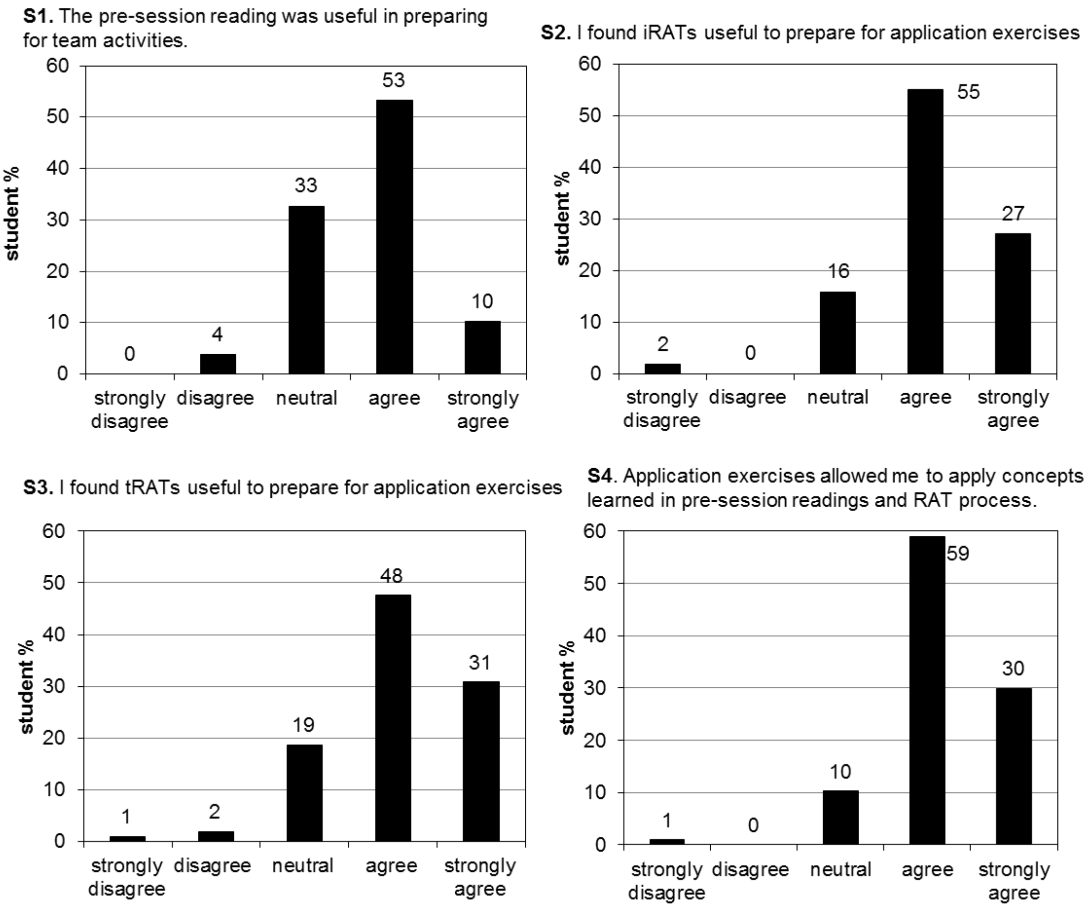


Fig. 2. Response to the statements in the readiness assurance process category.

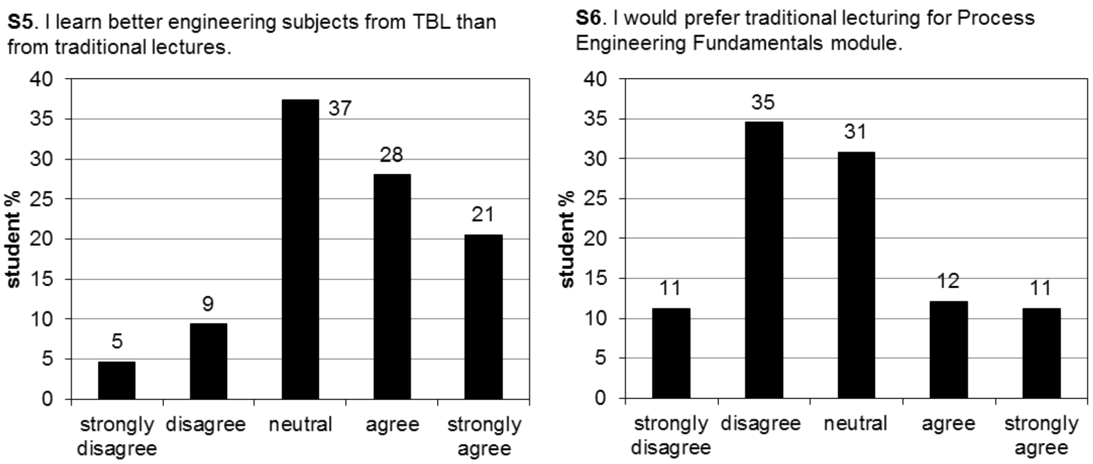


Fig. 3. Response to the statements in the perception of TBL vs. traditional teaching category.

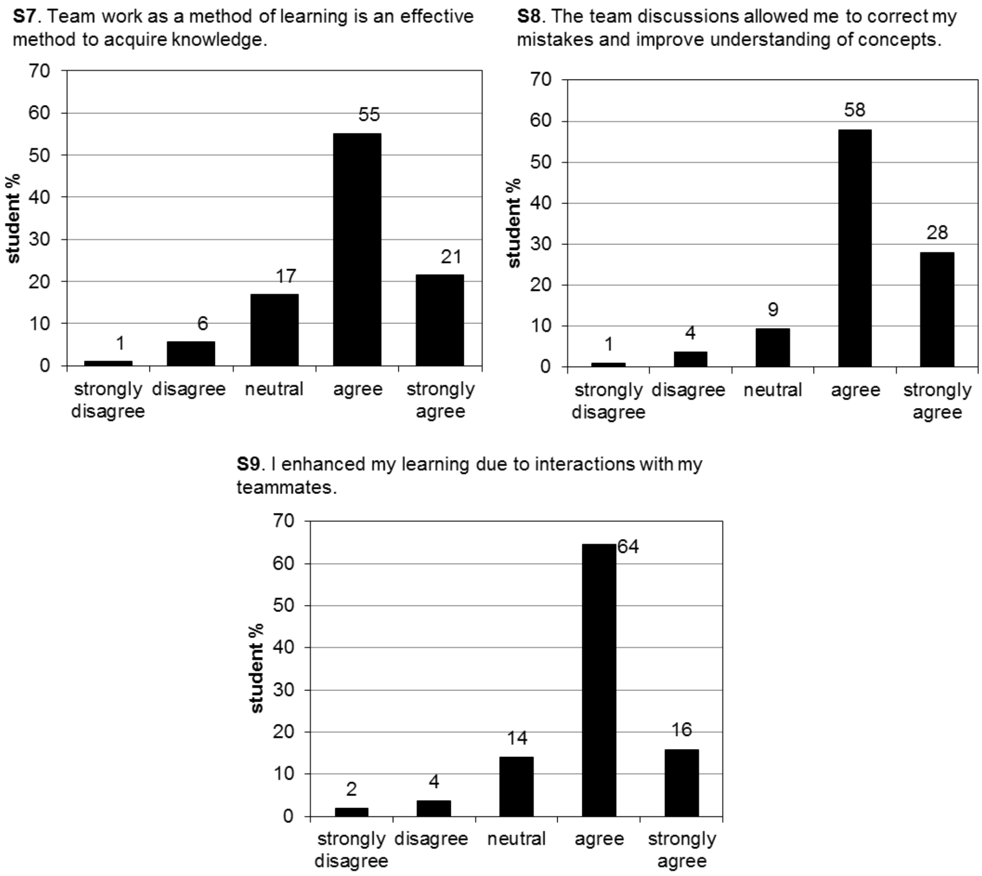


Fig. 4. Response to the statements in the perception of significance of team work category.

The comparison of the average scores for the statements in the readiness assurance process category (Fig. 2) comprising four elements (pre-session readings, iRATs, tRATs and application exercises suggests that high percentage of the students agreed or strongly agreed that these activities allowed them to prepare and apply acquired concepts, ranging from 63% for S1 to 89% for S4. It also seems that the pre-session readings were the least useful activities compared to iRATs, tRATs and application exercises. The scores on the perception of TBL vs. traditional teaching category (Fig. 3) suggest that almost half of students agree or strongly agree that their preferred lecturing style is team-based learning for an engineering module and for Process Engineering Fundamentals. However, it should be noted that high percentage of students exhibited a neutral statement – 37% and 31% for statements S5 and S6, respectively. Agree and strongly agree statements dominated in the perception of significance of team work category, demonstrating students' awareness that team work is important for their professional development. Furthermore, 86% of students agree or strongly agree the team discussions allowed them to correct mistakes and improve understanding of concepts while 80% agree or strongly agree that their learning was enhanced due to interactions with teammates. Interestingly, comparison of three categories shows that students are very positive in respect to all TBL activities and their learning is enhanced but they are somewhat hesitant to prefer TBL format over traditional teaching – 23% would prefer traditional and while 31% are neutral. This might be due to the fact that students encountered TBL for the first time and it takes some time to adapt.

Two open-ended questions on positive and negative aspects of students' experience with TBL were analysed. One of the listed positive aspects mentioned numerous times is benefit of working in teams allowing knowledge sharing, such as:

“I was able to identify where my working differed from others in my group, and therefore learn from my mistakes.”

“When we reached different answers, the group could discuss their methods to identify problems and find the correct answer.”

“If you get something wrong your group can help you see where you went wrong.”

“I could observe other people’s thought process and understand what knowledge they had based to solve a certain problem.”

Many students mentioned that their engagement was enhanced due to the TBL. Some comments include:

“It was very engaging and it kept everyone on their toes.”

“Made you attend more because it would make you feel guilty having not.”

“More engaging than the standard lectures.”

“It’s a change of teaching style, it keeps us more interested for longer.”

“It made the lectures a huge amount more enjoyable, so I actually wanted to come to the lectures, rather than just feel I ought to. It was also very useful for cementing the information we had learnt.”

It is also apparent that students enjoyed all elements of the readiness assurance process, stating that answering multiple questions on each topic is helpful to consolidate what is learnt in lectures.

The most listed negative aspects were about choosing the team, peer assessment and engagement of teammates. Some students stated that they were against the teams created by instructor as they found difficult and intimidating to work with new people. Many concerns were raised about peer assessment. Students showed a lot of doubts about objectivity of peer assessment:

“Grade is dependent on our groups and can be changed solely on if someone likes you or not.”

“Our grades are affected by other people’s opinions of us. If you’re weaker at Chemistry then your grades will be affected which I feel is unfair.”

“I feel that peer assessment becomes a personality test and it is how other people view you as a person.”

“Bit worried about other people mocking me.”

Many students pointed out the problems associated with participation: sometimes members of the team didn’t turn up, putting team at disadvantage, some people were less involved in the group discussion or were not focused.

3 SUMMARY AND ACKNOWLEDGMENTS

Team-based learning is a promising pedagogical tool which can be implemented within large-class environments, offering many benefits of deep learning and enhanced engagement. In the recent years, TBL has been successfully implemented widely within medicine, health, life science and business disciplines. However its use in engineering education is scarce. This work reports on the benefits of the team-based learning implemented for the first time within the Year 1 engineering module at the Engineering Department of Lancaster University.

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Embedding social impact in engineering curriculum

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ABSTRACT

The prospect of having a positive social impact motivates many students to study engineering. However, this motivation is largely ignored in engineering curricula, which have traditionally focused on the transmission of content knowledge.

The growth of humanitarian engineering education in recent years is part of a trend towards addressing social impact in engineering education and appealing to this student motivation. For example, many Australian universities now offer the Engineers without Borders (EWB) Design Challenge, humanitarian engineering research projects, or even entire degree specialisations. However, despite the success of these programs, what is lacking is a way of embedding social impact in all engineering curricula.

At Swinburne University of Technology, this lack is being addressed with a new curriculum being co-designed with industry partners, grounded in education research, and built around work-oriented pedagogies including project-based learning. Projects will be aligned with 4 Pillars: Emerging Technologies, Entrepreneurship, research & Development, and Social Impact.

In this paper, we will report on the development of our new Social Impact curriculum pillar, drawing on research from the fields of social science, engineering education, and humanitarian engineering, and from real-world case studies of how engineering has been used to achieve lasting positive social impact.

Conference Key Areas: Curriculum Development, Ethics in Engineering Education, Attractiveness of Engineering Education

Keywords: Curriculum, Social Impact, Project-based learning

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INTRODUCTION

Swinburne University of Technology (SUT) is developing a bold new practice-based engineering undergraduate degree, through a consultative curriculum co-design process with industry. Rather than a traditional content-driven approach, this new *Bachelor of Engineering Practice (Honours)* degree aims to develop the professional skill-sets and mind-sets that graduates will need in the 21st century engineering workforce. Project-based learning will be a fundamental aspect of this curriculum, with projects aligned to 4 Pillars: Emerging Technologies, Entrepreneurship, research & Development, and Social Impact. The ongoing process of developing a curriculum framework for this last Pillar, Social Impact, is the subject of this paper.

1 CONTEXT

1.1 The growth of service-learning and social impact in higher education

Service-learning is about combining activities with a positive impact on community and society with the learning goals of an educational program. It is a recent but burgeoning development in tertiary education. Research publications in this area only started coming out in the 1990s. For example, in 1993, Markus & Howard [1] addressed a perceived gap in the literature, by conducting an ‘experiment’ to investigate the learning outcomes from student participation in community service programs. And as recently as 2000, a paper was published with the title “What is service learning?” [2].

Growth in this area has accelerated in the last decade, and the study of it has become a topic in its own right. For example, the *International Journal for Service Learning in Engineering: Humanitarian Engineering and Social Entrepreneurship* issued its first Volume in 2006 [3], and the *Journal of Service-Learning in Higher Education* followed suit in 2012 [3].

The advent of humanitarian engineering education in recent years is part of this trend towards addressing social impact in engineering. For example, some universities now offer humanitarian engineering research projects or degree specialisations [4, 5]. And since starting a decade ago, the Engineers without Borders (EWB) Challenge, a competition for undergraduate students to develop designs to address issues facing community partners in developing countries, has had thousands of participants from the United Kingdom, Australia, and elsewhere. Starting only in 2015, EWB-Australia has run the Design Summit, an extra-curricular program for Australian undergraduate students to learn about human-centred design in Cambodia, India, Nepal, Malaysia, and Samoa that has quickly grown to now have almost a thousand alumni [6].

Addressing social impact is an important trend in engineering education that is being centrally incorporated in the new co-designed curriculum at SUT.

1.2 Co-designing a new engineering curriculum with industry

At SUT, the process of co-designing a new engineering curriculum with industry, as well as with input from students and the relevant peak body, is well underway. It will be summarised briefly here, as it has been reported in detail elsewhere [7].

The curriculum co-design process is represented below in *Fig. 1*, with a structure adapted from the *Design your Discipline* stakeholder consultation process [8]. The process is iterative in nature but moves through three broad stages: “stakeholder consultation” to gather as many different perspectives as possible, “consensus building”, and “engagement for change”.

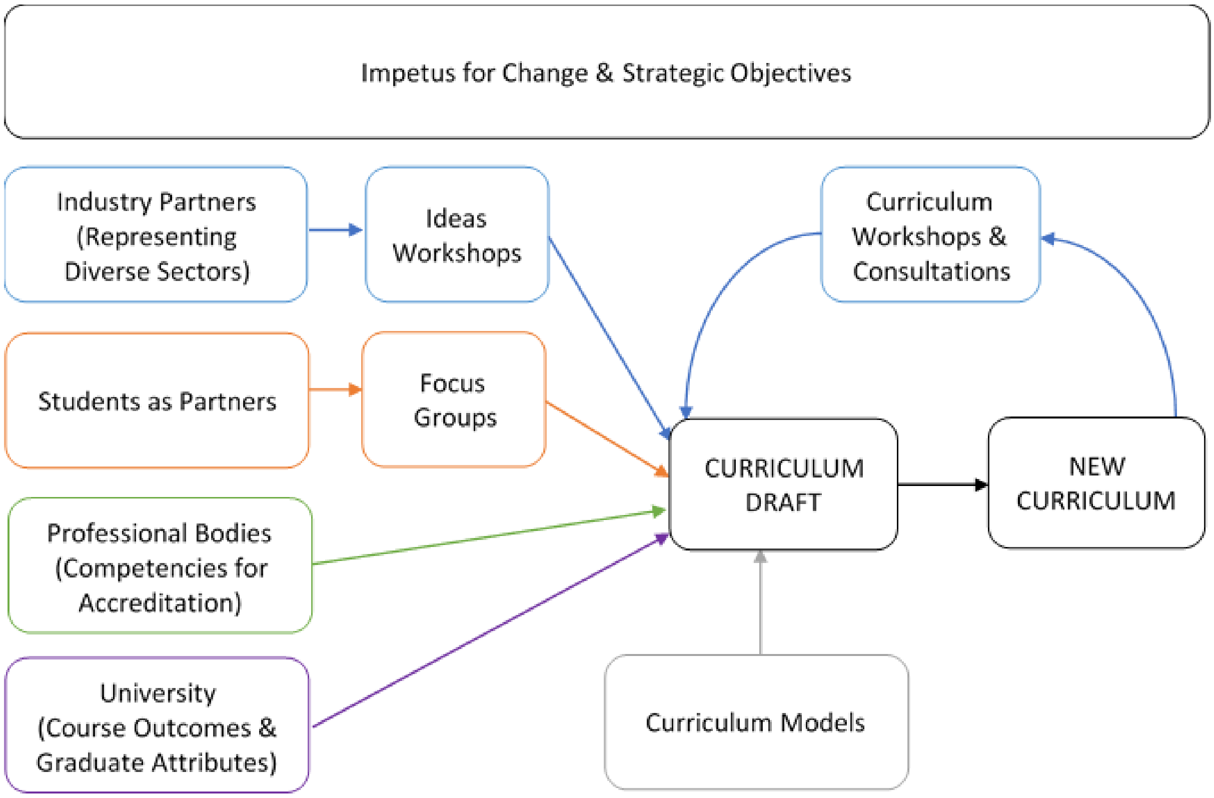

Fig. 1. Framework for consultative curriculum co-design

The "stakeholder consultation" process included three ideas workshops, in which altogether 66 individuals from 50 diverse engineering organisations discussed emerging industry trends, the skill-sets and mind-sets required of graduates, and more. These inputs were analysed and distilled into a draft curriculum framework, that was then the subject of a second round of workshops.

Two curriculum development workshops were held in this "consensus building" stage, with a total of 21 participants from 18 different organisations giving feedback and input into revising the draft curriculum.

1.3 Draft curriculum framework

The draft curriculum of the *Bachelor of Engineering Practice (Honours)* degree is summarised below in *Fig. 2*. It consists of four domains, each of which is divided into three sub-domains. Each of these sub-domains in turn subsumes a number of underlying skills. For example, **Communication** has been unpacked to include: listening, questioning, adaptive communication style, persuasion & pitching, presentation skills, networking, and writing. Similarly, **Management** includes project management, risk management, time management, people management & team building, feasibility & prioritising, and budgeting.

Each year, the student experience will be centred around four 6-week terms. Each term, students will work in small groups on a project drawn from one of 4 Pillars: Emerging Technologies, Entrepreneurship, research & Development, and Social Impact. Over the course of each year, by completing projects from each of these 4 Pillars, as well as through a variety of other learning experiences on a smaller scale, students will develop professional skills in each of the curriculum domains and sub-domains.

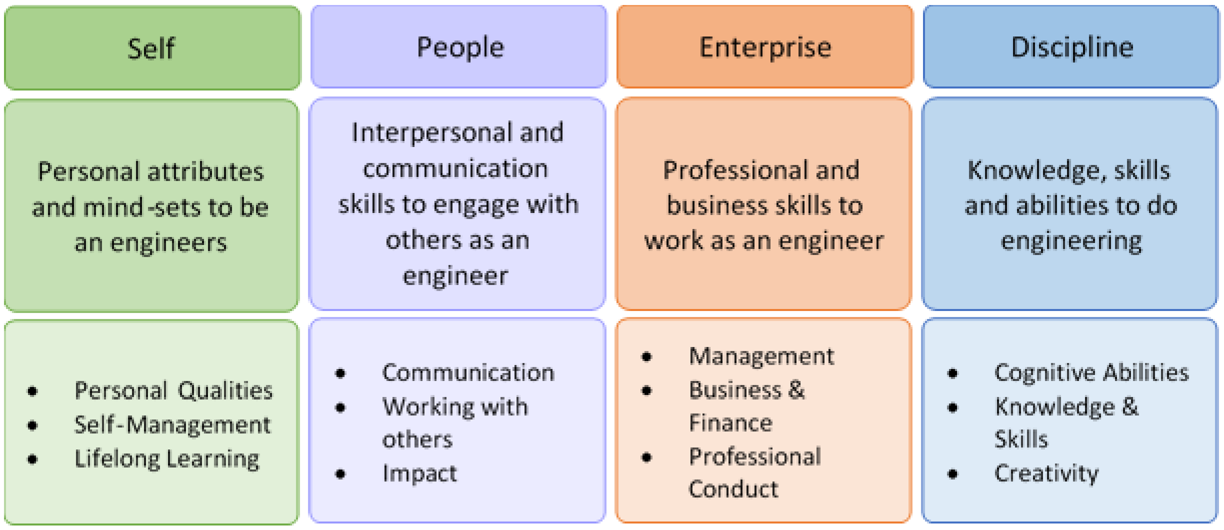

Fig. 2. The domains and sub-domains of the draft curriculum

2 EMBEDDING SOCIAL IMPACT – THE PROCESS SO FAR

The draft curriculum above summarises the skill-sets, mind-sets, and knowledge-sets identified by industry partners as being necessary to work and succeed as a graduate engineer. These will be engendered over the 4 years of the *Bachelor of Engineering Practice (Honours)* degree, starting with the first cohort of students in 2018.

The next steps in the development of this program are the identification of appropriate learning experiences to develop these skills in students, delineation of what this means at the different year levels, and strategies for authentic assessment. In particular, frameworks will be developed to differentiate 'what counts as a Social Impact project', and what this means at different year levels (and likewise for the other project Pillars). Complementary assessment frameworks for these different types of projects will also be developed. Lastly, through consultation with potential project partners, specific projects will be detailed for the first 'pathfinder' cohort in 2018.

To these ends, various explorations of the literature and community are underway, for example reviewing similar service-learning programs at other universities, identifying prospective project partners and learning experiences, reviewing relevant education research, and more. The steps taken so far are summarised below.

2.1 Social impact and service-learning projects at other universities

Service-learning has been used in a wide variety of academic disciplines and university courses [9]. In this section we describe some service-learning programs in engineering that serve as a comparison for our approach.

Bielefeldt et al. [10] reviewed a number of such programs, primarily in the United States. One of the most well-known service-learning programs is the Engineering Projects in Community Service (now known only as EPICS) program, which started at Purdue University in 1995 [11]. It involves inter-disciplinary undergraduate student teams earning academic credit by working to solve technology-based problems for local community organisations, and a number of research papers have explored different aspects of its implementation [12-15].

Similar programs exist at other universities. With the vision of integrating service-learning into every semester of the engineering degree, the *Service-Learning Integrated throughout the College of Engineering (SLICE)* program at the University of

Massachusetts Lowell perhaps most closely parallels our own goals and will provide an important touchstone in the development of our program [16].

Engineers without Borders has partnered with universities around the world to offer service-learning opportunities to students [17, 18]. Jolly et al. [19] evaluated one of the flagship EWB educational programs, the EWB Challenge, and found that in order to draw meaningful lessons from its implementation to improve future iterations, it was not enough to simply ask students how they felt about it. They argued that a much more detailed understanding of the student experience, how they managed success and failure, and what criteria they used to evaluate the course, were needed to inform any future changes to the program. We will have to keep this conclusion in mind when evaluating our own initial offering of our program in 2018.

As a complement to these programs, there are a number of relevant online resources for Social Impact in engineering. For example, websites like *Appropedia* and *EngineeringforChange* not only give examples of appropriate technology, but also detail numerous case studies of engineering projects with real impact [20, 21]. Other sites, like the *Generator School Network*, offer more general service-learning resources [22]. Students will be able to reflect on these case studies and build on these resources in their own project work.

2.2 Identifying prospective project partners

A central Pillar of the new engineering degree will be students working on real-world Social Impact projects. Prospective partners that will offer these projects include local community groups and other non-government organisations (NGOs), or the corporate social responsibility arms of larger corporations. Another avenue for identifying projects is through partnering with other disciplines in the university, such as education or social work, that already have their own networks in the community [23].

In addition to working on term-long projects, students will have the opportunity to participate in international service-learning programs. Prospective program partners include the *EWB Humanitarian Design Summit* [6], *Project Everest* [24], or the *Laika Academy* [25]. Exposure to such global issues and experiences can foster social responsibility [26].

2.3 Education research literature on teaching aligned skills

Working successfully on Social Impact projects will entail the development of a number of underlying skills, such as working cross-culturally, ethical decision-making, engaging community members, designing inclusively, and more. A good starting point in the literature is the collection edited by Colledge of service-learning pedagogies [27]. In this section we'll review some of the other relevant education research literature, that we will use to design learning experiences to cultivate these skills.

Herkert [28] reviewed the literature around ethical problem solving in engineering and argued that 'macroethics', regarding societal decisions about technology and the collective social responsibility of the profession, is often overlooked in teaching ethics. Colby & Sullivan [29] reviewed ethics teaching in engineering more systematically, identifying the strengths and weaknesses of different approaches, but generally concluding that current practices are inadequate. From their review, they made a number of recommendations: "defining ethics and professional responsibility broadly", "integrating with other learning goals", "using active pedagogies", "engaging faculty", and "increasing institutional intentionality" (p. 335-336).

Another aspect of having Social Impact is engaging the communities you are working within. Mazzurco [30] researched methods of 'facilitating community participation' by interviewing experienced practitioners and subsequently generated 5 sets of questions, one for each of the key principles of engagement he identified, as a guide for reflection, planning, and implementation of Social Impact projects, that could easily be adopted with students [31]. Gilbert et al. [32] focused more on the teaching of community engagement skills, reviewing the literature on various pedagogical strategies and analysing one case study of an inter-disciplinary program involving engineering students collaborating with social work students. They described, for example, highlighting the importance of understanding power dynamics, and recommending a strengths-based approach and good listening. Participatory rural appraisal and related methods are also evidence-based approaches for community engagement that students will be expected to understand and critique [33-36].

Understanding different cultures and developing the skills to work across them is vital in a globalised workforce. Hofstede, and those he inspired, identified different dimensions (e.g. power-distance, or individualism versus collectivism) for comparing cultures and subsequently developed associated learning resources [37-39]. Some researchers have also examined cross-cultural skills and their development within the particular context of engineering education [40-42]. One challenge in working across cultures is understanding the complex social dynamics of a community different to one's own. Some researchers have adopted systems thinking approaches to help students understand these complexities [43-45].

Rather than the approach pejoratively characterised as 'drag-and-drop', imposing so-called solutions on communities without meaningful engagement and collaboration, human-centred approaches to engineering design have a number of advantages including quality, acceptance, cost, and more [46]. Understanding students' ideas about human-centred design and implementing strategies to encourage them to consider more inclusive designs will be a priority in our Social Impact program [46, 47].

Many of these skills are predicated upon the cultivation of a strong emotional intelligence, and it is certainly a requirement to succeed in the workforce [48, 49]. Explicitly cultivating emotional intelligence through our Social Impact programs should have many flow-on effects to other aspects of student development.

2.4 Evaluating student learning

Apart from more typical project-based assessment, other factors to consider in evaluating our program are whether students demonstrate any changes in their cross-cultural sensitivity, perceptions of the importance of Social Impact, or more broadly how they see the role of engineers in society. Various survey instruments have been developed to investigate these questions. For example, surveys have been developed and validated to measure multicultural competency [50], ethnocentrism [51], as well as attitudes towards community service [52], sustainability skills and dispositions [53], and the perceived social responsibility of engineers [54]. It is envisaged that these tools could be adapted to not only investigate changes in student attitudes and understanding, but also for feedback and evaluation of our Social Impact program.

2.5 Synthesis

The initial and ongoing development of a curriculum and assessment framework for the Social Impact Pillar will involve a number of inputs and interactions. This includes input from similar programs, feedback loops with industry partners and other ongoing monitoring and evaluation, and engaging with the relevant research literature (*Fig. 3*).

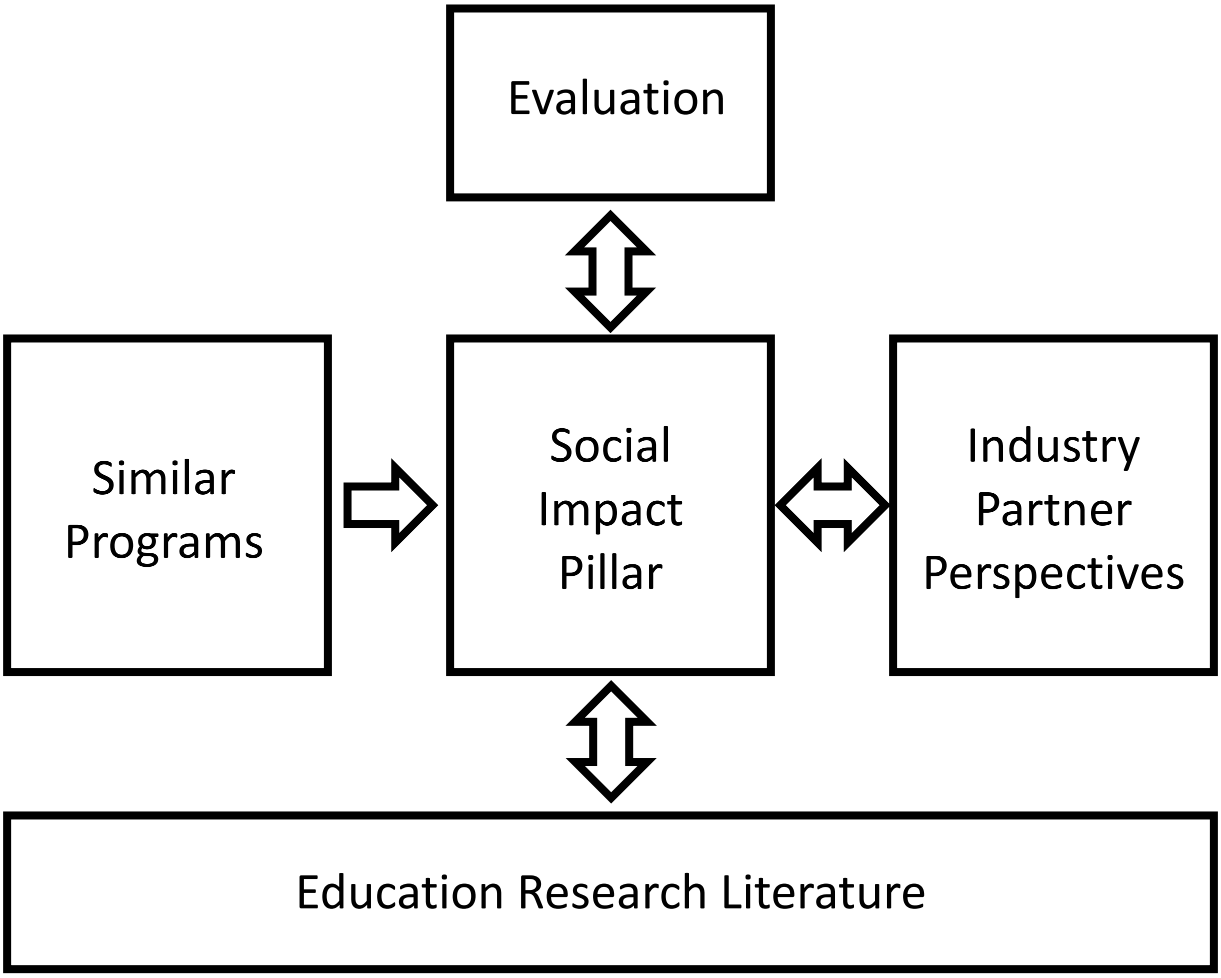

Fig. 3. Inputs and interactions informing the Social Impact curriculum pillar

3 CONCLUSION

The new *Bachelor of Engineering Practice (Honours)* degree at SUT is an exciting development in engineering education, doing away with outmoded traditional approaches to instruction, instead co-designing a new curriculum centred on work-oriented pedagogies and grounded in education research. Social Impact is one of four Pillars of project-based learning that will comprise a key aspect of the student learning experience.

In this paper, the first steps towards embedding Social Impact in this curriculum have been described. An update of this process will be presented at the SEFI conference in September.

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Curriculum co-design using participatory rapid prototyping tools

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ABSTRACT

Higher education is experienced by many academics as a highly individualized

environment where they work in relative isolation and often do not see how their teaching fits together with other courses and into the wider curriculum. But, when the ultimate goal of that curriculum is the development of something as complex as engineering expertise, this requires collaboration between teachers across a programme. The goal here was to use low tech rapid prototyping tools in a participatory design approach to involve a range of stakeholders in conceptualizing a curriculum for the teaching of open-ended problem solving and design skills across engineering programmes. The intention was not to prototype the curriculum itself, but rather to use the prototyping process as a means of facilitating collaboration and engagement from across stakeholders. The process undertaken is potentially scalable to other engineering schools and programmes.

Conference Key Areas: *Curriculum Development; Engineering Skills; University-Business cooperation*

Keywords: *Curriculum development; Rapid prototyping; open-ended design projects*

INTRODUCTION

Despite the frequent use of the term academic 'community', higher education is experienced by many academics as a highly individualised environment where competitive promotion and tenure procedures mean that academics often work in relative isolation. One consequence of this is that they often do not see how their teaching fits together with the teaching of others into a wider curriculum picture [1].

At the same time, engineering accreditation bodies such as the CTI or ABET typically require that students are taught the skills of working in teams and in multidisciplinary environments as a core part of the engineer's skill set [2]. Because these skills cannot be taught through a single course but must be developed over time through practice, this in turn requires a coordinated and collaborative approach to curriculum development. Hence accreditation bodies such at the CTI in France or ABET in the US indicate that curriculum decisions should take account of the needs of stakeholders such as students, industry and – perhaps – civil society [3]. How this is to be done, is, however, not specified.

One area of concern in relation to engineering curricula is the teaching of design. It has been noted, for example, that engineering programmes are often heavily weighted in favour of analysis and the solution of closed questions with single correct answers and against the solution of open-ended complex questions that require creativity, interdisciplinarity and group work [4, 5]. There is a certain recursive irony here: some, perhaps many, engineering programmes appear weak in teaching engineering design, while engineering programme teachers often do not participate sufficiently in programme design. This recursive irony can be rethought of as a recursive opportunity: can design tools that are used in creative problem solving be applied to the problem of inclusive participatory curriculum design?

The goal here was to use a set of low tech rapid prototyping kits in a participatory design approach to involve a range of stakeholders in conceptualizing a curriculum for the teaching of open-ended problem solving and design skills across engineering programmes. In doing so, the approach also modelled industry-university research and development collaboration in that the prototyping kits had been developed in private industry and were being used for the first time in the new context of engineering education curriculum development.

The kits were provided to mixed teams of different stakeholders who needed to discuss with each other their interests and goals in order to construct prototypes relevant to the programme's goals. The intention was not to prototype the curriculum itself, but rather to use the design process as a means of facilitating collaboration and engagement from across stakeholders. The process undertaken and the results obtained are potentially scalable to other engineering schools and programmes.

1 CURRICULUM DESIGN FOR DESIGN AND PROJECT MANAGEMENT

Design has long been identified as the central or distinguishing activity of engineers, and teaching design skills is identified as a key goal for engineering programmes. Engineering design is defined by Dym and colleagues as "a systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints" [6, p. 104]. Design thinking involves a range of different dispositions including creativity, a tolerance for ambiguity, thinking in terms of systems, switching between 'big picture' and 'fine detail' views of an issue, thinking as part of a team, and using several design languages including written, graphical, and mathematical forms of communication. While some of these skills – such as the use of mathematical and formal means of communication – are shared with typical ('analytical') engineering courses, others – such as a tolerance for ambiguity and creativity – are perhaps somewhat different from those found in mainstream engineering courses. Respondents to Kazerounian and Foley, for example, highlighted that that "The typical engineering program teaches that there is a known correct answer that we are aiming toward and that we should find this particular answer as quickly and efficiently as possible" [5, p. 762], a practice that seems out of keeping with the development of design thinking.

Working on open-ended design projects also provides an opportunity for students to learn project management skills. The last few decades have seen significant growth in interest in project management, with professional engineering associations introducing numerous standards and certification processes. Despite this, it has been noted that, "failures to plan accurately and control within ''acceptable" limits are commonplace and projects fail at an astonishing rate" [7, p. 304]. Reflecting the importance of project management as an engineering skill, there has been a growing emphasis on group projects as part of engineering education programmes. Ideally, such projects should include explicit training in project management skills. For example, Crawley et al. [8] cite the Linköping University introductory course in Engineering, which accompanies the group project with lectures and seminars that look at the role of the engineer, group process, project management skills, both oral and written communication skills, and accessing and using information. However students will be unlikely to value the above training unless they see it as relevant to their needs and concerns in their current project, which can be difficult given their limited prior experience and typically short project timeframe [9].

There are also numerous approaches to teaching engineering design across curricula. Traditional engineering curricula consisted of an initial period of scientific education followed by a shift to more engineering-oriented courses. These were typically rounded out with a capstone design course in the final year of studies which allowed students to integrate their learning in a design context. The recognition that this was insufficient to teach engineering design led some programmes to supplement this with a first-year design course, sometimes called a cornerstone course [6]. Others have proposed more radical, curriculum-wide reforms such as those based on Problem-Based Learning (PBL), or the Conceive-Design-Implement-Operate (CDIO) models [8, 10]. Indeed, there is evidence that an integrated programme-wide approach to project management is also desirable [11].

Although widely cited in literature, it is not clear that the CDIO and PBL approaches have had substantial influence in practice. While they argue that a systematic curriculum design process can greatly enhance the chances of promoting effective student learning of engineering skills, Litzinger and colleagues noted that “when we sought examples of engineering programs where effective learning experiences were systematically integrated across an entire curriculum”, the found only a few [12, p. 144].

2 PARTICIPATORY CODESIGN AS A CURRICULUM DEVELOPMENT TOOL

In order to work on building a shared understanding of a programme trajectory for the development of design and project management skills, we adopted a ‘co-design’, approach to building a common sense of the curriculum. The term ‘co-design’ can refer to either a design strategy where complementary components are designed together to provide more feedback loops and interaction between the component designs [13], or to a process in which several different people work together on the design of an artifact [14]. In this paper, we use the term in this second sense. In this approach designers typically involve different stakeholders, but in particular end users, in the design of their artefacts; the idea being to move closer to end-users during the design process.

In the 1970’s several strategies were developed for moving closer to end-users during the design process such as user-centered design (which argues that user concern must be at the center of design decisions), and participatory design [15], (later co-creation, or co-design), which explicitly argued to include the end user in the design process [14]. It has been noted that co-design principles are sometimes pushed by people from business or marketing who see co-design as providing added value to customers [16] rather than by designers. They argue that one reason that has contributed to the slow adoption of co-design is that it requires “that one believes that all people are creative”. As is the case with other bottom-up approaches it also tends to reduce the power of the expert and threatens established power holders.

Indeed, the traditional model was for researchers to analyse users and hand a report of their findings to designers who would create artefacts. In a co-design approach, these roles are blurred. End-users are given a larger role in idea generation, concept development and so on. The role of the researchers and designers in this context is to provide adequate tools to scaffold the ideation and design processes. Research must become facilitators rather than translators of user needs to be given to designers. Designers must “make the tools for non-designers to use to express themselves creatively” and, furthermore, provide expert design skills to the co-design team [14]. Co-design can be used at any stage of product development and some brands are using it to give customers the options at the last stage of design (such as Nike allowing you to change the color of parts of your shoe http://www.nike.com). However, [14] argue for co-creation at the early stage of product design, such as at the moment of idea generation.

Several researchers have investigated co-designing approaches in the context of curricula design [17, 18, 19, 20, 21, 22]. Roschelle and Penuel [18] define co-design as “a highly-facilitated, team-based process in which teachers, researchers, and developers work together in defined roles to design an educational innovation, realize the design in one or more prototypes, and evaluate each prototype’s significance for addressing a concrete educational need.”

However, authors note that “curriculum designers seldom consider the full potential of teachers as co-designers of curriculum materials” [17], even though teachers – as well as students – can offer “critical and constructive perspectives” regarding aspects that make “a lesson engaging and motivating” [17]. Tissenbaum et al. [19] further argue that involving teachers in curriculum design is essential for its success. Penuel and Roschelle [22] argue that co-design is the best way to ensure buy-in by the teachers. This opinion is also echoed by Peters and Slota [20] who find it “essential for helping teachers feel committed to the curriculum.”

Roschelle and Penuel [18] point to a central challenge which is to manage tensions that arise during the codesign process. They find that “managing these tensions led to increased agency on the part of the teachers, increased reflection on their practice, and increased ownership of the resulting design.” Cober et al. [21] argue that in order to achieve the best results, co-design methods should include “support in emergent processes and an atmosphere of trust and inclusion”.

3 CURRICULUM CODESIGN WORKSHOP

Building on some strands of the design philosophies described above, a series of events was conceived to gather different stakeholders in a tertiary education ecosystem to foster collaborative design practices.

The philosophy of the workshops is very much aligned with Schulz et al. [23], i.e. fostering the emergence of innovation in heterogeneous groups through the use of representational methods in a goal-oriented but playful way. It also shares their “manual toolkit-based modeling” approach. The event made use of rapid prototyping kits developed by a design agency (Codesign-it!). The set of tools ("Outdabox') is made of 6 boxes representing 6 languages:

1. ‘Make Da System’ which makes use of LEGO blocks to allow for systems to be represented in a 3D space
2. ‘Make Da 2D things’ which makes use of various bricolage items for a representation in 2D (scissors, tape, etc.)
3. ‘Make Da 3D things’ which allows 3D prototyping with foam and a hot wire
4. ‘Make Da space’ which permits modeling at the 1/24 scale (very close to Playmobil)
5. ‘Make Da app’ which allows to design the wireframes of an application on a series of whiteboards
6. ‘Make Da movie’ which equips users with a camcorder

These various languages offer different ways to represent a question/issue and, in doing so, allow numerous dimensions to emerge. For instance, participants can collaboratively design a map, a poster, an architectural design, a short video, an interactive ICT tool, or a physical artefact relevant the issue/question and, in doing so participants come to a better and shared understanding of the issue itself.

Under the title “Teaching how to develop creative and practical solutions to real-life, complex, scientific and engineering problems”, the initial workshop made use of the Outdabox tools to address the following questions:

- What skills do students need to learn if they are to successfully deliver creative and practical solutions to real-life, complex problems?
- What means (resources) and paths would best support the development of these skills?

A number of different stakeholders were invited to the workshops, which was attended by 33 people including section directors (i.e., department heads), researchers, lecturers, students, lab technicians, teaching assistants and staff. The participants were each assigned to mixed teams based around one of the boxes/languages and were asked to collaborate on building a rapid prototype. In the first instance each team built a prototype which represented the curriculum vitae of an ideal student. This activity allowed collaborative creation of a shared idea as to what the overall goals of the educational programmes should be, while at the same time gaining familiarity with each of the boxes. In a second activity, the teams chose a set of prototyping tools to represent the pathways and means necessary to aid students in developing these skills.

The workshop gave rise to a number of outcomes:

- A number of participants noted that, unlike traditional meeting formats which do allow for individuals to contribute their opinion, but which often take a conflictual form in which participants argue over priorities etc., the co-design activities – which required participants to collectively produce an artefact – meant that participants had to collaborate and compromise. These were described as being “…yes, and…” conversations rather than “…no, but…” conversations. Working in a design language rather than through a more traditional means of representing the curriculum also meant that the participants were discouraged from getting hung up on debate about specific details (credit weighting, exam formats, etc.) and instead described the overarching curriculum trajectories because these aspects were most directly translatable into these design languages. One participant noted that “it seems a bit strange being asked to play with Lego, but we may never have come up with this if it weren’t for the Lego”.
- A number of participants noted that while they had previously worked as an individual to help students develop design and project management skills, the workshops brought them together with other people interested in the same sets of questions. Furthermore the format of the workshop – which maximized time for interaction and discussion – meant that participants left having built connections with each other. As such, the workshop is the beginning of a process of building a community around this issue within the school.

The approach was not universally popular however, with one participant commenting that he did not have time to play with toys, and another suggesting that the same outcomes could have been achieved in half the time. Another criticism was that participants did not learn any new techniques or pedagogical methods in the workshop.

This workshop was conceived as a first in a series and the goal was to generate ideas and participation rather than to subject the participants’ propositions to rigorous analysis. The need for rigorous analysis is to be picked up in further workshops. This initiative demonstrates a serious yet playful way to build a community while enabling people to locate themselves and their work within a broader curriculum vision. These boxes/languages provide a rich way of representing and visualizing complex and multi-layered learning experiences.

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Engineering Education Interdisciplinarity in Global Teams

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ABSTRACT

Multiple disciplines approach, which includes global enhanced interdisciplinarity, has been discussed in the engineering education context from the early 21st Century. There is very little disagreement about its importance for the engineers, the key question has been how to implement theory into practice both in the curriculum and in the actual learning enhancement phase. In this paper, we discuss how to mitigate the social distance in these global education teams and therefore how it becomes the primary management challenge for the global interdisciplinary team leader.
Flexibility and appreciation for diversity are at the heart of managing a global interdisciplinary team. Leaders must expect problems and patterns to change or repeat themselves as teams shift, disband, and regroup. Several strategies to enhance interdisciplinary teams in engineering education are presented.

Conference Key Areas: Curriculum Development

Keywords: Interdisciplinarity, Global collaboration, Team work, Engineering Education

INTRODUCTION

Multiple disciplines approach, which includes global enhanced interdisciplinarity, has been discussed in the engineering education context from the early 21st Century. There is very little disagreement about its importance for the engineers, the key

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question has been how to implement theory into practice both in the curriculum and in the actual learning enhancement phase.

If we try to answer the question what is driving global collaboration in higher education, then among the answers will for sure appear the following options:

- Funding
- Internationalization
- Cultural changes
- Cross-fertilization of ideas
- Intrinsic rewards

At the same time the are some global factors that have their impact at different scale in different areas including industry and engineering education as well. To succeed in the global economy today, more and more engineering companies are relying on a geographically dispersed workforce. They build teams that offer the best functional expertise from around the world, combined with deep, local knowledge of the most promising markets [1].

1 SOCIAL DISTANCE AND INTERDISCIPLINARY TEAM MANAGEMENT

It is important to understand what is the difference between global and local interdisciplinary teams. Creating successful work groups is hard enough when everyone is local and people share the same office space. But when team members come from different countries and functional backgrounds and are working in different locations, communication can rapidly deteriorate, misunderstanding can ensue, and cooperation can degenerate into distrust.

Teams that come from different fields or backgrounds, where people can interact formally and informally, align, and build trust refer to the local scale. For global teams it is common that coworkers do not only come from different fields, but are geographically separated, can't easily connect and align, so they experience high levels of social distance and struggle to develop effective interactions [2].

One basic difference between global interdisciplinary teams that work and those that don't lies in the level of social distance—the degree of emotional connection among team members.

In this paper, we discuss how to mitigate the social distance in these global education teams and therefore how it becomes the primary management challenge for the global interdisciplinary team leader. The management of the social distance is then paramount to identify and successfully improve the social distance. Leaders must expect problems and patterns to change or repeat themselves as teams shift, disband, and regroup. Several strategies to enhance interdisciplinary teams in engineering education are presented (Fig.1).

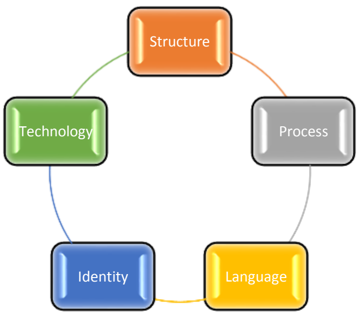


Fig. 1. Management of the social distance

1.1 Structure and the Perception of Power

In the context of global interdisciplinary teams in engineering education, the structural factors determining social distance are the location and number of sites where team members are based and the number of educators who work at each site.
The fundamental issue here is the perception of power. If most team members are located in United States (US), for instance, with two or three in Russia and in Portugal, there may be a sense that the US members have more power. This imbalance sets up a negative dynamic. People in the larger (majority) group may feel resentment toward the minority group, believing that the latter will try to get away with contributing less than its fair share. Meanwhile, those in the minority group may believe that the majority is usurping what little power and voice they have.
To correct perceived power imbalances between different groups, a leader of a global enhanced interdisciplinary team needs to get three key messages across:
who we are; what we do; and that I'm there for you (Fig. 2).

Fig. 2. Key messages

It is important that the answer to the who we are question is, that the the team is a single entity, even though individual members may be very different from one another. The leader should encourage sensitivity to differences but look for ways to bridge them and build unity. To bring people back together a leader for a global interdisciplinary team should create opportunities for employees to talk about their cultures, and instituted a zero- tolerance policy for displays of cultural insensitivity.
About the question of what we do, it is important to remind team members that they share a common purpose and to direct their energy toward team unit or the academic goals. The leader should periodically highlight how everyone's work fits into the course's overall strategy and advances its knowledge. For instance, during a weekly coordination conference call, a global team leader might review the group's performance relative to the academic objectives. The leader might also discuss the level of collective focus and sharpness the team needs in order to keep innovating.
About the question on if I'm there for you, team members located far from the leader require frequent contact with him or her. A brief phone call or e-mail can make all the difference in conveying that their contributions matter. The team appreciated his attention and became more cohesive as a result.

1.2 Process and the Importance of Empathy

It almost goes without saying that empathy helps reduce social distance. If colleagues can talk informally around a nice tea – whether about work or about personal matters

– they are more likely to develop an empathy that helps them interact productively in more-formal contexts. Because geographically dispersed team members lack regular face time, they are less likely to have a sense of mutual understanding. To foster this, global team leaders need to make sure they build the following “deliberate moments” into the process for meeting virtually: feedback on routine interactions; unstructured time; and time to disagree.

Feedback on routine interactions: Face-to-face visits are one, but not the only, way to acquire learning about the impacts of set work routines. Remote team members can also use the phone, e-mail, or even videoconferencing to check in with one another and ask how the collaboration is going. The point is that leaders and members of global enhanced interdisciplinary teams must actively elicit this kind of “reflected knowledge,” or awareness of how others see them.

Unstructured time: Think back to your last face-to-face meeting. During the first few minutes before the official discussion began, what was the atmosphere like? Were people comparing notes on the weather, their kids, that new restaurant in a town? Unstructured communication like this is positive, even when people are spread all over the world, small talk is still a powerful way to promote trust. Especially during the first meetings, take the lead in initiating informal discussions about work and non- work matters that allow team members to get to know their distant counterparts.

Time to disagree: Leaders should encourage disagreement both about the team’s tasks and about the process by which the tasks get done. The challenge, of course, is to take the heat out of the debate. Framing meetings as brainstorming opportunities lowers the risk that people will feel pressed to choose between sides. Instead, they will see an invitation to evaluate agenda items and contribute their ideas. As the leader, model the act of questioning to get to the heart of things. Solicit each team member’s views on each topic you discuss, starting with those who have the least status or experience with the group so that they don’t feel intimidated by others’ comments. This may initially seem like a waste of time, but if you seek opinions up front, you may make better decisions and get buy-in from more people.

1.3 Language and the Fluency Gap

Good communication among coworkers drives effective knowledge sharing, decision making, coordination, and, ultimately, performance. But in global teams, varying levels of fluency with the chosen common language are inevitable – and likely to heighten social distance. The team members who can communicate best in the organization’s lingua franca (usually English) often exert the most influence, while those who are less fluent often become inhibited and withdraw [3]. Mitigating these effects typically involves insisting that all team members respect three rules for communicating in meetings: dial down dominance; dial up engagement; and balance participation to ensure inclusion.

Dial down dominance: Strong speakers must agree to slow down their speaking pace and use fewer idioms, slang terms, local technical terms, and esoteric cultural references when addressing the group. They should limit the number of comments they make within a set time frame, depending on the pace of the meeting and the subject matter. They should actively seek confirmation that they’ve been understood, and they should practice active listening by rephrasing others' statements for clarification or emphasis.

Dial up engagement: Less fluent speakers should monitor the frequency of their responses in meetings to ensure that they are contributing. Don't let them use their own language and have a teammate translate, because that can alienate others. As with fluent speakers, team members who are less proficient in the language must always confirm that they have been understood. Similarly, when listening, they should be empowered to say they have not understood something. It can be tough for nonnative speakers to make this leap, yet doing so keeps them from being marginalized.

Balance participation to ensure inclusion: Getting commitments to good speaking behavior is the easy part; making the behavior happen will require active management. Global team leaders must keep track of who is and isn't contributing and deliberately solicit participation from less fluent speakers. Sometimes it may also be necessary to get dominant-language speakers to dial down to ensure that the proposals and perspectives of less fluent speakers are heard.

1.4 Identity and the Mismatch of Perceptions

Globally enhanced interdisciplinary teams work, most smoothly, when members "get" where their colleagues are coming from. However, deciphering someone's identity and finding ways to relate is far from simple. People define themselves in terms of a multitude of variables—age, gender, nationality, ethnicity, religion, occupation, political ties, and so forth.

Although behavior can be revealing, particular behaviors may signify different things depending on the individual's identity. When adapting to a new cultural environment, a savvy leader will avoid making assumptions about what behaviors mean. Take a step back, watch, and listen. For example, in America, someone who says, "Yes, I can do this" likely means she is willing and able to do what you asked. In India, however, the same statement may simply signal that she wants to try – not that she's confident of success. Before drawing conclusions, therefore, ask a lot of questions. In the example just described, you might probe to see if the team member anticipates any challenges or needs additional resources. Asking for this information may yield greater insight into how the person truly feels about accomplishing the task. Misunderstandings are a major source of social distance and distrust, and global team leaders have to raise everyone's awareness of them. This involves mutual learning and teaching [4].

1.5 Technology and the Connection Challenge

The modes of communication used by global interdisciplinary teams must be carefully considered, because the technologies can both reduce and increase social distance. Videoconferencing, for instance, allows rich communication in which both context and emotion can be perceived. E-mail offers greater ease and efficiency but lacks contextual cues

Choosing between instant and delayed forms of communication can be especially challenging for global interdisciplinary teams. Instant technologies are valuable when leaders need to persuade others to adopt their viewpoint. But if they simply want to share information, then delayed methods such as e-mail are simpler, more efficient, and less disruptive to people's lives. Leaders must also consider the team's interpersonal dynamics. If the team has a history of conflict, technology choices that limit the opportunities for real-time emotional exchanges may yield the best results.

Decisions about structure create opportunities for good process, which can mitigate difficulties caused by language differences and identity issues. If leaders act on these fronts, while marshaling technology to improve communication among geographically dispersed colleagues, social distance is sure to shrink, not expand.

2 INTERDISCIPLINARY ENVIRONMENT AT UNIVERSITIES

A successful interdisciplinary and multidisciplinary teaching/learning depends on the general team dynamics. Flexibility and appreciation for diversity are at the heart of managing a global interdisciplinary team. But university managers who actually lead engineering faculties are usually not so focused in building global teams for engineering education [5]. What are the reasons why interdisciplinary global teams in engineering are not so widespread as they could be?

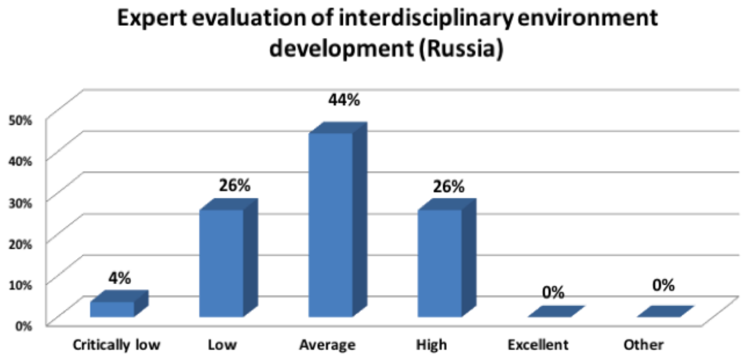
The lack of interest in global interdisciplinary work in academic world could be explained by:

- Tradition
- Academic reward system
- Insufficient funding
- Time
- Attitudes
- Performance evaluation system
- Learning styles
- Communication across disciplines

This topic was of utmost interest at the Network International Conference “Interdisciplinarity in Engineering Education: Global Trends and Management Concepts – SYNERGY” that took place in Russia, 2016 [6]. Within the conference more than 40 participants, took part in the expert workshop «Managing university environment for interdisciplinary projects implementation:conditions, grants, consortium partnership». Participants acting in the role of experts evaluated the current state of interdisciplinary environment at Russian and foreign universities based on their personal experience and expert opinion [7]. Experts had to choose from the list of rates:

- critically low;
- low;
- average;
- high;
- excellent;
- other opinion.

According to the obtained results most particpants from Russia estimate the level of interdisciplinary environment as critically low or low – 30%, average – 44% and high - 26%.Among representatives of HEIs from USA, Hungary, Czech Republic, Spain, Portugal, Republic of Kazakhstan, Peoples Republic of China the evaluation results were more positive: critically low – 13%, average - 25, and high – 63%, as shown at Fig. 3.



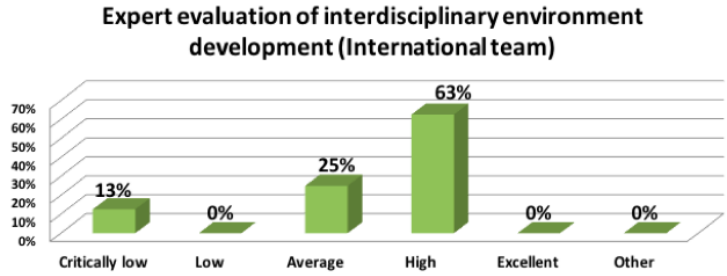


Fig.3. Expert evaluation of interdisciplinary environment at HEIs

While working in teams participants listed the following criteria to define the development of interdisciplinary environment at engineering HEI. Specific attributes for assessing the state of interdisciplinary environment at universities were proposed:

- Ratio of resources and infrastructure to develop interdisciplinary projects
- Involvement of stakeholders (transfer of knowledge)
- Curriculum (syllabus)
- Ratio of students involved in interdisiplinary projects (Teaching through projects)
- Ratio of staff, who completed professional development programs (each 3-5 years)
- Learning outcomes (knowledge & ability)
- Legal requirements
- Management structure.

Teamwork was followed by an open discussion that identified the key obstacles on the way for resolving the problem. Among the major barriers to develop interdisciplinary environment at university the experts named the following, being quite unonimous in their views:

1. Lack of innovative environment (infrastructure)
2. Learning outcomes do not include interdisciplinary aspect
3. Lack of motivation among the teaching staff and students, psychological unpreparedness
4. Lack of political (top management) support
5. Resistance to change the environment, organizational barriers
6. Resistance to share knowledge and ideas
7. Faculty is overloaded with routine tasks
8. Inflexibility or absence of a regulatory framework for interdisciplinary global interaction
9. Lack of assessment system for interdisciplinary projects, lack of experts to review

10. Lack of understanding the role of leader to generate ideas and run interdisciplinary projects
11. Low level of motivation for cooperation between universities and industry
12. Teachers do not want to leave their comfort zone to get involved in interdisciplinary cooperation.

3 FINAL WORDS

There is no doubt anymore that global collaboration is one of the most important skills of the graduates of the 21st century. Universities need to break down "silos", resolve "turf" issues and embark in inter/multi-disciplinary global collaboration. Individual silos, "self-interest", is human nature… but imagine the impact if we think in terms of long-term prosperity instead of short-term greed. Silos everywhere hinder our ability to address the interdisciplinary problems we face. Professors need to learn to work in global teams and be role models for the future generations. In this model, everyone is a teacher and a learner, which enables people to step out of their traditional roles. Team members take on more responsibility for the development of the team as a whole. Leaders learn to see themselves as unfinished and are thus more likely to adjust their style to reflect the team's needs. Embrace and learn from mistakes… nobody is perfect!

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Recognition of Prior Learning

Is our performance test of English a good fit for the purpose?

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ABSTRACT

Living in learning societies has brought an increased focus to lifelong learning and educational policies that support it. One such policy is recognition of prior learning (RPL). In Finnish higher education, the most popular procedure for RPL is a test. This raises the question of how well this assessment method serves its purpose. To examine this theoretically, we used Andersson's 2006 template. Empirically, we gathered anonymous data on the type and range of prior learning among 273 students from engineering and industrial design seeking RPL of English, and analyzed the data in Excel using raw numbers. This analysis shows that the tasks in our RPL test of English differs considerably from those reported in our survey of RPL seekers. This mismatch indicates that we should either adopt an open, divergent assessment method, such as a portfolio, or change our undergraduate English curricula for both engineering and industrial design to better align them with the working-life communication tasks identified in this study – if a closed, convergent assessment method (such as a test) is preferred. Either way, the change would provide better support for RPL and for development action at our university related to strengthening academic-industry relations.

Conference Key Areas: Engineering education research, Curriculum development, Continuing Engineering Education and Lifelong Learning

Keywords: engineering education, university practices, curriculum development, learning assessment

INTRODUCTION

To support internationalization linked to the European Higher Education Area (EHEA), a recent development in higher education institutions (HEIs) in Finland includes implementing procedures that support *recognition of prior learning* (RPL)[1] [1], [2]. An aim of the international strategy for HEIs in Finland has been to create comparable and compatible systems in Europe for higher education. A related measure includes HEIs implementing practices of accreditation and recognition of prior learning that are consistent for students [3], [2], [4]. Not only are policies being implemented but also much of the RPL research at Finnish HEIs tends to address policy, administration, or quality issues, e.g. [5], [6], [7], [8]. Other research in Finland also suggests that the administrative stance towards RPL assessment limits recognition to formal learning, e.g. [9], [10 pp. 20-30]. Similarly, benchmarking at 12 Finnish Language Centres reveals the most common practice for RPL of English to be exemption tests linked to formal learning [11 p.13].

In the present study, the exemption exam is a performance test, covering oral and/or literary skills. The test includes tasks, such as writing an email, giving a presentation and answering related follow-up questions. The selected assessment was easy to implement, as exemption tests for the two skill areas were already an option for students[2]. In the modified version for assessing RPL of English, the aim is for candidates to demonstrate their acquired professional English competence that is comparable to that achieved in the undergraduate English course (for which they are seeking recognition).

Over time, however, the English teachers at the Aalto University Language Centre began to question whether the RPL of English performance test is adequate for the intended purpose or whether an alternative procedure, such as a portfolio, would better capture RPL of English (for students of engineering and industrial design). This question arose as some of the RPL seekers who failed the task-based, performance test complained that test was not representative of their prior learning of English at work (i.e. non-formal learning). To investigate this problem from a theoretical perspective, we analyze our performance test using Andersson's template on the faces of RPL [12 p. 47]. From an empirical perspective, we analyze the task type and range of prior non-formal and informal learning (of English) among engineering and industrial design students seeking RPL of English. These analyses serve as tools to inform the content validity of an assessment for RPL of English for students of engineering and industrial design.

1 SOME RPL ASSESSMENT CONSIDERATIONS

For RPL, different procedures are required for the three learning paths: formal, non-formal, and informal. In the case of formal studies, a common procedure is to request a transfer of credits from one institution to another. This procedure entails submitting evidence, such as transcripts, course descriptions, and other relevant documentation[3]. Thus, this learning path creates fewer challenges for RPL than the non-formal and informal paths, where there may be no official documentation showing a qualification or certification. The RPL procedure for accrediting the latter two paths is the focus of the present study since these paths require a demonstration of previously acquired competences. This demonstration can include passing an exam, submitting a portfolio,

[1] Although the Council of Europe (Recommendation 2012/C 398/01) uses the term *validation of prior learning*, we adopt the term *recognition of prior learning* as it is used in the English-language documents published by the Finnish Ministry of Education and Culture.

[2] The existing exams were first given in 2004, and originally designed for a different purpose (i.e. targeting bilinguals, international baccalaureate, and native speakers). In 2011, they were modified to fulfill the new intended purpose (i.e. RPL of English). The main modification was to emphasize professional English in the tasks and criteria.

[3] For details on the European credit transfer system, see European Commission 2015

partaking in an interview, or participating in some other established procedure as defined by the target department or institution[4]. Furthermore, the type of RPL in the present study is known as *credentialism* since it involves an exchange value: candidates can receive credits upon successful demonstration of their prior learning. In short, it is a venue for gaining credit for a specific course given at a particular institution, a result that is determined by the RPL assessment.

For assessing non-formal and informal RPL, what knowledge can count as valid is not straightforward. For example, some scholars perceive RPL assessment as a venue for widening what disciplinary knowledge can count as valid, e.g. [13], [14]. This discussion covers different angles, including views that see RPL as a way to integrate knowledge holistically [15] as well as to engage heterogeneous knowledge rather than concentrate on academic ones [16]. Another scholar also argues that RPL involves interrelated knowledge on three levels: mainstream curricula, RPL curricula, and prior learning considerations. She contends that such a view enhances the epistemological accountability of RPL practices [13]. As these examples illustrate, much of the theoretical positioning for RPL questions what knowledge to count as valid in an RPL assessment.

Although assessing RPL is a complex issue, Andersson [12] sheds some light on it in his discussion, which culminates in what he calls the two faces of RPL. Based on this idea, he presents a template for practical use that helps to interpret the faces of an RPL assessment practice. In the template shown in Table 2, there are eight aspects to RPL outlined in the left-hand column. In the center are the two faces with their different foci. To develop understanding of our RPL of English test, we will use this template as a heuristic device. The right-hand column shows which foci describe the RPL of English performance test in the present study.

Table 1 Analysis of our RPL of English test using Andersson's template in [12 p. 47].

Aspects of RPL	**Difference in focus**		**RPL of English**
	Face 1	***Face 2***	**Analysis**
Relation to the system	*RPL adapted to the existing system*	*RPL changing the system*	***Face 1***
Close/open	*Convergent*	*Divergent*	***Face 1***
Foundation of trust	*Reliability*	*Validity*	***Face 1 & 2***
Focus of measurement	*Commensurability*	*Particularity*	***Face 1***
Horizon of meaning	*Universal/global*	*Local*	***Face 1***
Constitution of knowledge	*Atomism*	*Holism*	***Face 1***
Orientation	*Competence*	*Potential*	***Face 1***
Functions	*Selection Summative, predictive*	*Transformation Formative*	***Face 1***

What the analysis shows is that our RPL of English test aligns primarily with the foci of Face 1. Given that we adopted a modified version of an existing exam, it is not surprising to find that our RPL of English test is convergent. This approach supports

[4] For an example of RPL in Finnish HEIs, see in Finnish http://tunnistaosaaminen.fi/node/20

confining RPL knowledge to that defined by a closed system. Because our assessment methods require producing language, the measurement of language competence involves individual responses that contain different content and thus require rating scales. Although this type of assessment is generally higher in validity than in reliability, it may be that this ‘reliable’ approach excludes valid content in RPL assessment. Moreover, assessing with rating scales generally suggests a holistic approach. However, we would describe our rating scales as atomistic since they focus on discrete points relevant to course content (not to holistic learning as is the case in RPL). In short, the scales provide a comparison between two test-taker responses on a limited range of features that do not provide the depth of knowledge that a holistic approach might reveal. This type of assessment, nevertheless, increases reliability and commensurability. From the template, we also see that the function of the RPL of English test is summative. The grade reported (at the end) indicates whether an RPL of English seeker has succeeded. A pass mark suggests that the candidate is likely to pass a final exam in an undergraduate English course. Although this method of RPL assessment, i.e. a test, is common practice in Finnish universities, it is unclear whether the approach is a good fit for the purpose. At least, the data in the present study suggest that this closed approach may be marginalizing RPL.

Using Andersson’s template clarifies the faces of our RPL of English test. It also raises the question of whether our RPL of English test is a good fit for the purpose. To what extent does an approach that controls ‘valid’ knowledge in a prejudiced way serve our RPL seekers? Is it possible that their prior experiences could contribute to defining valid knowledge in our RPL of English test and simultaneously inform our curricula on real-world communicative competences in academic-industry relations? This kind of information could help to inform the English curricula as well as support development actions at our university, which include both preparing students for working life and strengthening skills for lifelong learning.

2 METHODS AND RESULTS

To investigate the research question, members of the testing team distributed a questionnaire on the type and range of prior non-formal and informal learning among 379 students participating in the RPL of English oral performance test. The responses were anonymous and the response rate for the questionnaire was 273 or 72%. The purposive sample included students from engineering and industrial design, who wanted to demonstrate their prior knowledge of English.

The questionnaire consisted of 15 items. Of those, 12 were multiple choice with an open option and three were open-ended. The main themes included context of usage, frequency of English use, task types and work experience. From the multiple-choice alternatives, students could select more than one option. The categorical data were analyzed using a data spreadsheet to count raw numbers, and the results are presented in charts.

Regarding student background, the results show that about two thirds were aiming at a bachelor’s and one third a master’s degree. This spread can be expected since most students complete their compulsory foreign language studies at the bachelor’s level and those who have not then complete it at the master’s level. Because the respondents are attempting RPL of English, it is assumed that they need to meet an obligatory foreign language requirement.

An examination of the types of prior non-formal and informal learning of English, the responses to Q3 reveal a wide range. In Fig. 1, the types of prior learning indicate that about two thirds worked in English, roughly half engaged in self-study, and approximately one quarter used English in leisure activities. The findings also indicate a range of activities not related to academic or professional English, but which may have an impact on general proficiency. These items include the following: English courses at school, living/studying abroad, and being an English native-speaker or having an English native-speaking parent. What these responses suggest is a focus on nativelikeness as the measure of success as opposed to academic and professional communication skills. This fallacy explain one reason why some students attempt RPL. In other words, they have misconceptions about what they need to demonstrate in RPL of English. Even native speakers are not born with academic and professional English.

Another interesting point in Fig. 1 is the context of learning, particularly those supporting professional English via academic-industry relations. These contexts include using English in student exchange programs, International Baccalaureate (IB) degrees, English-native-language (ENL) universities, and English-medium instruction (EMI) at university. Although these contexts pertain to a small number of respondents, they point to venues for acquiring academic and professional English related to the respondents' fields of study. This prior learning provides evidence of non-formal learning that supports developing knowledge within the field of study, where developing communication skills in English may be a by-product.

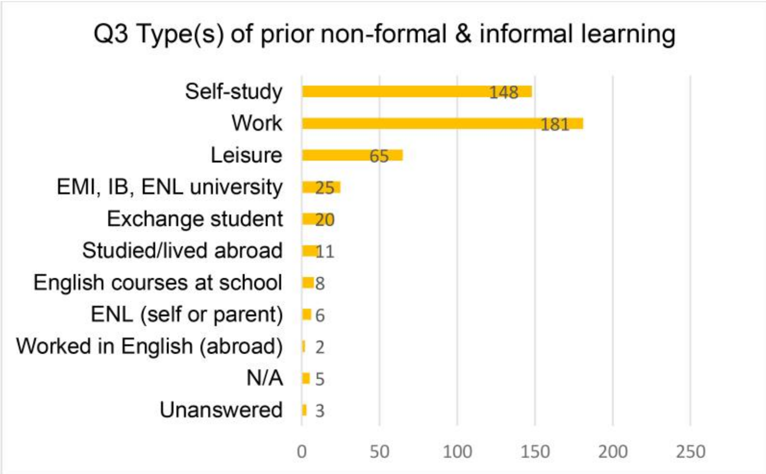

Figure 1 Types of prior non-formal and informal learning (responses in raw numbers).

In Fig. 2, the responses on RPL workplace roles indicate that many students acquired English through professional training. For example, roughly one third (95 of 273) used English as project workers and as interns (86 of 273), ten percent both as project leaders (27 of 273) and as apprentices (29 of 273), and a small number in a range of other types of professional training, such as doing research, teaching as an assistant, working in customer service. However, some of the roles reported also include roles unrelated to the field of engineering or industrial design. It is questionable whether these are relevant to RPL of English for engineering. In addition, roughly twenty percent (57 of 273) responded

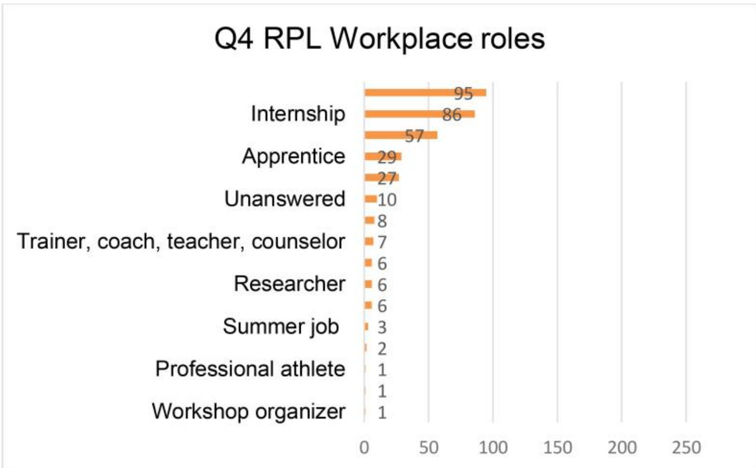

Figure 2 A variety of workplace roles (in raw numbers) reported by RPL seekers.

that workplace roles were inapplicable. From this response, we do not know whether the respondents had no workplace roles or no work experience.

Findings on the task types reported for English at work (Q5) are presented in Fig. 3. What this chart shows is that tasks in spoken English are central to the prior work-related experiences, with small talk being the most frequently reported task. Nearly half of the respondents reported having engaged in small talk as a work-related task. The next most frequently reported tasks include participating in projects and meetings, each roughly 45%. Following this is partaking in phone/video calls and giving presentations, each nearly 40%. On other tasks, there were very few responses. This observation includes writing tasks in English, where roughly 10% reported needing to write emails and documentation. In addition, similar to Q4, roughly 20% reported work-related tasks as inapplicable. This finding seems to suggest that the respondents have no prior work-related experience in English.

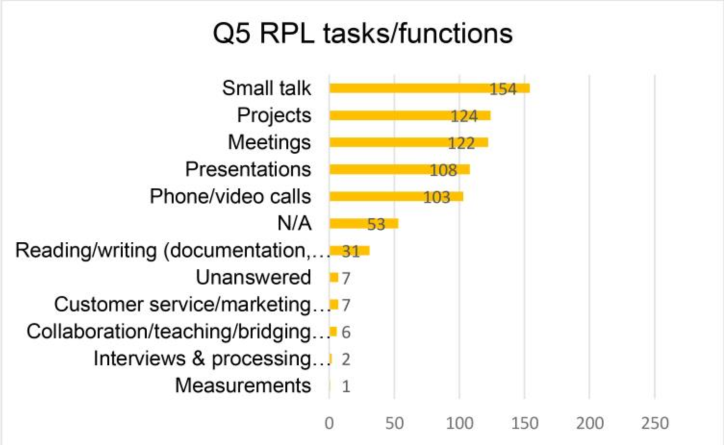

Figure 3 RPL seekers reported a variety of workplace roles.

To gain understanding of the professional context of prior learning of English, we investigated the skill areas in which the tasks were performed. Fig. 4 indicates the most common professional areas to include studies (nearly 50%), engineering (nearly 50%), and doing business (26%). These findings are not surprising given that many of the respondents have completed a study exchange or internship and that some are also doing their engineering studies through English-medium instruction.

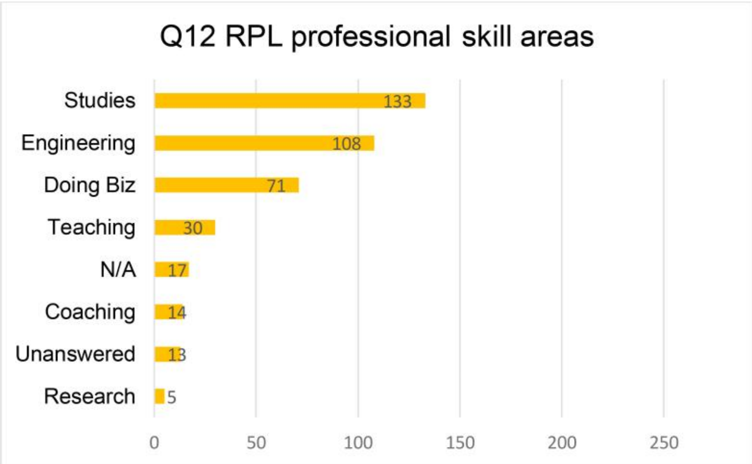

Figure 4 Professional skill areas reported by RPL seekers.

Not only did we investigate the task types and range but also the international context of English usage. As Fig. 5 and 6 show, the prior learning of English primarily occurred with other non-native speakers of English in international contexts outside the English native-speaking world. In Fig. 5, the findings show that nearly half operated in English with other non-natives of English, and almost 40% used English equally with native and non-natives. This finding suggests that English is the language of choice for communicating in English as a lingua franca (ELF). The responses in Fig. 6 also support the primary use as ELF, with Europe being the main hub of prior learning of

English. Overall, the data indicate that using English with native speakers only is uncommon. As shown in Fig. 5, less than 10% reported using English with only native speakers, which suggests that their prior learning of English took place in an English-speaking country in a non-international context with only locals. Moreover, roughly 20% (i.e. 55 of 273) reported the location of prior learning of English as inapplicable. We do not know why, but perhaps it is related to communicating via technology, such as Skype, NetMeeting, or other social networking tools, where interaction occurs in a space not defined by a single location. In addition, those who reported no interaction in English may have participated in self-study, a form of prior learning that could involve using English (e.g. reading, playing computer games, and so on) without social interaction.

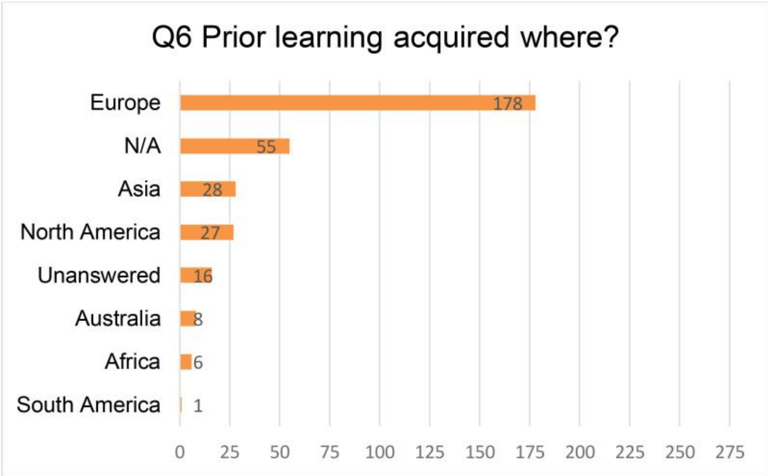

Figure 5 The continents on which prior learning of English occurred.

All in all the spreadsheet analysis provides some general information about the data. It shows the versatility of the prior learning of English among engineering and industrial design students. These prior experiences could also be relevant to learning professional English for the field-specific area.

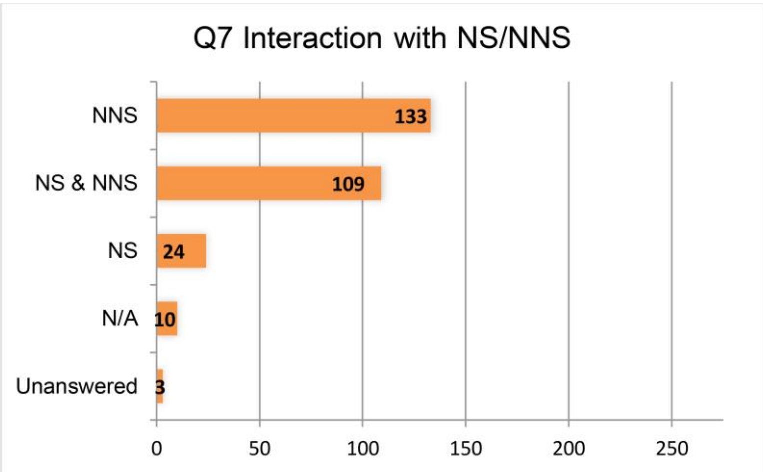

Figure 6 Interaction with English native (NS) and non-native speakers (NNS).

3 DISCUSSION AND CONCLUSIONS

This study investigated whether our RPL of English test for engineering and industrial design students is a good fit for the purpose. Theoretically, it analysed the RPL of English performance test using Andersson's template in [12 p.47]. The findings show that our RPL of English test is a closed, convergent approach to RPL assessment. A primary goal of this type of assessment is to control knowledge in a biased way. In other words, academics decide what knowledge is valid in university curricula. However, the present study indicates that such an approach can exclude relevant RPL curricula, thereby marginalizing RPL.

Empirically, the study investigated RPL seekers' prior learning of English through a survey. The findings show versatility with the task type and range for prior learning of English. This observation suggests that our performance test with set pre-defined tasks (e.g. writing an email and giving a presentation) is too limited to serve the purpose. While the performance test adequately covers tasks from an undergraduate English course, it omits many tasks important to working-life skills reported in the present study (e.g. phone/video calls, small talk, and meetings). Our findings indicate that an analysis of RPL seekers' prior learning is one way to inform not only the academic curricula but also the RPL assessment practice, given a divergent approach.

Although exams may be preferred, it does not mean that this assessment practice is a good fit for RPL. For example, a recent small-scale study at a university in Finland (N=21) found that students preferred an RPL exemption exam to other assessment methods [17 p. 121]. This finding seems surprising given the myriad of prior learning of English reported by the RPL seekers, both in that study and in the present one. While the reasons for this preference are unclear, a familiar assessment option may be viewed as 'safe' over a less familiar one that requires gathering evidence and a comprehensive reflection of prior learning [18 p. 72]. Although preferred, an RPL exam limits what can be assessed and fails to include authentic assessment, a test facet considered important in language assessment.

From the point of view of serving (authentic) RPL seekers and supporting prior learning, a key question is what changes might improve our current RPL assessment practice? As the present findings suggest, performance testing may not be an adequate choice for covering the domains of non-formal and informal learning, which encompass a diversity of learning tasks, contexts and processes. For example, the contextual and tacit nature of the learning that occurs in these domains complicates the validity of an assessment constructed to cover a narrow sliver of content. Not only are tests narrowly focused, they are also teacher-centered. For instance, it is the teacher who decides both the content and the tasks to be assessed. The teacher is also the sole assessor of the test-taker's performance. This situation raises the question of whether testing can be properly constructed to measure out-of-classroom learning where the task type and range is much broader and richer than those taught in a course. In other words, the current teacher-centered method of assessing RPL of English appears to be inadequate for assessing learner-centered learning. This observation also implies that our current RPL practice falls short of goals supporting European educational policies regarding recognition of prior non-formal and informal learning.

The pedagogical implications of the present study suggest that a more divergent assessment practice would be a better fit for the purpose. Ideally, the RPL assessment practice would be more learner-centered, address authentic learner needs, and provide a means to document a comprehensive collection of learning achieved in non-credited, non-credentialed contexts. For this purpose, portfolio assessment is especially useful. This assessment method is designed to support learning and to capture its connections to instructional objectives. These features are relevant to assessing prior non-formal and informal learning. A portfolio assessment would also support learners trying to attain educational qualifications while learning in out-of-classroom contexts.

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Linking Practical and Theoretical Learning to Understand Mechanics of Materials

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ABSTRACT

In this research paper, a practical methodology was adopted to stimulate the students for understanding the mechanics of materials course GENG305 through a practical exercise from our life to explain the principals of the subject by building a structure with a regulated specifications, testing the structure under static load until failure, then repairing the structure and re-applying the load until second stage of failure so the structure would fail under the impact of different types of mechanical stresses. Throughout the exercise, the students were requested to explain the causes of the failure, types of stresses involved and proposed a procedure for the repair, since the whole practice is under evaluation. A constructive discussion was conducted with each team during the assessment to ensure that the students are in the right direction of the analysis. At the end, the students' feedback was collected and analyzed to evaluate the experience of the proposed methodology that showed many positive directions that could be implemented for other engineering courses.

Conference Key Areas: Continuing Engineering Education and

Lifelong Learning, Attractiveness of Engineering Education, Engineering Education Research

Keywords: Mechanics of Materials, learning, practical, failure

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INTRODUCTION

Mechanics of materials is a fundamental topic in the college of engineering especially for the civil, architecture, and mechanical engineering department. At UAE University, this course Mech305 is required for the aforementioned engineering departments. Students enrolled in the mechanics of materials after they finish statics course. The course has three credit hours, which consists of two hours lecture and two hours lab and tutorial per week. Both lecture and the lab must cover the learning outcomes of the course that is described in the course syllabus. In general, the course is considered a difficult to the students [1].

Many attempts have been made to reduce this impression through the development of physical demonstration models or using video for classroom use [2], development of computer programs to help, stimulate and facilitate independent learning by students [3], concept inventory research to uncover the underlying cause of learning difficulty with the content [4]. An integrated approach of a new course linking mechanics, materials science and design were developed entitled ‘Mechanics and Materials in Structural Design’, that educates students in the total design of structures, where one important aspect of this approach is to develop multimedia-based virtual laboratory modules [5]. This module links the mechanics experiment with the fundamentals of materials science and highlights its usefulness in generating design information. On the other hand, a new pedagogy in teaching Strength of Material is experiment-oriented in teaching different units of the Strength of Material in contrast to the math-oriented approach popularly used in most of the Engineering schools. New experiments emphasize on visually observable mechanical behavior so that students can visually inspect the deformation of members when subjected to different types of loadings [6]. A software package, called MDSolids, presents an alternative to tutorials, worksheets, or basic analysis packages. The software was conceived as a tool to help students solve and understand homework problems typically used in the mechanics of materials course. The software is versatile, graphic, informative, and very easy to use. It had been used at a number of schools around the world, and feedback from users has been uniformly positive and enthusiastic [7]. A learning and teaching approach for the course Mechanics of Materials and Structures to level 3 undergraduate Mechatronics and Mechanical Design Engineering students as well as the various technologies that are used to enhance the learning and teaching of the course [8]. To encourage students to be collaborative learners, the students are given the opportunity to generate questions and answer questions generated by other students. This has been implemented using the open source learning resource Peer Wise. Students can learn by both developing questions and answer questions posted by their peers. As matter of fact, the Materials Science and Engineering department at MIT is large enough to offer its own Mechanics of Materials subject, and this subject naturally seeks to blend the materials and mechanics aspects of the discipline. A series of NSF-sponsored, web-available modules are being prepared to support this approach, along with Java applets and other electronic teaching aids. Roylance et al [8] provided an overview of this effort, emphasizing the teaching of fracture mechanics and microstructural failure mechanisms. Jianwei et al [9], showed that during the teaching of material mechanics, with the core of practical cases can not only retain the original advantages but also overcome its disadvantages at a maximum level. Accordingly, the advantage of this methodology is to carry on. Proofed by practice, that the teaching of material mechanics with a core of practical cases is one kind of very effective teaching model. Wei [10] developed a short course on the mechanical properties and testing of materials in conservation. The goal is to provide students with a basic understanding of what mechanical properties are, how they are used in engineering practice, and how this can be translated to their conservation practice. The course has been successful due to its simplicity, and its emphasis on proper terminology and practical experience. Kadlowec and Navvab [11] had adopted active strategies that also interest and engage students in the learning process could be used to promote learning in educational settings. In an effort to interest and introduce students to engineering principles through a familiar context of sports, a multidisciplinary team of academic staff and students from two universities and a county college developed a set of hands-on modules. Experimentation in one such module allowed for students to explore mechanics of materials at an introductory level. Muscat [12] used the four-stage Kolb learning cycle was used as a model on which to design the set of laboratory activities. An example of a topic in mechanics of materials is used in this study to assess the students' response in terms of Kolb's proposal for effective learning. The topic selected (combined bending and torsion) is part of the mechanical and civil engineering degree curriculum.

The mechanical engineering students of the UAE University enroll in the mechanics of materials course GENG305 at the third year. During teaching in the course, it has been noticed that usually the students face difficulty in understanding the impact of the stresses on the failure of the structures, especially when most of the course subjects are coved and this observed before the final stage of the course. In order to overcome this weakness and before two weeks of the final exam, a comprehensive project was delivered to the students that cover the essential parts of the course material, axial, bending, direct shear and buckling. The students had to choose a structure from the University campus and find the actual dimensions and then using the mechanics of materials principals to calculate the stresses. Part of the project requirements is to build a model on a small scale to represent the structure under certain conditions for the groups, and then during the assessment session, a load was applied gradually to the structure until it fails. Students should explain the reasons and try to repair it and re-apply the load again. This practice results a constructive discussion to clarify the reasons behind the failure of the structure. A survey was distributed after the session to collect the students' feedback that was analyzed to evaluate the knowledge.

1 THE EXPERIMENTAL PROCEDURE

1.1 The approach

A paper coated polystyrene foam board of thickness 5 mm (lightweight, strong, easy to cut, they have excellent processing properties) as shown in Figure 1 was used to build the lab model, where four groups used the same boards to maintain consistency. The students were to be asked to select a frame from the University campus as illustrated in Figure 2. The students allowed selecting part of the structure to build their model from the paperboard, so the whole groups followed the suggested part. A 50 mm paperboard was the limit of the paperboard width, and that no more one layer is used. Besides, a scotch tape with a specific type is the only bonding tool that could be used to connect the pieces of the paperboard. The groups agreed on one model to be built as shown in Figure 3 with the dimensions adopted.

 

Fig. 1. Paper coated polystyrene foam board

Fig. 2. Steel structure from the university campus

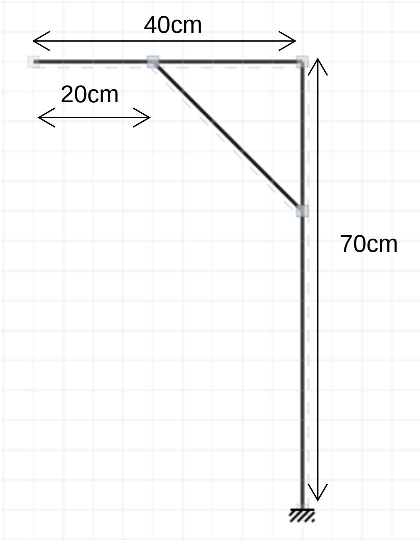

Fig. 3. The structure model

1.2 The applied load

After completing the model that was done by the groups, an incremental downward load of 0.1kg was applied on the left side of the structure and the students are instructed to collect observations. Once, a failure or large deflection occurred, the experiment was stopped. An open discussion was conducted to clarify the reasons as well as the alternates for the repair to overcome the consequences. As along as the structure was maintained and ready for another test, the students continue their job until another failure or large deflection occurred.

1.3 The structural model

The model was built using traditional paper coated polystyrene foam board as shown in Figure 4, where 50 mm is the limited width of the elements that can be used to build the structure. Moreover, no glue was permitted for the bonding purposes neither any sort of adhesive, except using traditional scotch tape. T-section was chosen at the beginning as a proposed structural element for both vertical and horizontal elements, whereas a parallel, two flat elements were fixed with the structure using a pencil to represent the joints. Triangular stiffeners were installed at the bottom of the column, that is similar to the real stiffener as shown in Figure 5, but later it was realized that they were not sufficient to resist the moment at the fixed support, therefore bigger pairs were used to resolve this problem, as depicted in Figure 6. Moreover, the T-section was modified to be H-section at the first applied load due to the instability observed in the structure when first launched the first load step.

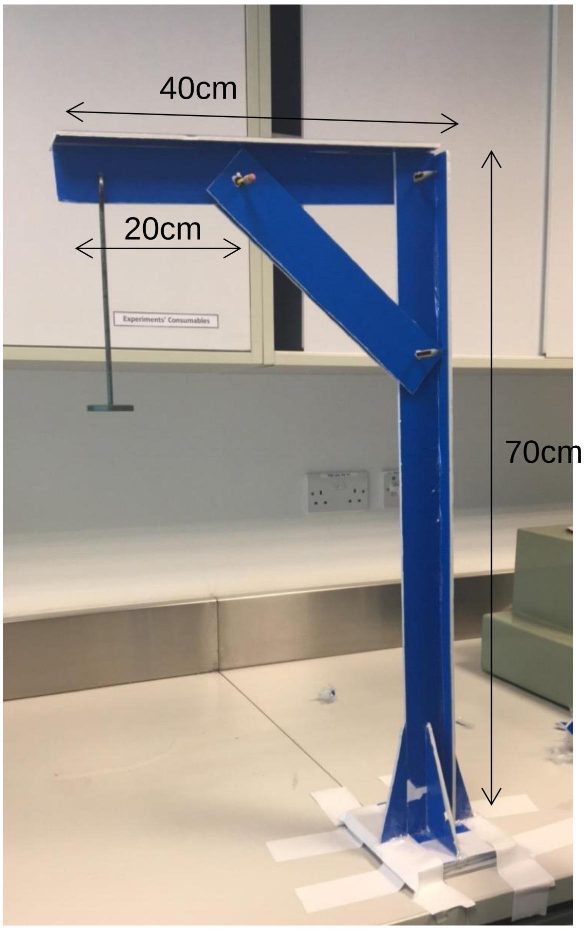

Fig. 5. Real stiffeners

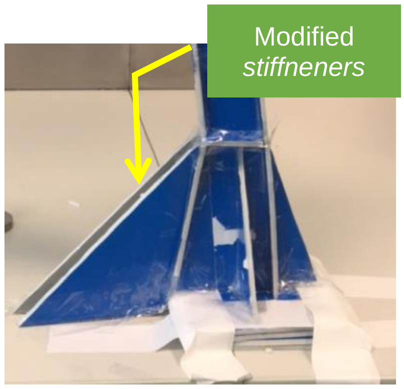

Fig. 4. The paperboard structural model

Fig. 6. New stiffeners

1.4 Types of stresses studied

Mainly three types of the stresses are considered in this learning experience:

Axial stress
$$\sigma = \frac{F}{A} \tag{1}$$

Bending stresses
$$\sigma = \frac{M.y}{I} \tag{2}$$

Shear stress
$$\tau = \frac{V.Q}{I.b} \tag{3}$$

And the critical bucking load
$$P_{cr} = \frac{\pi^2.E.I}{L_e^2} \tag{4}$$

The aforementioned formulas are used in conjunction with observations to explain the failure mechanism based on the mechanics of materials concepts.

2 EXPERIMENTAL OBSERVATIONS

It has been observed that the columns bracing are subjected to high deformation due to axial compressive load, which caused bucking of the braces, as illustrated in Figure 7. Although an attempt was done to add internal stiffeners to the two braces, still the braces failed eventually under bucking, as shown in Figure 8. The whole students with the theoretical explanation understood the buckling failure.

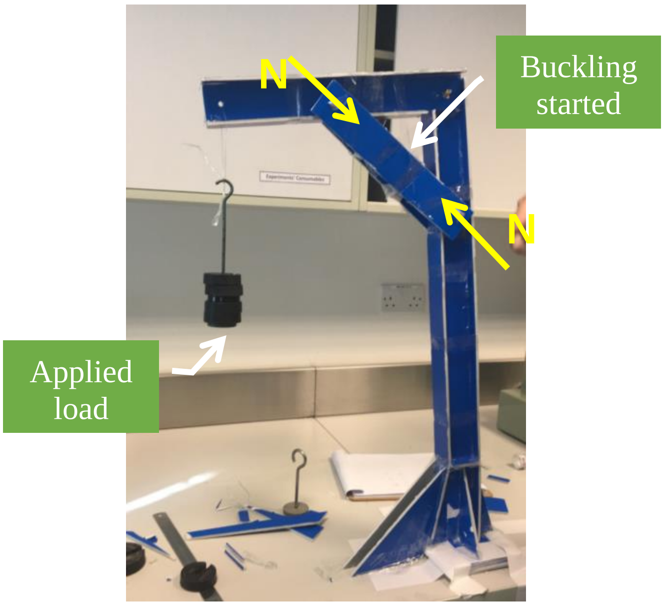

Fig. 7. Bucking started at the braces

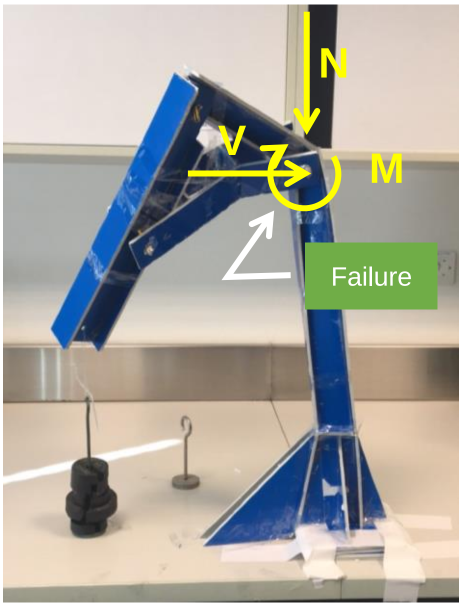

Fig. 8. Structure axial load

With applying more incremental load, and despite of the reinforcement done to the failed braces, the structure subjected to high deformation at the column which cause eventually to the failure of the column at the joint, which was caused by the action of three types of the combined loading, bending moment, shear force and axial load. The section failed at the joint, due to the high stresses as well as to the stress concentration caused by the hole of the bolt. A satisfaction and a happiness atmosphere were prevailed among the students due to the unique experience that they faced. Eventually, a survey was distributed and the feedbacks were collected, as listed in *Table 1*.

Table 1. Students' assessment of the lab

(1=very low, 2=low, 3=good, 4=very good, 5=excellent)	**1**	**2**	**3**	**4**	**5**
1. How do you evaluate the project idea	☐	☐	☐	☐	☐
2. Do you like doing a project instead of HWs	☐	☐	☐	☐	☐
3. Do you think a project covers multiple subjects is a good idea	☐	☐	☐	☐	☐
4. Did you understand the axial, SF and BM through the project	☐	☐	☐	☐	☐
5. Did you distinguished between the hinge and the fixed edge	☐	☐	☐	☐	☐
6. Did you like the experience of testing the project practically	☐	☐	☐	☐	☐
7. Are you able to understand why it did fail	☐	☐	☐	☐	☐
8. Were you able to fix the damage happened based on your understanding	☐	☐	☐	☐	☐
9. Were you able to build the structure from carton and tape without glue	☐	☐	☐	☐	☐
10. Have you ever analyzed a real structure in your study	☐	☐	☐	☐	☐

3 RESULTS AND DISCUSSION

In general, the students to reflect their feedback about the project experience answered the questionnaire given in Table 1. However, the detailed evaluations of the questions are shown in Figure 9. In general, question one has attracted 79% of the students, which is the highest percentage among the whole questions side by side with questions six and nine., that reflects the overall positive feedback of the project as well as it measures their satisfaction in conducting a practical experience in the course. Although this percentage is reduced to 64% in question, two, which gives the impression about their preferable of the project over the homework, but still the results, are encouraging. Around 93% of the students believe that the project covers multiple subjects of the course that is revealed through the very good and the excellent feedback evaluation, which is an important point at this stage. Nevertheless, this satisfaction for question four is decreased to 72% of the majority positive feedback (i.e., very good and excellent) except the good, which is still an outstanding achievement. A 100% of the positive feedback goes to the understanding the difference practically between the hinge and the fixed support, whereas as grasping the failure causes is dominated by 50% of the excellent and 50% of the very good, which means the obviousness of the practical failure in conjunction with the theoretical explanation. Questions 8 and 9 are a mirror of the hands-on skills that the student have gained as well as reflecting their ability to repair the damaged element during the lab, which is shown by 93% for question 8, and 86% for question 9 for both very good and excellent feedback respectively. Whereas, 7% of the students seem to have poor hands-on skills dealing with building things from soft boards. Eventually, it is clear that a little percentage, 7%, have excellent experience in analyzing structures before, and that is opposite to the students with low (i.e., 21%) practical side, but still 71% have a good and a very good knowledge.

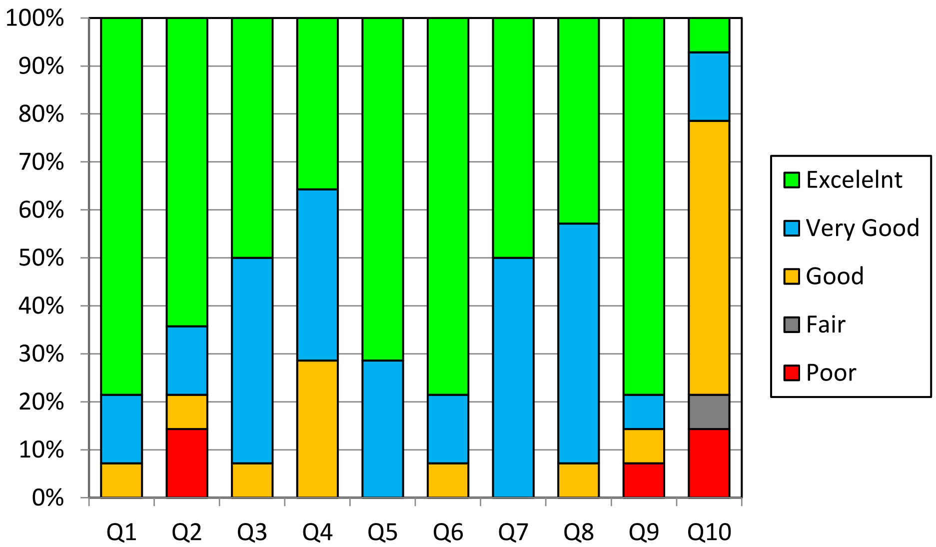

Fig. 9. Results of the students' evaluation of the project

4 SUMMARY

The objective of the study is to improve the students' learning by introducing performance oriented active learning elements in the subject area of the mechanics of materials. Therefore, by linking the theoretical and a practical practice as an additional practice would improve the students' grasp of the course subjects. The advantage of the pedagogical method is to stimulate the students through applying load to the structure until failure, and then they have to explain the reasons behind it. However, it has been observed that the in-class practical test that covers multiple subjects got a positive feedback and satisfaction in general from the students through understanding the types of the stresses and the failure types and causes

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Engineering Course Specially Designed to Face Retention Issue

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ABSTRACT

Many engineering colleges have been facing the retention problem in engineering programs due to difficulties and lack of knowledge about what really means being an engineer. It is mainly due to the fact that the first 3 years are particularly intense and hard. A possible way to overcome this period is to implement a new kind of course more attractive and dynamic, which is the idea of COPEC's engineering education research team, to embed a course with a more interesting activity for students in the first year. It is a short-term workshop in order to show the students the possibilities of performing as engineers in a global environment – a project developed for a private university in order to augment the retention rate in their engineering courses.

Conference Key Areas: Curriculum Development, Attractiveness of Engineering Education.

Keywords: engineering retention, project development, real world work, international skills, innovations.

INTRODUCTION

Fortunately, the rich base of research and practice in engineering education provides clear clues of what is needed, as long as we are willing to step out of the box to tap knowledge and techniques that have previously been on the fringes of practice.

Today, more than ever, a nation's prosperity and security depend on its innovative spirit, technological strength and entrepreneurial skills. To capitalize on opportunities created by scientific discoveries, the nation must have engineers who can invent new products and services, create new industries and jobs, and generate new wealth.

It is also a fact that "under skilled" workers are disappearing, due to automation and low-cost labour markets abroad. Nations worldwide recognize, (particularly in the western part of the globe) that it is urgent to train a larger number of engineers with technical knowledge and soft skills.

In general, engineering programs are full of important core subjects, however it is necessary to innovate and find ways to embed the curricula with important topics to attend the current global trends. Another important fact is that once engineering skills are internationally portable, leading to international mobility that engineering can easily provide and it is, in fact, an increasing trend. Intercultural skills, knowledge of languages and cultural prejudice management are very important because the opportunities are broad less and it is important to be able to adapt to any different cultural environment.

Another fact, which is not new, is that many engineering colleges have been facing the retention issue, due to the difficulties and lack of knowledge about what being an engineer really means. The first 3 years are particularly intense and hard. A possible way to overcome this period is to implement a new kind of course, more enticing and dynamic. This is one of the proposals of COPEC's engineering education research team: - to embed a course with a more interesting activity for students, sooner, in the first year. It is a short-term workshop in order to show the students the possibilities of performing as engineers in a global environment – a project developed for a private university in order to reduce retention rate among students of engineering courses.

It is a 3 months' period in the second semester of the 1st. year, when the students have different classes, which are more dynamic due to the mix of site visits, lectures, project proposals, travel period and project presentation. It is a very dynamic experience that provides the students a clear view of what it is to be an engineer and what their possibilities for the future are.

The main objective of this project is to provide a sophisticated period to implement integrated environments for teaching/learning systems. It is in fact a way to reduce the evasion of engineering courses, showing a glimpse of what it is to be an engineer and the wide varieties of opportunities worldwide.

1. COPEC: SCIENCE AND EDUCATION RESEARCH COUNCIL

The importance of professional work is observed in the results of projects and actions. In order to accomplish the difficult task of increasing the retention rate of a program the COPEC – Science and Education Research Council has been hired with this objective. COPEC is a multi-disciplinary organization that is a leader on advance science and its application to the development of technology serving society. It started its activities sixteen years ago and, since then, this organization has made a major contribution to the development of science and education, working to increase the best practices in several research fields.

Integration activities, promoted by COPEC, provide qualified coordination and building partnerships, because COPEC is an organization that brings together scientists, who share the mission of promoting and developing science, technology and education.

The objectives of COPEC are to promote professionalism, integrity, competency, and education; foster research, improve practice, and encourage collaboration in different fields of sciences.

Contents, tools and services provided by COPEC, through courses, publications and consultations, with national and international experts, contribute to the promotion of the professional who wants to be privy of new achievements and service of men to technology.

COPEC enjoys respect and recognition internationally characterized by the open discussion, the free exchange of ideas, respectful debate, and a commitment to rigorous inquiry. Its IIE – International Institute of Education – is a bold and resilient source of innovation in higher education [1].

2. ENGINEERING EDUCATION TRENDS

Engineering practice, in our changing world, requires an ever-expanding knowledge base requiring new paradigms for engineering education and research that better link scientific discovery with innovation. The complex challenges that nations worldwide are facing will require engineers with a much higher level of education, particularly in professional skills such as innovation, entrepreneurship, and global engineering practice. So, engineering practice, research, and education must adopt a systemic, research-based approach to innovation and continuous improvement of engineering education. Working closely with industry and professional societies, higher education should establish graduate professional schools of engineering that would offer practice-based degrees at the post-baccalaureate level as the entry degree into the engineering profession.

Work environment worldwide has changed drastically, and today millions of professionals are also unemployed, even in advanced economies. On the other hand, businesses in economically advanced countries claim that they are often not able to find workers with the required skills. It is a fact that, this is a symptomatic dysfunction due to the structural changes that are transforming the nature of work and reshaping employment opportunities. This shows that organizations and policies are not keeping up with the changes in business practices and new technologies are defining what kind of jobs will be created and where they will be located. So there is a need for companies to redefine how and where different tasks have to be carried out, requiring new skills and new employer and employee relationships [2]. Although it has not been quantified it is clear by the number of jobs that are not filled because of a lack of qualified professionals principally in technological fields.

Generally speaking, the most imperative challenges facing the nation–global competitiveness, health care delivery to an aging population, energy production and distribution, environmental remediation and sustainability, security, communications, and transportation all set complex system challenges that require both, new knowledge and new skills for engineering practice.

Although governments need to invest in the entire system, which builds workforce skills, in some places it is up to private initiatives to offer opportunities for young ambitious talented professionals, who can cooperate for a better future of generations to come. There is no better place than universities to offer these opportunities, pushed by the enterprises. It is important for nations to train highly skilled native-born citizens as well as to attract highly skilled immigrants in order to be competitive in a global scale and assure a future for people [3].

Finally, government agents should be aware of the fact that: if there is no production system, there will be no financial resources to maintain the social assistance system. This idea of an innovative office will help to generate more quality services to improve industry service, as well as the production system, generating opportunities and jobs, which is a need everywhere in the world today [4].

3. DEFINING THE PROBLEM – NEW DEMANDS FOR ENGINEERING PROGRAMS

Engineering is a challenging and dynamic profession, however, it is unknown mainly for young population. Some very bright students are advised to pursue medicine or Engineering. For those who choose engineering however the first three years are not charming and do not show what it is to be an engineer. It does not show the students the very important work that they might accomplish in their lives. How much they will help human beings in daily life and how much engineering is important for the world and especially for the world in which people live today.

It is a perception problem; young people have negative perceptions about engineering and segments of the public at large. These negative perceptions are compounded by the fact that the public has a generally narrow understanding of what engineers actually do.

If some students think engineers are much smarter, creative and imaginative than just being good at math and science, many young people also think that engineers only sit at their desks or computers and have little interpersonal contact in their work.

Besides it is facts that presently in accordance with some reports hiring managers have to look far beyond to find the right candidates to fill open positions in several engineering sectors. One of the main reasons is because many of the responsibilities required for these engineering positions will change by the time employees are even hired.

Based in these facts COPEC team considers that currently requirements for good engineering training emphasize the importance of engineers' skills to:

- Apply knowledge of science, mathematics, and engineering;
- Design and conduct experiments and analyse data;
- Design a system, component, or process to meet desired needs;
- Function on multi-disciplinary teams;
- Identify, formulate, and solve engineering problems;
- Understand professional and ethical responsibility;
- Communicate effectively;
- Understand the impact of engineering solutions in a global/social context;
- Engage in life-long learning;
- Exhibit a knowledge of contemporary issues;
- Use the techniques, skills, and modern engineering tools necessary for engineering practice.

4. THE PROPOSED COURSE

Many studies about engineering education have suggested that profound transformation is necessary in engineering education to prepare engineers for a rapidly changing world.

So, the proposed course promotes and allows students to get to know what it is to be an engineer. It is a short-term workshop in order to show the students the possibilities of performing as engineers in a global environment with the goal to reduce the retention rate in engineering courses. The idea is to take the chance to work with a course in a civil engineering program that already exists and that is having difficulties to increase the number of students who finishes it.

It is a 3 months' period, during the second semester of the 1st year, when the students have different classes, which are more dynamic, due to the mix of sites visits, lectures, project proposal, travel period and project presentation.

Besides the proposal of a project, which students have to develop, the course includes a short study abroad period, preferably in Europe. It happens between the project proposal and the presentation of it, after the trip, ending in October before the tests period.

The period abroad includes Technical, Academic, Social and Cultural activities, all very important to have a real experience, however brief, and to understand a little about the lifestyle, history and culture of a country elected by COPEC education team.

All activities are performed within two weeks of intense work, generally in September. During this period, student also have lectures, visits to companies, universities, as well as social and cultural activities, which will provide students with a great experience and discover a different world.

It is a very dynamic experience that provides students a clearer view of what it is to be an engineer and what their possibilities for the future are. The students acquire inputs and ideas that instigate their imagination.

The period abroad can be done in more or less days according to the needs of the course proposal for the period. Activities can be altered to fit the availability of organizations and people involved, as well.

5. APPROACH

The course has three phases:

Phase 1 – when the students have lectures of industry, preferably, and are challenged to develop a project proposal in a specific engineering theme.

Phase 2 – when the students go abroad for a short period.

Phase 3 – when the students present their project proposal to a group of invited professionals who evaluate them.

The course has been designed to introduce the world of engineering to the students and also to present them a bit of another culture, touring through several academic and business environments, developing cultural activities, exploring the history, experience local public services, where engineering plays an important role. The proposed course consists of an opportunity to improve the training of engineering students, providing them with an excellent experience, by meeting the practice of engineering in many sectors as well as providing them an experience abroad.

The students are graded and the best project group is invited to have an internship in one of the enterprises of the region, interested in having some of these students for a training period.

6. DETAILS OF THE PERIOD ABROAD

The period abroad includes lectures, visits to companies, universities, as well as social and cultural activities, which will provide students with a great experience and allow them to discover a different world.

The course can be done in more or less days according to the availability of the group of students. Activities can also be altered to fit the goals of the course. It is in fact a very flexible part of the course.

Within the academic activities, students have classes and participate in activities in different universities.

Technical activities include visits to some companies of the visited country. The lecturers are very technical in content in general, being some of them of administration aspects of projects and business generated from them.

Visits to laboratories and research canters are the main activities developed in a framework pre-established in accordance with the objectives of the program. In general, they follow the main theme developed by the students' groups in their project proposal. For example, "the development of senses for data collection in subway fluxes in rush hours", one of the main themes developed by the groups in the year 2015.

During social activities, students have the opportunity to visit some local meetings with other students in a friendly environment.

Cultural activities provide students with concepts of history and art, as well as the way of life, including guided tours, visit to museums, and other related activities.

All proposed activities take place in a way that students can experience the educational environment, business, culture and lifestyle of the country.

The proposed course consists of an opportunity to improve the training of engineering students, providing them with an excellent experience abroad and to acknowledge the international career that an engineer can develop. Besides the technical knowledge they acquire in site.

The course has the reputation of being demanding, rewarding and intense providing a challenging educational environment by following high quality standards. The course is also developed to provide the participants also some free time to relax and enjoy the city and all it can offer.

Accommodations could not be better; students stay in comfortable hotels with all facilities in downtown areas of cities [5].

Fig. 1. Schedule for 2016/2017

7. COURSE SPECIFIC OBJECTIVES, GOALS AND EXPECTED RESULTS

The primary goal of the course is to foster curiosity and passion for the engineering profession. To provide engineering students an opportunity to experience different environments in the chosen profession.

Furthermore, the course aims to:

- Improve the academic and leadership skills;
- Living in different cultures;
- Strengthen their career goals;
- Search;
- Travel;
- Global experience;
- View new opportunities;
- Enrichment of life [6].

The project goals are:

- Providing an international academic experience;
- Make the students feel what it is to be an engineer;
- Assist in the development of critical analysis;
- Provide the overall experience.

The expected outcomes of the extra academic classes are:

- Dynamism for undergraduate careers;
- Long-term friendships;
- Technical skills and knowledge;
- Experience different cultures and histories;
- Enrichment of life;
- Valuing the profession [7].

8. PARTIAL RESULTS OF THE COURSE

2016 is the third year of this 1st year effort program and the results are as follows:

Table 1. 1st year effort program and the results

YEAR	1st. year students number enrollment in Engineering	*students number enrollment in the special course	% of enrollment rate
2014	213	68 students	31.92%
2015	225	77 students	34.22%
2016	236	95 students	40.25%

The College conducted a survey among the students participating in this program and the results are as follows:

Table 2. Survey among the students participating in the Program (2014-2016)

Questions	2014	2015	2016
Satisfaction with knowledge acquisition	56%	64%	72%
Satisfaction with international experience	62%	68%	69%

Satisfaction with acquired skills	65%	79%	81%

For the year 2017 (by the presentation of this work) the proposal is to have a complete chart with statistics about the retention rates acquired with this program so far. The decision relies in the fact that it is necessary at least three years of program to have significant data.

9. CONCLUSION

At such a technological singularity, the paradigms shift, the old models must be discarded, and a new reality appears, perhaps beyond our comprehension. It is clear that, along history, universities have become international organizations, not only receiving students from all parts of the world, but also through international research partnerships and providing students opportunities. No doubt that this role has become imperative for countries in order to keep up with the challenging and global educational and research environment. Best universities attract the best students and best students make the university better.

The enhancement and promotion of students' quality training, as well as employability, brings financial resources, increases teacher's quality and promotes regional development, along with the future professional, no matter the field, but mainly in engineering. It is necessary to adopt a systemic, research-based approach to innovation and continuous improvement in engineering education, recognizing the importance of diverse approaches.

And so, this course, in particular, promotes engineering courses, trying to overcome the retention issue, providing the students a glimpse of what it is to be an engineer and increases their possibilities of finishing the program and also developing an international career besides its contribution for the betterment of human kind.

10. ACKNOWLEDGMENT

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Passing our students while we fail upwards: Reflections on the inaugural year of CSU Engineering

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ABSTRACT

CSU Engineering University introduced its radical new Civil Engineering degree in 2016. The program (described in full elsewhere) was deliberately designed to eschew the traditional lecture-lab-model of engineering education, and instead focus on training student engineers in an authentic and actual engineering work environment. The program was built upon a strong foundation of engineering educational research from around the globe, with clearly identified best practices being woven together to form the CSU Engineering curriculum. Each of the pieces was chosen for its proven impact in its original environment; with the challenge for CSU Engineering being how to make the integration of these pieces work without the underlying traditional environment. While the overall program rollout was a success, there were a number of mistakes made along the way; this paper highlights some of our key learnings, and the improvements made for the second year to overcome them.

Conference Key Areas: Curriculum Development, Quality Assurance and Accreditation, Skills and Engineering Education

Keywords: New Program Development, Academic Integrity, Program Culture

INTRODUCTION

CSU Engineering is a new program established in 2016. This program was established from scratch in a university that has not previously taught engineering. As such, there was a significant opportunity to build a revolutionary new program structure and philosophy [1]. With this opportunity, however, brings the risks of operating something new, and the inevitability of making mistakes. This paper will outline the key changes necessary for the second year of our program, based on the lessons learned from the inaugural year of operation.

To a certain extent the program has been immunised to its mistakes as a result of its culture and philosophy, and our clearly defined mission of living our spoken values. We have a clearly defined goal of educating entrepreneurial engineers; as such it is essential that we ourselves demonstrate an entrepreneurial mind-set and outlook. All of our students are aware that ours is a new course, and that it is in the first years of its operation. As a result they are more understanding that the program is yet to settle down into steady-state operation.

A key objective of the program is to train entrepreneurial engineers; in order to be authentic in this space the program itself, and the academics, need to be (and need to be seen to be) entrepreneurial. Entrepreneurship requires the taking of risks, and a willingness to make mistakes along the way. An important part of entrepreneurship is the ability to "fail upwards" - to make mistakes, learn from them, and improve practice. In this way some of our mistakes were forgivable as providing an authentic teaching environment; although care had to be taken not to rely upon this as an excuse. In this culture, our mistakes are not to be hidden – they are to be presented to the students as teachable moments, and as examples of what it is to be an entrepreneurial engineer.

1 TOPIC ACQUISITION

Students at CSU Engineering complete a sequence of three semester-long PBL-style challenges across the first three semesters; after this point they then commence work placements in industry. The underlying technical curriculum that supports the projects is broken down into fine-grained topics, where each topic is intended to take around three hours to complete. These topics are then arranged into a tree structure where the recommended learning order is made explicit (fig 1).

In this way the students engage with theory at the point at which it is required in their work, rather than in a synchronous syllabus driven manner. This has the advantage of ensuring the content is relevant at the point at which is it learned; it introduces the risk of how the student manage their progression through the tree.

Students are required to complete a total of at least 240 topics from the tree before they are eligible to go on industry placement in their fourth semester. 80 of these topics are compulsory, selected after a process of engaging with our industry partners [2] the students are free to choose the other 160 from throughout the tree.

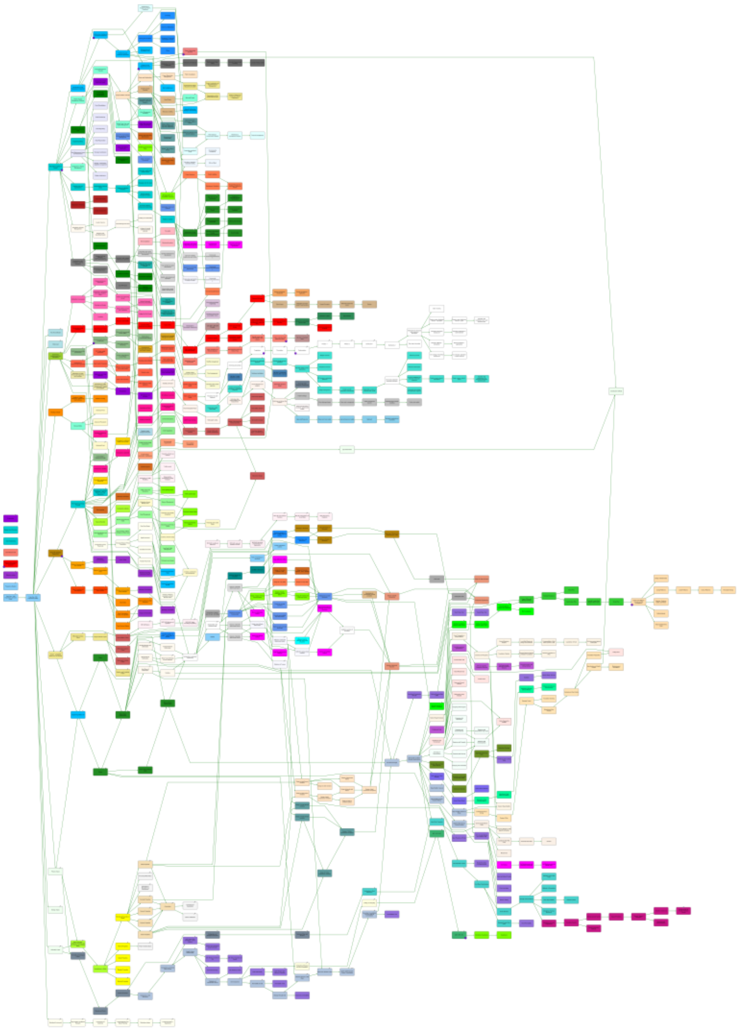

Fig 1: The Topic tree

A deliberate choice was made to prioritise independent learning over micromanagement. Intermediate deadlines could have been included throughout the subject, whether on a semester-by-semester or even week-by-week basis. The philosophical challenge with this is that it encourages a shallow, compliance-based engagement with the curriculum – topics are completed when a deadline looms, rather than topics being completed when that knowledge is valuable for the on-going challenges. It was also important that we be able to certify to employers that our cadets are self-directed independent learners, rather than students who are able to deliver when micromanaged to deadlines.

The emergent problem was that giving student engineers the freedom to manage their own workload also gives them the freedom to dig themselves a hole they can't get out of, and this was a risk that we did not mitigate well enough.

There were essentially no consequences for an inadequate rate of progression through the topic tree. The challenges had mid- and end-of-semester milestones that needed to be met, including public presentations and exhibitions at which a lack of achievement would have been clearly highlighted. The topic tree, however, has only two requirements, and neither of them manifest until the very end of the three-semester subject.

The cohort effectively bifurcated on the basis of their ability to learning independently. Student engineers with good internal management skills planned well, and worked consistently throughout the three semesters. Student engineers who lacked the self-directed learning skills consistently put off the work – utilising the flexibility not as to when they did the work, but rather as to if they did the work.

This led to two sub-cohorts – one who was up to date, and on track to successful complete the subject, and one that was well behind, and unlikely to complete. The structure of the program, however, meant that there were no explicit differences in the way that these two groups were treated. This was perceived as an injustice on the part of the up to date students, who felt that they were entitled to better treatment on the grounds that they had worked harder.

In order to prevent this from occurring with our second cohort, it was essential to give the students a regular signal as to what progress was expected from them. A public "scoreboard" with all students' progress displayed was considered as an option. This would introduce clear accountability; however it would also have consequences for students' privacy. There was also a concern that while it would potentially introduce a motivating level of competition amongst those who were performing well, it was likely to serve as a demotivator to the students who were performing the least well – the ones most in need of support.

As such a neutral cadence for progress was required. This is provided through the introduction of a "MetroGnome" (Fig 2). Each week the teaching team announce to the students the fictional progress of the MetroGnome; this allows us to set a benchmark level of minimum performance, and to trigger conversations with students who are falling behind. The MetroGnome's performance is calibrated to be somewhat below average initially, but nonetheless still adequate to eventually be successful throughout the course. While we are concerned that students have taken this signal to represent adequate progress rather than a minimum, evidence on student progress shows that the second cohort is progressing far quicker overall than the first cohort.

Fig 2: The MetroGnome

Another area where we did not provide sufficient up front consequence was in the balance of contributions to group projects. Teams were accountable to their mentors on a weekly basis; however it was not always clear from these meetings how teams were managing their workloads. It became apparent that some kind of moderation was necessary; however by the time this could be implemented it was a post-hoc reconstruction, rather than a week-by-week capturing of actual inputs. The net result of this process did indeed mitigate some of the more egregious imbalances; but there was little perceived direct consequence for those who were only mildly underperforming.

To address this issue, we introduced the SparkPLUS teamwork tool [3,4] commencing in the start of the second year. SparkPLUS has the ability to capture on a week by week basis each team member's perceptions of their own contributions, as well as those of their colleagues. In this way unbalanced teams can be detected; further, imbalances in perceptions of contribution can also be identified. Conflict in teams can arise from mismatches in effort; but there is also a significant risk of conflict if a student's self-perception of their contribution differs from the way their colleagues value their input.

Throughout the first semester of use, the SparkPLUS results have not been automatically released to students each week. Mentors who have chosen to discuss the results each week have been able to promote better working relationships within teams; however teams whose mentors who have not emphasised this data still display some unbalanced behaviours. The decision not to automate the release was taken on the grounds of privacy and unfamiliarity with the software; it is likely that for the second and subsequent semesters of use the information will be passed on each week.

2 ACADEMIC MISCONDUCT

CSU Engineering operates a very pro-active culture of Integrity, drawing from the safety culture to publicly count the number of days without an incident. There has been only one identified academic incident in the first three semesters of operation of the program. The origins of the incident were traced to workload-related panic, rather than a deliberate intent to deceive; nonetheless the cheating occurred and our counter had to be reset.

We did not think through all the way the consequences of sending a very loud public signal that one of the cohort had cheated. Normally incidents of academic misconduct are not publicised; they remain fully anonymous, and invisible to the rest of the cohort. We did not identify the student in question; nonetheless rumours spread throughout the student body.

In particular this served to further divide our bifurcated cohort – the stronger students were clear that it had not been one of them that had been responsible, and this increased the existing tension between the two sub-cohorts.

The tension – and its implicit lack of trust / faith – manifested again when we discussed adjusting the controls we had used to address the academic misconduct issue. We made changes in our IT systems to prevent a recurrence of the incident; however a side effect of this change was that some legitimate access to the system was made more difficult. When we discussed with the cohort whether they wished us to remove this control, and to make the learning process easier, the feedback we received was a clear no. The Student engineers preferred that we did not re-introduce the risk of misconduct, even at the price of reduced functionality – a sign that they did not trust their weaker colleagues.

3 MANAGING CADET PLACEMENTS

Our first cohort of cadet placements saw 17 Cadet Engineers placed with industry partners. These placements are full-time work positions, with the cadets paid by the employers while they are with their organisations. This placement program is one of the key points of distinction for the program, running contrary to the current trend in

Australia to move away from industry experience for undergraduate engineers. The success of this placement program is critical to CSU Engineering overall; while it has worked well in the first instance, there is still room for improvement.

The process for allocating cadets to partners was entirely utilitarian in nature. A parameterised "Happiness Function" was developed to give comparable numerical values to alternative allocations; and then a decision tree was built to generate those alternative allocation patterns. Some matchings were common to all patterns – situations where a cadet is a host's first choice and vice versa – but other matchings offered degrees of freedom to optimise a solution.

This process was not finalised until the actual "Mad Monday" on which the matchings took place; as such it was not made clear to the cadets and the hosts in advance. While there was a clear understanding that preferences would be considered, and (we thought) a clear understanding that not everyone can get their first preference, the exact mechanisms were not clear to all involved. This led to some irate conversations on the Tuesday when the matchings were announced.

In our attempts not to burden industry partners with training too early, we left out delivering important information until too late. We wanted confirmation that they were in fact going to have a cadet placed with them, so that we we're training Host Engineers at organisations that were orphaned; instead we ended up withholding information from the larger majority of Host Engineers that did receive a cadet. Key amongst that information was the process by which we place our cadets; and so the process itself was explained many times rather than just the once.

4 CONCLUSION

Balancing the need for providing a safe space to fail upwards with the need to train engineers who can be compliant with standards and specifications was a difficult challenge for the team in the first instance, particularly during the single instance of academic misconduct that arose during the year. Mimicking the safety culture has provided an accessible way for the student engineering cohort to adopt an appropriate attitude towards academic integrity.

Difficulties also arose with the extent of scaffolding necessary to develop independent learning skills in the students. Too much support undermines the goal of instilling independence; too little support leaves the students lost. The first year of the program leaned too far towards freedom rather than close monitoring; an alternative approach employing gamification rather than coercion has been implemented for our second year. Early indications are positive; however it is too early to tell if the MetroGnome will provide a sufficient level of guidance to avoid the introduction of more coercive, enforceable intermediate milestones in the future.

CSU Engineering has been able to live the value of failing upwards – our program is a safe space for reflective practitioners to make mistakes, and to improve their practices for the next iteration. The second year of our implementation is already an improvement upon the first; these measures are improving learning outcomes for our students, both directly and in the culture they support.

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Transition from high schools to engineering education

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ABSTRACT

Pre-university engineering education has increasingly received attention to attract more students to engineering and make them better prepared to enter engineering studies at university level. Denmark is one of the countries that offer established high school curriculum that makes engineering the core identity of the school. In a longitudinal research project, the cohort of all Danish engineering students who were enrolled in 2010 has been followed. This study takes a quantitative approach to highlight the differences in preparedness for engineering students who have a background in respectively general high schools and professional oriented high schools where the technical high schools represent the most common pipeline. The study highlights differences when just entering the study and just before graduation. Findings indicate that students from the professional oriented high schools do experience themselves better prepared in relation to the conduct of experiments, engineering analysis and tolls, as well as in relation to process competences as design, problem solving and teamwork. The students from the profession-oriented high schools also find themselves better prepared in relation to business awareness. On the other hand, students from general high school programmes are more oriented toward ethics. After five years of study, the differences, however, are vanishing.

Conference Key Areas: Attractiveness of Engineering Education, Engineering Education Research

Keywords: Pre-university engineering education, technical high schools, transition

1 INTRODUCTION

There is increasing attention on pre-university engineering education in technology education circles to clarify the E in STEM (Science, Technology, Engineering and Mathematics) to support the technological development [1]. In some countries, specific pre-university engineering programmes have been established, and independent technical high schools have even been founded.

Denmark is one of the countries offering an established high school curriculum that makes engineering the core identity of the school as an alternative to the more traditional high school. In this paper, we take the Danish case as starting point to compare professional oriented high school programmes such as the technical high school programmes with more general high school programmes.

1.1 Denmark – a case with pre-university engineering programmes

In the Danish high school system, different types of high school degrees exist that are relevant for engineering education. These types of degrees can be divided into two categories, whereas the latter includes an explicit focus on technical competences:

- General academically-oriented upper secondary programmes, including the Higher General Examination Programme (STX) and the Higher Preparatory Examination Programme (HF)
- Profession-oriented upper secondary programmes, including the engineering-oriented programme, the Higher Technical Examination Programme (HTX), and the commercial-oriented programme, the Higher Commercial Examination Programmes (HHX).

In 2016, more than 61892 students were enrolled in Danish high schools, with 67% of the students enrolled at STX/HF, 18% at HHX and 10% at HTX [2]. In engineering education, however, an overrepresentation of students occur with a HTX degree, as they represent around 30% of the students [3].

For the professional oriented programmes, there are a considerable higher percentage of students from HTX who move to engineering education. For example, an account from the Faculty of Engineering and Science at Aalborg University shows that among students from professional-oriented programmes enrolled from 2012-

2016, 86,75% were from HTX and 13,25% from HHX. Thereby, the technical high school, HTX, constitutes an important pipeline to engineering education in Denmark.

The Danish technical high school was inaugurated in 1982 as an experiment and from 1995 it became a permanent addition to high school education [4]. The overall differences in the curriculum and the teaching and learning methodologies have been rather stable in the two types of high schools. The technical high school apply more problem and project based learning methodologies [5], [6], and has technology subjects aiming at engineering education, whereas the general high school education is more traditionally focused on a disciplinary approach and applying classrooms teaching.

1.2 Research question and methodology

Current research elaborates on the strengths and challenges of pre-university engineering education (see for example [1], [7], [8] for pre-university engineering education case stories). The question is however, whether professional oriented high school programmes are in fact increasing the preparedness for engineering education more than general high schools programmes, and if so, in which ways.

Not much research has been done on the differences between the two types of high schools and nearly nothing on the variations in the transitions from the two different systems to higher education. A Danish longitudinal study following 20 students in their transition from high school (including both HTX and STX) to higher education concludes that almost all students experience a gap between their expectations and their actual experiences with engineering and science education [9].

In this study, we compare students from the professional-oriented programmes (HTX/HHX) with general high school programmes (STX/HF) in order to clarify whether professional-oriented high school programmes actually produce students who assess themselves as better prepared for engineering studies.

The data is obtained from a longitudinal study starting out in the Programme of Research on Opportunities and Challenges in Engineering Education in Denmark, PROCEED, (2009-2013), followed up by the project PROCEED-2-Work, (2013-2018). PROCEED-2-Work has a more specific focus on the transition to and from engineering education. In these two projects, a cohort of all Danish engineering students (N=3652) is followed from their enrolment in engineering education 2010 [3], [10]. In this article, we will look at the transition from respectively STX/HF and HTX/HHX to engineering education based on the 2010 and 2015 data. The findings presented are based on frequency analysis as well as Pearsons Chi-square to be able to detect significant differences. All statistical analysis in this article were made using SPSS.

2 FINDINGS

In studying students preparedness, we have used the list of possible engineering skills developed in the Academic Pathways Studies of People Learning Engineering Survey (APPLES) prepared by the Centre for the Advancement of Engineering

Education, US [11]. According to Atman et al. [11], these items have been developed from the ABET criterion 3 programme outcomes list [12] and the National Academy of Engineering report, “The Engineer of 2020” [13]. The engineering skills items covered can be characterised as follows:

- fundamental skills in natural science, including science, maths and the conduct of experiments
- specific engineering skills, including engineering analysis and the use of engineering tools
- process competences, including problem solving, design, teamwork, creativity, communication and life-long learning,
- business-oriented skills, including professionalism, business knowledge, leadership and management skills
- contextual skills, including awareness of the societal context, global context, ethics and contemporary issues.

In the following, we present our findings on how prepared students assess themselves to be in this respect when 1) entering engineering education 2) being at the end of the study.

2.1 Perceived preparedness entering engineering education

Figure 1 show the frequency and significance level (* $p < .1$, ** $p < .05$, *** $p < .01$) in the 2010 data considering students, they felt well prepared to apply the emphasised engineering skills.

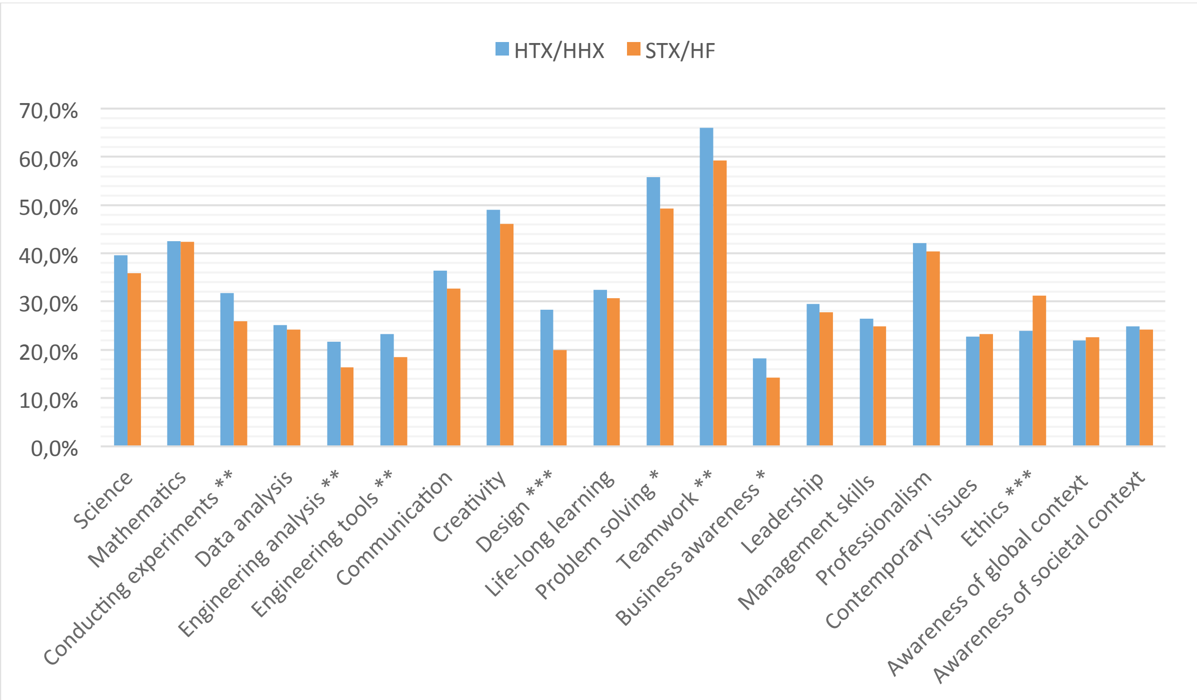

Fig. 1. Frequency and significance correlation(* $p < .1$, ** $p < .05$, *** $p < .01$), 2010 data (N=1241). The score show the percentage of students who felt prepared to apply the listed engineering skills.

For the specific engineering skills, including engineering analysis and the use of engineering tools, the students from HTX/HHX felt significantly better prepared. This result mirrors the HTX identity as engineering-oriented. For the so-called fundamental skills in natural science, the HTX schools have a higher sense of preparedness, although this difference is only significant for the “conducting experiments” item (**). These conclusions should be seen in relation to the admission requirements for engineering education including that students have attended high-level courses on math and selected natural scientific subjects.

For the process competences, students from HTX/HHX find themselves significantly more prepared in regard to design (***), teamwork (**) and problem-solving (*), whereas no significant difference occurs regarding communication, life-long learning and creativity. Thereby, the higher emphasis on PBL and the ability to “create” actual products at HTX does not seem to lead to a higher sense of preparedness considering creativity compared to students at the general high school. On the other hand, teamwork and problem solving elements of Problem Based Learning (PBL) are clearly reflected in the results.

Regarding business-oriented skills, including professionalism, business knowledge, leadership and management skills, there were only significant differences in regards to business awareness (**). The latter might be related to the increased possibility to focus on specific lines of professions in HTX/HHX schools. It is however notable that the considerable higher preparedness in terms of process competences are not aligned with the items related to business process, like business management and organisation.

For the contextual skills, students from the general education feel significant more prepared in related to ethics (**). On all other items (global context, societal context and contemporary issues), the students from the general education have a higher, but not significant, sense of preparedness.

2.2 Perceived preparedness at the end of the study

Table 1 presents the significant differences in preparedness in 2010, as presented in the previous section, compared to the account of significant differences in 2015,

	2010		2015	
	HTX/HHX	STX/HF	HTX/HHX	STX/HF
Conducting experiments	**			
Engineering analysis	**			
Engineering tools	*			
Design	***		*	
Problem solving	*			
Teamwork	**			
Business awareness	*			
Ethics		***		

Table 1. Significance correlation (* $p < .1$, ** $p < .05$, *** $p < .01$) in 2010 data (N=1241) compared to 2015 (N=1823). The data accounts for students stating that they felt prepared to apply the listed engineering skills.

As can be seen from table 1, the differences in the sense of preparedness have been evened out through the engineering study. In a critical perspective, this might be due to teaching based on the lowest common denominator, whereas a more positive mind-set could lead to assumptions about effective peer-learning and synergy in teamwork settings and situated facilitation of students. No matter the reason, attention to this alignment process could play a higher role in engineering education research.

But what can also be seen from table 2 is that HTX/HHX students are still feeling significantly better prepared to face design challenges at the end of the study compared to students from STX/HF. Based on previous PROCEED studies, Kolmos et al. [14] concludes that the Danish Engineering students does not emphasis design as much as their US peers. However, taking the tradition of Problem Based Learning (PBL) in Denmark into consideration, it is a possibility that students (and staff for that matter) conceptualise what others might call design processes in a PBL discourse. In other words, the processes of exploring potentials to solve problems or exploring problems to create solutions including the concern for societal as well as users needs, which is embedded in PBL incorporates design perspectives – but might not be characterised as such.

3 DISCUSSION

Henriksen [4] has used a qualitative approach to study whether the HTX technical high schools prepare Danish students for a future as engineering students. The conclusion from this study is that the ministerial framework constitutes a useful framework, but at the same time a call exists for a more in-depth discussion of the concepts ‘engineering’ and ‘technology’ and a recommendation to develop the pedagogical basis for students’ to work interdisciplinary and problem orientated even further. This is aligned with other prescriptive frameworks, as for example the Standards for Technological Literacy from the International Technology and Engineering Educators Society”, which have explicit emphasis on problem orientation and a multi-disciplinarily approach in grades 9-12 [15].

Taken into consideration the early inspiration from PBL at the Danish technical schools, they seem to have chosen an appropriate pedagogical starting point when we look at the high level of preparedness related to process-competences as teamwork and problem solving. However, in the merging of students with different educational background, it can be discussed whether to much emphasis on one educational model can in fact limit the cross-fertilisation of knowledge among students. A hypothesis could be that some students from the general high-school feel behind in relation to project oriented matter, whereas students from and engineering-oriented high school could be troubled by the broader system thinking and contextualisation embedded in engineering. The challenge is to empower the students to peer-learning activities and at the same time design study activities, which can create synergy of the different perspectives.

To design such study activities, staff need to be knowledgeable of the different perspectives they are to merge. Teacher collaboration in developing students’ study competences is essential [4]. But it might be easier said than done to train staff to embrace different cultures in a more systematic manner. Furthermore, the awareness of the differences as well as the potential synergies in the two streams in the pipeline to engineering education highlighted in this study raises attention to the collaboration between staff at different high school levels as well as with university staff.

However to make this bridge, we come back to the need for a more in-depth discussion of the concepts ‘engineering’ and ‘technology’, or ‘design’ for that matter, and the need for staff training that enables staff to actually enter a such discussion. Based on Australian experiences, Thomson [16] concludes that the greatest challenge to STEM development is the lack of depth of teacher training in engineering education. On the other hand, it might also be argued that university staff needs a kind of training that enables them to move beyond own high school experience in order to understand what is at stake in the transition from high school to engineering studies.

4 CONCLUSION

In this study, we have used a quantitative approach to compare students from the professional-oriented programmes (HTX/HHX) with general high school programmes (STS/HF) in order to clarify whether engineering-oriented programmes in Denmark actually produce high school graduates that assess themselves to be more prepared to address aspects of engineering than others.

Findings indicate that the HTX/HHX students do have an easier transition to project work in engineering education as they have already been using it at the high school level. Furthermore, the HTX/HHX students are more oriented towards teamwork, design and also specific engineering analysis and tools. However, STX/HF students are better prepared to contextualise, which corresponds to the increasing focus on system thinking in engineering education.

At the end of the study, differences are however fading which leaves a discussion of the synergy of having different approaches in the pipeline to engineering education. But it also leaves a call for research on how to cope with the inevitable challenge of closing what might be rather diverse gaps between expectations and experiences when students enter engineering education.

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The study on the relationships among organizational culture, strategies of the TVE Reform Project and competitive advantage of TVE Institutions in Taiwan

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ABSTRACT

The main purpose of the paper is to investigate the relationships among organizational culture, strategies of Phase II of the Technological and Vocational Education (TVE) Reform Project and competitive advantage of TVE Institutions in Taiwan. In order to achieve the objectives, the subjects of this paper were TVE Institutions that carried out the TVE Reform Project for phase II. Research methods of this paper included literary analysis, focus group interview, and questionnaire survey. The information obtained by the questionnaires had been analyzed by Hierarchical Linear Modeling (HLM). The results were discussed to analyze the relationship between strategies of Phase II of the TVE Reform Project and competitive advantage of TVE Institutions. Furthermore, the moderating effect of organizational culture was tested.

The paper constructed the relationships among organizational culture, strategies of Phase II of the TVE Reform Project and competitive advantage of TVE Institutions for hierarchical linear model. The positive influences between variables of strategies of Phase II of the TVE Reform Project and competitive advantage were supported. The positive influences between variables of organizational culture and competitive advantage were supported, too. However, the moderating effect of organizational culture was not supported. Finally, according to the results of empirical study, the suggestions for strategies of the technological and vocational education and future research were proposed.

Conference Key Areas：Curriculum Development, Ethics and Engineering Education, Quality Assurance and Accreditation

Keywords：Phase II of the TVE Reform Project, organizational culture, competitive advantage, Hierarchical linear modeling (HLM)

1 INTRODUCTION

The paper investigated the relationships among organizational culture, strategies of Phase II of the Technological and Vocational Education (TVE) Reform Project and competitive advantage of TVE Institutions in Taiwan. This chapter is divided into three sections, hereby issues statement on the research background and motivation, purpose and scope of the study and restrictions, are described as follows.

1.1 Research Description

In Taiwan, human Resource has been the proud competitive advantage in recent years. However, the school-age population will continue decrease, which affecting the use of educational resources at all levels and affect the future quality and quantity of human resources . By globalization, international politics, knowledge-based economy of environmental constraints, industry changes in industrial structure and production styles towards high-tech development, so internationalization and localization had attracted attention from industry-oriented technical and vocational universities.

School-based management has become a new force and new trends. Schools have been established to shape the characteristics of the school organizational culture. The school management will need to integrate education resources and meet new competition. Therefore, when environment changes, marketing strategy has become one of the important tasks for leaders, the study of the industry demand-oriented technology reform project, technical and organizational college organizational culture and competitive advantage are a very important issue in Taiwan.

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1.2 Research Background

Relationship between technical and vocational education and economic development in Taiwan is extremely tight. Education is an important basis for captial construction and economic development, and personnel training has been the most important national assets in the knowledge economy tide. Industry demand for specialized functions and management personnel is more demanded. Technical and vocational schools should play an important role to teach expertise skills. Therefore, to study the competitive advantages for vocational schools is necessary and is the researching motivations of the paper.

1.3 Purpose of Study

Based on the above research background and motivation of this study, to explore the industrial demand-driven technical and vocational reform project, research on organizations and cultures of vocational colleges and their competitive advantage may provide the value of reference of policy assessment and policy execution. Based on the above context, the present study has the following main purposes: First, discuss strategy and status of vocational colleges and cultural organizations and competitive advantages of the recycling program of technical and vocational school. Second, analyze the influence of strategies of the TVE Reform Project on competitive advantages. Third, analyze the influence of organizational culture on competitive advantage. Fourth, analyze the moderating effects of the technical and vocational colleges' organizational culture between strategies of TVE Reform Project and the competitive advantage.

2 LITERATURE REVIEW

2.1 Technical and Vocational Education Reform Project

The phase II of technical and vocational education reform project is mainly combined with industry, government, academia and research resources in Taiwan. The project cultivated the required technical human resources at all levels according to the Industry and business demands and enhanced the overall competitiveness of technical and vocational education. Below are the objectives:

1. Students will possess job-required expertise.
2. Provide the high quality technical manpower to the industries.
3. Change social views on technical and vocational education.

The phase II of technical and vocational education reform project includes the following three dimensions: system adjustment, activation programs, and employment promotion (Ministry of Education, 2013) [1].

2.2 Organizational Culture

For organizational culture, Lapiņa, Kairiša, and Aramina believe that organizational performance is directly related to the organizational culture and organizational effectiveness [2]. Arabaci believes that the existing education management and leadership theory ignores the importance of values and culture. Culture is a combination of the intelligence structures by beliefs, values and actions. Cultural Gives meaning of life. The values of school administrator are the source of intent [3]

The nature of vocational college's organizational culture is different from the normal universities. Positioning, functional organization, cultural structure, organizational competition, and general operating methods are all different from traditional organizations. Kathleen also mentioned that students were affected by organizational culture such as principal's behaviors from analyzing 81 reserch reports [4]. In addition, teachers are one of the main members of the school organization, so the main policy should focus on the professional competence of teachers.

2.3 Competitive Advantage

Competitive advantage in the school section, Prahalad and Hamel believe that the concept of core competencies of the organization can integrate the advantages of resources, thereby establishing a long-term competitive advantage [5]. Lynch and Baines emphasized the school's competitive advantage not only related to these competing resources and contents, and is also closely related with the development of resources (Mazzarol and Soutar, 1999) [6].

Lynch and Baines believes that if schools want to enhance their competitiveness to gain advantage, school leaders must first evaluate the schools themselves from all perspectives; it must construct schools as learning organizations, quality of leadership, and flexible administrative system in order to diversified management style. For identification of the university's competing resource, the reputation of the structure, innovation, core competencies, and knowledge advantage are significant factors [7].

3 RESEARCH METHDOLOGY

3.1 Research Structure and Sampling

The paper focuses on the relationship among the TVE reform project, organization culture, and competition advantage of schools. The research designs the TVE reform project as independent variable, organization culture as mediator, and competition advantage as dependent variable. The sampling methods are summarizes as the following: first, the population: teachers from vocational and technical high schools and universities. Second, the samples: the research applies purposive sampling to select even numbers of teachers from each of north, central, and southern Taiwan.

3.2 Research Implementation

The samples are selected according to their geographic locations. A total of 34 schools are selected in this research, and 1,196 surveys are returned, with valid surveys of 1,183; the valid rate is 98.9%. The school-level(organizational level) and personal(individual-level) samples collected in this study. The collected data are aggregated as organizational level from individual-level so the reserch is analyzed by hierarchical linear models (referred to as HLM).

3.3 Data Processing Method

After the surveys were collected and coded, the data is analyzed by HLM to process information. In this study, the statistical significance is $\alpha = 0.05$. In this study, statistical analysis HLM verifies the hypothesis proposed in this study to explore the relationship among the strategies of the TVE reform project, organization culture, and competition advantage of schools.

4 RESEARCH ANALYSIS

A hierarchical linear mode is used to analyze the data, and according to null model, random coefficient regression model, intercept model and full model, the test to the statistical results indicate significant influence among the variables. Before hierarchical linear mode analysis, the research needs to examine each of the variables – independent, dependent, and mediator – reach the within-group agreement of σ^2 and the between-group variation, of τ_{00}. According to the research framework of this study, technical and vocational schools belong to the organizational level of each vocational school are directly responded from the teachers of each school in order to satisfy the within-group agreement and between-group variation.

4.1 Null Model

In this study, null model verifies the effect of different schools of competitive advantage, correlation coefficients, and the overall reliability. When the competitive advantage among schools are significantly different, detailed HLM analysis is required for further research.

Random Effect	Standard Deviation	Variance Component	*d.f.*	χ^2	*p*-value
INTRCPT1, u_0	0.21791	0.04748	33	240.53438	<0.001
level-1, *r*	0.50641	0.25645			

Random effect is the variation of the number r_{ij} = 0.256, U_{0j} = 0.047, significance value <0.001. The correlation coefficient of this study group, ICC_1 represents degree of variation, and ICC_2 refers to the reliability of the mean of entire group. The ICC_1 is calculated as (between-group variation, of τ_{00}) / (total variation $\tau_{00} + \delta^2$). The ICC_1 $=\tau_{00} / (\tau_{00} + \delta^2) = 0.047 / (0.047 + 0.257) = 0.156$. ICC_1 of 0.156 refers that the between-group variation that cannot be ignored, which means that the competitive advantage of vocation school is significantly related to the reform project. Secondly, the ICC_2 = 0.86 is the reliability of the mean of the entire group.

4.2 Random Coefficient Regression Model

According to the previous analysis, both ICC_1 and ICC_2 show that competitive advantages among schools are significantly different. Random coefficient regression model is applied in this research to examine the relationship between the TVE reform project and school's competitive advantage. Below is the results of the model.

The fix effect is presented as the following: γ_{00} (intercept) = 0.547, with significant value <0.001, and γ_{10} (slope) = 0.844, with significant value <0.001. Both values are significant. Random effect is presented as the following: r_{ij} = 0.065, u_{0j} = 0.193, with significant value <0.001, u_{1j} = of 0.012, with significant value <0.001. Both variables are significant.

4.3 Intercept-as-Outcome Model

The fix effects are the intercept γ_{00} = 3.787, with significant value <0.001, γ_{01} = 0.988, with significant value <0.001. and slope γ_{10} = 0.844, with significant value <0.001, γ_{11} = 0.028, with significant value > 0.001, which is not significant. The random effects are the variation numbers r_{ij} = 0.255， u_{0j} = 0. 091, with significant value <0.001. u_{1j} = 0. 112, with significant value > 0.001.

According to the above analysis, the strategies of the TVE reform project and the organizational culture have a significant and positive influences on the competitive advantage. However, the moderating effect of organizational culture is not significant.

4.4 Hypothesis Testing

According to the hypotheses propose in this study, the HLM has analyzed the variables which prove the establishment of hypotheses. Results are summarized as follows in the table below, and conclusions of the test results are shown in Table 1 as follows:

Table 1. Hypothesis Testing

Hypothesis	Research Result
H_1 : The strategies of the TVE reform project of individual-level have a significant positive influence on competitive advantage	Established
H_2 : Organizational culture variables of organizational level have a significant positive influence on competitive advantage	Established
H_3 : The moderating effect of organizational culture in the strategies of the TVE reform project on competitive advantage degree is not significant	Not Established

5 SUMMARY AND ACKNOWLEDGMENTS

The study constructs the relationship among strategies of Phase II of the TVE Reform Project, organizational culture and competitive advantage of TVE Institutions by hierarchical linear model. The positive influences between variables of strategies of Phase II of the TVE Reform Project and competitive advantage were supported. The positive influences between variables of organizational culture and competitive advantage were supported, too. However, the moderating effect of organizational culture were not supported. Finally, according to the results of empirical study, the suggestions for strategies of the technological and vocational education and future research were proposed.

Phase II of the TVE reform project has taken place from 2013 to 2017 in Taiwan. The project will conclude in the middle of this year. As the TVE reform project has successfully impact on technical and vocational schools, technical and vocational colleges and universities in Taiwan. The implementation of the project is able to shorten the gap between industry and education, and cultivates job-required expertise skills of students of TVE schools, and the government believes that this program should continue to promote. The characteristics of technical and vocational education are closely linked with the practice of industry and the cultivation of the practical needs into the industry. Curriculum flexibility, equipment updates, technical practices, and employment convergence should get a higher attention in order to effectively solve the industrial and school gaps and problems.

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Student Experience and Motivation

Industrial Management Masters' Degree Programme

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ABSTRACT

The Industrial Management Master of Science degree programme at Tampere University of Applied Sciences has a graduation rate of 50 %. The programme is non-conventional adult education but is not distance or online learning programme and has traditional lectures and other class room work. Students' inadequate motivation is expected to be one of the major reasons for low graduation rate. This paper studies student' expectations, motivation and learning experience. The motivation is defined as an incentive element which creates the mental energy to carry out a learning process. The research method was qualitative grounded theory. When we look at the students' studies beginning and end motivators, the goal based motivators that the students started with have been replaced by situational motivators. The motivation level remains high with the clear majority of the students. About half report intrinsic motivation and the other half extrinsic motivation. It looks that we have succeeded in maintaining students' motivation and the low graduation rate cannot be directly explained by low motivation. Thus, the research failed to provide a direct answer for the low graduation rate. On the other hand, it may be asked whether the main source of low graduation rate is the good motivation. Students may be so challenged and motivated by the courses that the thesis work moves to a secondary place.

Conference Key Areas: Engineering Skills

Keywords: University of Applied Sciences, Masters' Degree, Pedagogy of Higher Education, Industrial Management

INTRODUCTION

The Industrial Management Master of Science degree programme at Tampere University of Applied Sciences has existed since 2009. During this time 92 Bachelor of

Science engineers have continued their studies to the higher degree. The student intake has been 180 students. The programme represents non-conventional adult education since the average age at the start of studies is 38,4 years. The programme consists of lectures on Fridays and Saturdays and home work. All students work full time but have an agreement with their employers to take every second Friday off for their school work. This is not distance or online learning, but traditional in the sense of lectures and a permanent body of students organized into a class that meets every second Friday and Saturday. The reduced number of lecture hours is offset with more reading and reporting the reading with essay type book reviews.

The major obstacle for graduation has been various problems with the thesis work. Some part of this obstacle is related to the changes in the employers' organisation but the rest can be helped by actions that we can take at the university. Earlier we have improved the graduation rate by developing thesis supervision as reported in our previous paper. These steps included organising students into thesis supervision groups based on the thesis topic (e.g. project management or financial indicators), and selecting thesis supervisors based on their practical experience with the thesis topic. This improved the guidance the students receive during the thesis work. This paper studies student experience and motivation. The aim is to see whether the university can do more to improve students' motivation which in turn may lead to improved graduation rate.

1 EARLIER RESEARCH

There has been research with regards to student “achievement gap”, in which students underperform and don’t graduate. Most of this has been in relation to various socio-economic factors. For example, Martin, Galentino and Townsend found that students who had clear goals, strong motivation, managed external demands and who were self-empowered could overcome obstacles and graduate from college. In Finland, socio-economic factors are non-existent so none of these studies are directly comparable. In addition, the programme is non-conventional adult education, research that concentrates on students who are 18 years’ younger is most likely not accurate in our case. There are motivational studies regarding distance and online learning, but these are not applicable since we have a traditional student class and only contact learning. Our lectures are not transmitted online. We are left with a very short research review with the lack of relevant earlier research.

The motivation is defined by Illeris as an incentive element which creates the mental energy to carry out a learning process. There are many potential ways to consider motivation, e.g. extrinsic vs. intrinsic or goal vs. situational motivation. We also expect that motivation may not be steady but changes during studies.

2 RESEARCH QUESTION

The research topic is formulated to be student expectations, motivation and learning experience. Rather than assuming steady motivation and motivating factors, we want to find whether the motivation and the motivating factors change during the studies.

The data is collected qualitatively with open topic essays. The research method is grounded theory, which means that there is no research question. The research question is formulated from the collected data, i.e. data leads the research where ever it may go. The grounded theory is suitable when the research aim is only to increase understanding which is precisely the situation here. The findings are coded into categories in a mind map tree. The categories are derived from the data. When the essays have been coded, single findings are removed and only those with multiple hits are left remaining. The categories are explained and form the research results.

Students were asked during the first term to write an essay about their expectations, motivation and learning experience so far. This is intended to form a baseline. The second time, students are asked to write a similar essay at the end of their studies. When compared to the baseline we can see if there are any changes. This comparison hopefully reveals the motivational issues, failures to meet the expectations and negative and positive learning experiences. This information can be used to improve the programme and hopefully improve the graduation rate.

The topic was broadly explained but students were encouraged to write their own ideas thus reducing the guidance by the researcher. Since the research is so small we didn't use interviews, i.e. same students would both be interviewed and write essays thus the interference by the researcher would only increase.

3 RESULTS

3.1 Beginning of Studies

In the beginning of studies students reported high motivation. The number one motivating factor was career advancement, which was reported by 8 out of 29 students. Four students explained that career needs new skills. The two second highest motivators were that career needs formal qualifications and the job needs more skills. Both were listed at 4 out of 29 students. Two also explained in detail that problems at work need more solutions. The third motivator was the will to learn new things with 3 students. Two students did not list any special motivators, but felt themselves to be very motivated to study. However, two students immediately reported that it is hard to start learning new things. The remaining students reported various other things including programme's good reputation and need for time management. These were reduced out of the mind map tree since they all were single findings. The motivators are collected into Figure 1. The number represents the number of hits per each finding. A total of 21 students out of 30 were left in the mind map three with multiple findings but all reported some form of motivation.

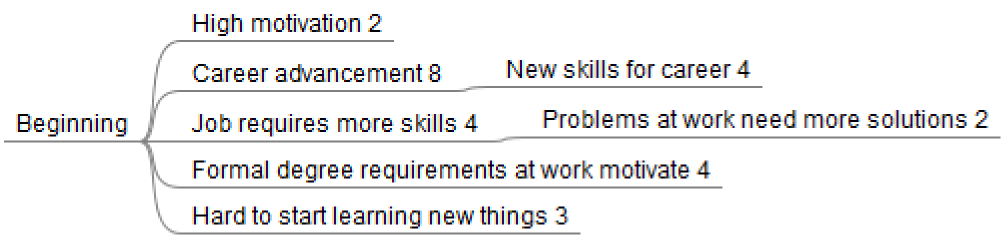

Fig. 1. Beginning of Studies Motivators

3.2 End of Studies

At the end of studies students' motivation had changed very much as shown in Figure 2. The previous motivators had all disappeared and were replaced by new programme based situational motivators. Also, as expected, some demotivators had appeared. Some students also reported both motivators and demotivators at the same time.

Two students reported increased motivation and explained that they see work and life in a new light. This is the transformal learning experience. Seven students reported decreased motivation. This was the most interesting category for our research. The decreased motivation was all based-on schedule problems. Students explained that school work piles up and family problems increase over time. Three students also reported lack of support from their employer and therefore continuous schedule problems as they were expected to have every second Friday free for lectures.

Twenty students out of 29 reported maintained motivation. This was mostly based on the very good programme. This was further divided into good courses and excellent visiting lecturers. None of the students reported any failures, negatives or failures to meet expectations during the studies. Regarding the university there was nothing negative in all the collected data. Eight students also reported the student group as one source of motivation. In addition, there were numerous other single findings that were reduced out of the mind map tree.

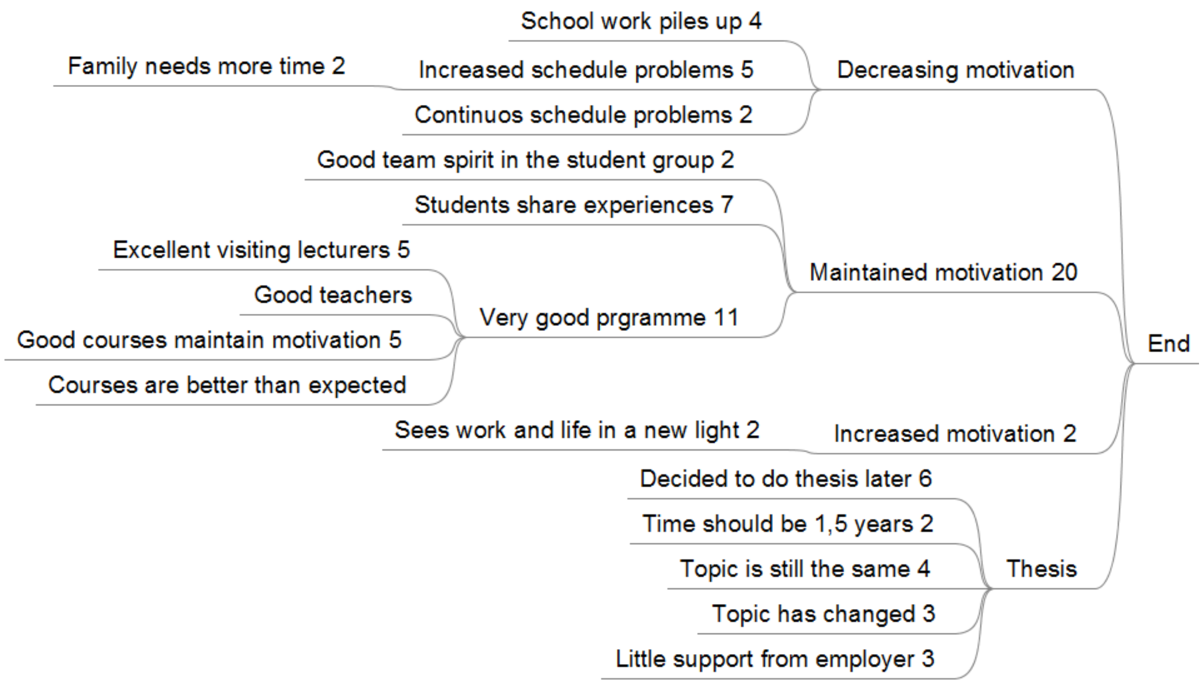

Fig 2. End of Studies Motivators and Thesis Issues

Eight students had made clear decision to postpone their thesis to the second year. Two of them felt that the time should be 1,5 years. The thesis topic had changed during the year with three students and one of the reported that he is now working on the third thesis topic.

4 DISCUSSION

Our results can be considered using Illeris' three dimensions of learning which is represented in figure 3.

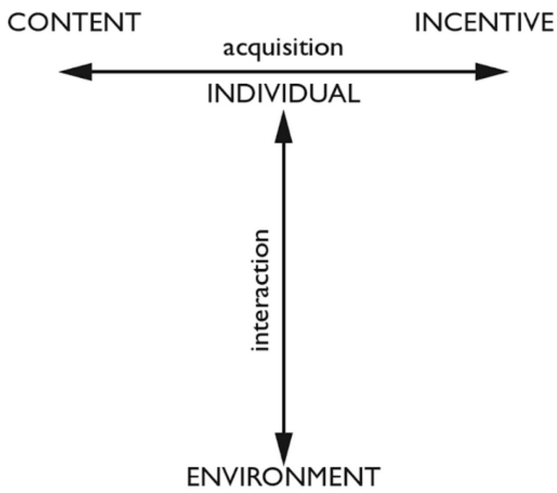

Fig. 3. Fundamental Process of Learning

The content dimension means in practise that the programme must provide challenging and interesting learning content. An individual also must have an incentive to learn, i.e. motivation. Learning is hampered if the incentive and content don't match or if one or both are not provided. The knowledge acquisition happens in the interaction between incentive and content. Since students report high satisfaction with the programme, it would seem that we have managed to provide sufficiently good content for students. At beginning of the studies, students also have personal incentives, although it is no longer so relevant at the end of the studies. However, most students are well motivated so that we can estimate that the incentive to learn still exists.

Environment dimension means in practise that the environment should provide support and supportive positive interaction for the learning experience. It would also seem that we have a good learning environment since 8 students reported a very good team spirit and that students share experiences among themselves. But the environment can be a challenge to some students since 7 students reported decreasing motivation due to time problems and also lack of support from the employer.

It is interesting to note that two students reported transformal learning experience. This, while interesting, is not the topic of this study, but clearly is something that is worth studying further. It may be that we can further develop this programme so much that we can foster more transformal learning.

5 CONCLUSIONS

When we look at the beginning and end motivators, the goal based motivators have been replaced by situational motivators. The motivation level remains high with the clear majority of the students. About half report intrinsic motivation and the other half extrinsic motivation. The assumption that low motivation would explain low graduation rate is not directly supported. The reduced motivation, that was expected to be main source for low graduation rate and delayed thesis, received support only with seven students. Their source of demotivation were the schedule problems which were largely beyond their control. For example, students cannot dictate employer's demands for attendance and effort at work. The schedule problems are hard to solve since studies do need time and effort and therefore one cannot maintain similar family life and presence at work as before, during the studies.

It seems that we have done good work in maintaining students' motivation. If we take a broader glance it seems clear that to maintain students' motivation the university and the programme must provide new motivators during the studies. The goal based motivators in the beginning of studies will not carry very long and cannot maintain sufficient motivation to the end studies.

What is then the reason for low graduation rate? The research failed to provide direct answer. On the other hand, it may be asked whether the main source of the low graduation is good motivation. Students may be so challenged and motivated by the courses that the thesis work moves to a secondary place. The general trend is that our students are not satisfied with low grades but continue extra work until they reach one of the two highest grades (4 or 5). Also, the student satisfaction index which is collected from student feedback and from all programmes at the university is the highest with this programme. In other words learning becomes more important than graduation.

The other possible explanation for low graduation rate may be that many students actually don't need formal credentials. Instead they need more skills to improve their career. Staying at the university and taking more courses is the best possible course of action if you want more and more skills.

At our university, other programmes with a low student satisfaction index and low number of applicants, tend to reach high graduation rate. It may be, that students who don't like the university and their programme, want to get the formal credentials as soon as possible. They get low grades and graduate quickly. Students who like the university and the programme want to stay long, learn as much as possible and do not always graduate. Still they recommend studies to others and we get a lot of applicants.

This small research did not provide help in improving graduation rate. Instead it set in question the idea that good motivation is needed for graduation. We have systematically taken steps to improve motivation and have reached possibly the highest motivation level at the university, but it doesn't help with the low graduation rate problem.

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CDIO as the definitive tool for Engineering Curriculum Development

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ABSTRACT

In recent years engineering education and real-world demands by engineers are increasingly more disparate, there are many examples of upgrading that our engineers must follow before starting to work for a company.

This element is associated with the fact that many students of Technical Engineering, or STEM subjects in general, do not have a future vision of the job they want to opt for, simply because this job post has not yet been invented/developed. With the purpose of preparing the Engineering students in a closer and better way to the current working world and working market, more and more institutions and individuals follow the CDIO initiative [1].

The common result, in addition to the improvement in the passing rates, is the fulfillment of the required competences in the subject and the satisfaction of having

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Intials Last name
e-mail address

been able to learn motivated, acquiring a personal security that will be reflected in their attitude in the world of work.

In this paper we show immediate practical elements to implement CDIO in the centers, but not only that, we go a little further and define a guide of guidelines so that the CDIO initiative can be an active element in the curricular development of Engineering degrees.

Conference Key Areas: Engineering Skills, Curriculum Development, Attractiveness of Engineering Education

Keywords: Curriculum Development, CDIO, Engineering Education

INTRODUCTION

In order to prepare the engineering students for the improvement of techniques and tools that meet the needs of business and society, the development of a methodology for teaching CDIO (Conceiving — Designing — Implementing — Operating) is carried out in educational classrooms.

The students perform innovation and invention of new products and systems through the implementation of the knowledge and technical foundations.

CDIO also becomes an attraction for companies looking for people able to highlight the features of the engineer as results of these students.

From the CDWG of SEFI we think that the CDIO initiative is the definitive agent to improve the curriculum of our students in an effective way.

1 THE CDIO INITIATIVE

The CDIO™ INITIATIVE is an innovative educational framework for producing the next generation of engineers. The framework provides students with an education stressing engineering fundamentals set in the context of Conceiving — Designing — Implementing — Operating (CDIO) real-world systems and products. Since Boeing issued a list of “Desired Attributes of an Engineer” in the nineties, changing higher education in engineering has been the subject of an on-going discussion among industries and engineering universities in the US and Western Europe. [2]
The CDIO initiative was designed specifically as a model that can be adapted and adopted by any University School of engineering. CDIO is a model of open architecture, it is available to be adapted to the specific needs of the University engineering programs. The participating universities ("contributors") regularly develop methodologies and material to share with others.

The objective of engineering education is to educate students who are “ready to engineer,” that is, broadly prepared with both pre-professional engineering skills and deep knowledge of the technical fundamentals. It is the task of engineering educators to continuously improve the quality of undergraduate engineering education in order to meet this objective.

We could show three premises which reflect the principal goals of this new methodology [3]:

- That the underlying need is best met by setting goals that stress the fundamentals, while at the same time making the process of conceiving-designing-implementing operating products, processes, and systems the context of engineering education.
- That the learning outcomes for students should be set through stakeholder involvement, and met by constructing a sequence of integrated learning experiences, some of which are experiential, that is, they expose students to the situations that engineers encounter in their profession.
- That proper construction of these integrated learning activities will cause the activities to have dual impact, facilitating student learning of critical personal and interpersonal skills, and product, process, and system building skills, while simultaneously enhancing the learning of the fundamentals [4].

2 OUR HYPOTHESIS

There are so many advances, the growth of active people in CDIO and the benefits obtained by the students who experience it, that makes us think that the inclusion of the CDIO initiative in the curricular development of engineering education would improve the efficiency in the integral formation of students. For this, we will show different examples and indicators of improvements.

3 PRACTICAL EXAMPLES

This guide includes practical elements for CDIO teaching in subjects such as robotics, signal processing, computer programming, or bioengineering.

We also include aspects that we think are determinant and that would have to be in all curricular development in engineering [5]. The work methodology consists of a study of both the applied subjects and the mentioned initiative, extracting those common beneficial elements in the teaching of any degree in Engineering, and raising these elements for inclusion in the correct curricular development.

3.1 Degree in Mechanical Engineering of the Chalmers University, Sweden

Internal Combustion Engines and Chalmers Formula Student are the examples of the Chalmers University of Technology as examples of CDIO courses [6].

The learning objectives for Internal Combustion Engines making use of CDIO are:

- Be able to use basic combustion terminology
- Be able to describe the combustion process inside a cylinder, and specially the difference between an SI and a CI engine.
- Use the knowledge about combustion properties to design a combustion chamber

On the other hand, Formula Student is the largest engineering competition in the world with the aim of creating better engineers by giving the students hands-on experience. Every competing team designs, manufactures and tests a vehicle with which they then compete against other teams in several different events – all of this takes place during less than one year. There are both dynamic events such as endurance and acceleration, and static events where the cost of manufacturing and the business idea of the project are presented to the judges.

The yearlong project of building a competent race car, provides the students with immense knowledge, experience and aids in moving from being a student to an accomplished engineer of tomorrow.

3.2 Degree in Computer Engineering of the Univ. of Cádiz, Spain

Carrying out more practice and less theory is the main aim of the subjects “Design of embedded computers” and “Microrobotic applications” between the third and fourth year of the Degree in Computer Engineering of the University of Cádiz. The students learn how to use a 3D printer and two numerical control machines in order to develop the project they will have to deliver at the end of the corresponding subject.

Forming groups, students will be able to apply their knowledge joining all the concepts learnt until that moment and also the technical skills, and the importance of systems integration in designing and building products. *Fig. 1.*

Professor is not who leads or directs in the classroom, but students, who are educated to lead the creation, increasing their ability to solve problems by themselves. The image of the teacher is translated to an advisor, facilitating and supporting demand for students. *Fig. 2.*

*Fig. 1.*Students supervised by the professor printing a piece modeled in 3D.

Fig. 2. Students mechanising a methacrylate sheet in a CNC cutting machine

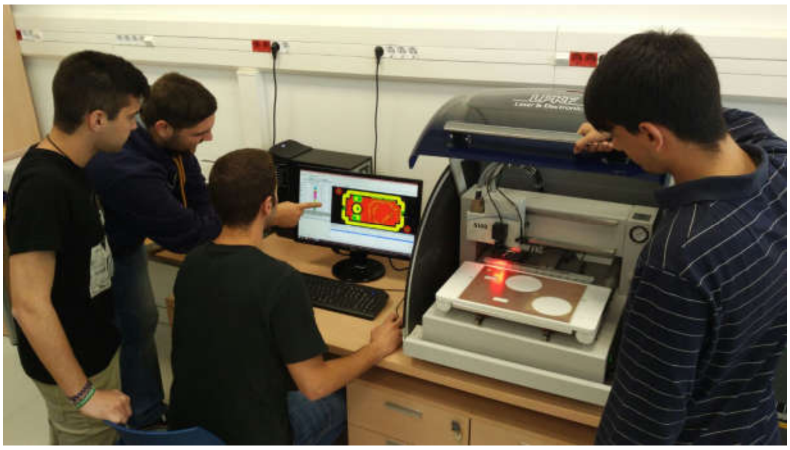

*Fig. 3.*Students printing in the machine of Printer Circuit Board the design of a prototype board.

The evaluation of the results showed that this methodology helps students to be motivated during the learning and favours the future relationship with companies though what initially will be internships demonstrating the company a different student profile that will be able to boost its benefits and since its incorporation and quickly work productively in engineering teams. *Fig. 3.*

3.3 CDIO design of five Engineering Programs at UCSC, Chile

The UCSC (Universidad Católica de la Santísima Concepción) School of Engineering redesigned the Computer Science, Industrial Engineering, Civil Engineering, Logistics Engineering and Aquacultural Biotechnology Engineering programs using a CDIO-based approach. [7]

They presented the motivations behind this work, namely, the desire to update the curricula so as to incorporate novel teaching and learning methodologies, and to improve their performance indicators. Their curriculum design process started in 2008, and to date they have completed the Conceive and Design phases of the CDIO approach, with the Implementation phase.

The active learning pilot experiences proved to be a very effective way of achieving the technical learning outcomes, as well as the so-called soft skills heretofore found lacking in previous students. Also, they were shown to highly motivate students as they engaged them in their own learning process. Introducing real engineering problems and experiences in the classroom helped students understand the fundamentals and see the theory into practice.

In retrospect, even though the curriculum design process described presented many difficulties and challenges, the application of the CDIO approach proved to be effective, synergistic and also a great hands-on learning experience.

3.4 Degree in Industrial Electronics Engineering of the Univ. of Cádiz, Spain

Fifteen students were selected for participating on this study for the subject "Automatic systems in intelligent buildings", framed in the fourth year of the plan of the engineering degree in Industrial Electronics of the University of Cádiz. [8]

The study is part of the search for alternatives to the practical teaching in the field of the home automation that allows students the access and manipulation of a domotic installation in conditions of hyper-realism, *Fig. 4*, and enables work in operations of optimization of energy efficiency, safety and comfort. Practice sessions were designed and evaluated on the control of a virtual home simulated with the software HOME I/o using different technological alternatives.

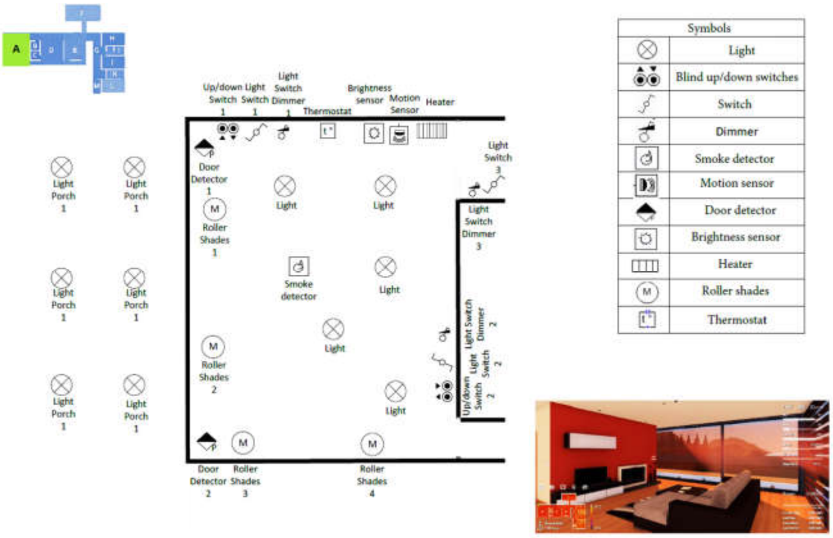

*Fig. 4.*Illustration of one of the scenarios designed for a practical session: automation of the living room of the digital housing.

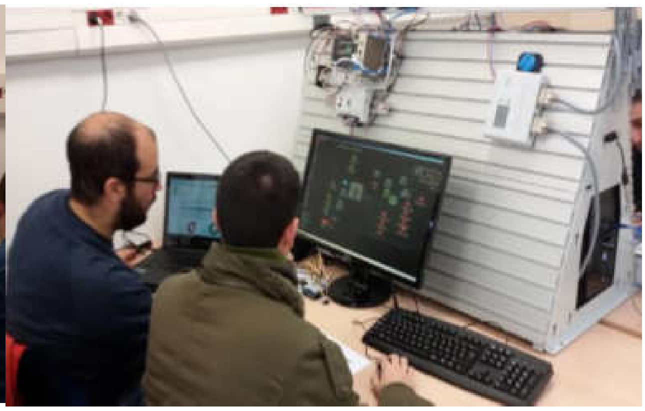

Fig. 5 y Fig.6: Students working in the automation and domotics lab in the resolution of the tasks during a work session

In terms of the assessment of this experience, the participants had a very positive attitude towards the serious game as a tool for learning home automation concepts, and was found that the game was an entertaining, easy-to-use and very useful tool. *Fig. 5* and *Fig. 6*.Participants who completed the objectives set out in the working sessions showed high values on the scale of improvement of the ego while higher values on the scale of self preservation were obtained on those participants who did not complete the proposed tasks. Students improved their esteem associating their efficiency to a winning team.

The results suggest that the game can be used as a strategy of instructive method and as a motivation tool to improve technical skills, which coincides with similar teaching strategies proposed. *Fig. 7.*

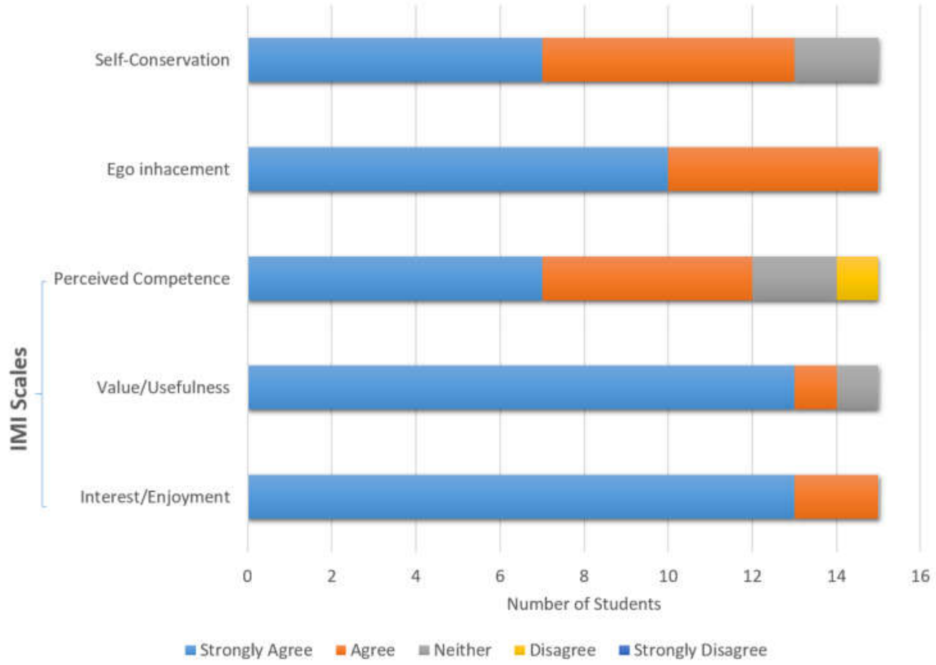

*Fig. 7.*Results of the evaluation

4 SUMMARY

A lot of students like engineering by the conviction that engineers build things and nevertheless feel disappointed by the first years of traditional engineering education when they are taught theory and complain that engineering education discourages them with a demanding schedule of the theory with little reward. By using experiential learning techniques, CDIO offers students a chance to develop a sense of strengthening and self-efficacy critical to their perception of self-worth. [9]

Showing that the education leads to higher quality employment is another factor in motivating students. Industries would prefer to hire engineers from CDIO programs because they have received excellent training in how to apply their basic theoretical knowledge to the development of practical product- or process-related projects and they will be more likely to succeed.

This new methodology, CDIO, also allows students to develop skills such as engineering reasoning and problem solving making the transition between university study and work life easier and quicker.

The list bellow shows the different subjects for some Engineering degrees marking those where the inclusion of the CDIO initiative in their curricular development would be recommended.

Information Technology Engineering
Databases Administration
Servers Administration
Computer Networks Security and Administration
Algorithm Analysis and Data Structures
Computer Architectures
Parallel and Distributed Computer Architectures
Quality of Computing Systems
Calculus
Hypermedia Systems Development
Multimedia Systems Development
Direction and Management of Software Projects
Algorithm Design
Embedded Computer Design
Computer Networks Design
Software Systems Design
Principles of Computer Structures
Principles of Physical and Electronic Computers
Implementation and Implantation of Software Systems
Software Engineering
Web Engineering
Artificial Intelligence
Network Interconnections
Internet and Electronic Business
Programming Introduction
Enterprise's Organization and Management
Perception
Language Processors
Concurrent, Real-Time Programming
Internet Programming
Object Oriented Programming
Parallel and Distributed Programming
Web Programming
Informatics Projects
Pattern Recognition
Information Recovery
Computer Networks
Security in Computer Systems
Enterprise Information Systems
Distributed Systems
Intelligent Systems
Operative Systems
Database Advanced Technologies
Computer Design Techniques

Aerospatial Engineering
Mathematics Ampliation
Avionics and Navigational Aid Systems
Materials Science and Engineering
Elasticity and Resistance of Materials
Electricity
Electrical Engineering
Aeronautic Structural Elements
Aeronautical Structures
Graphic Expression and Assisted Design
Introduction to Aerospace Engineering
Aerospace Materials
Flight Mechanics (Aircrafts)
Digital Electronic
Aerial Navigation

Industrial Engineering
Electrical Activation
Elevation, Transport and Manutention Artifacts
Microrobotics Automation
Industrial Automation
Science and Engineering of Materials
Industrial Drawing
Substations and Design of Transformation Centers
Configurable Electronic Design
Graphic Expression and Assistive Design
Electrical Facilities
Industrial Facilities
Electronic Instrumentation
Lines and Electrical Networks
Industrial Maintenance
Electrical Industrial Maintenance
Mechanisms and Machines
Fluid Mechanics
Robot Mechanics
Industrial Electrical Measurements
Electric Machines
Chemistry
Automatic Regulation
Microcontroller-based Automation Systems
Smart Buildings Automatic Systems
Power Electric System
Environmental Technology
Fabrication Technology

Industrial Design and Product Development
Science and Engineering of Materials
Technical Product Drawing
Assisted Computer Design
Communication Design
Electronic and Product Automation
Statistics
Graphical Expression and Assistive Design
Graphic Product Engineering
Material Resistance

Master in Industrial Engineering
Installations and Hydraulic / Thermic Machines
Electrical Technology
Machine Technology
Fabrication Integrated Systems
Numeric Methods
Electronic Design
Quality Management
Electronic Design

5 CONCLUSION

CDIO mode constructs the curriculum system according to the engineering concept, it trains technical experts and system engineers under the modern management mode and operation of the market mechanism [10].The training objectives of the CDIO involve the role and the social responsibility of the engineers understanding the influence of the engineering to environment and society.

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9.

Attractiveness of Engineering Education

Mind the Gap

Why do technical alumni stay in the technical sector

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ABSTRACT

This study seeks to explore why around 40% of the alumni of technical degree programmes in higher education in the Netherlands leave the technical sector in spite of the high number of technical vacancies available. The study is part of a larger project called Mind the Gap that explores professional identity as a constellation that provides a key to understanding the career choices of technical alumni, assuming that a stronger and deeper professional identity as an engineer leads to stronger commitment to the engineering profession. Through life history interviews with eight male engineering alumni from a university and a university of applied sciences who stayed in the technical sector, a contextualisation for their choices in study and career is provided. Results indicate that there are two trajectories the alumni went through, one being a more applied and focused engineering trajectory, the other being a more theoretical trajectory where engineering was one of the options amidst a number of other technical and less technical options. Further research into life histories of women and those who left the technical sector, male and female is foreseen.

Conference Key Areas: Attractiveness of Engineering Education, Engineering Education Research

Keywords: professional identity, engineering alumni, life history research

INTRODUCTION

The technical sector is continuously looking for engineering graduates. Initiatives have been taken to educate more students in Science, Technology, Engineering and Mathematics (STEM), but the number of students in these fields in the Netherlands that are in the end available for the industry is still insufficient, as around 40% of the graduates choose to work in other than the technical industry [1]. In trying to understand why all these people leave the technical sector, professional identity proves to be a useful concept. A more developed and stronger professional identity as an engineer or technician increases the chance of a choice for a career in the technical sector than a weaker, less developed professional identity. In the project Mind the Gap a digital tool was developed to understand the professional identity of STEM students and professionals and how it is related to their career choices. The tool is based on a large quantitative study. This article describes a qualitative study that is complementary to the quantitative study and helps to interpret its findings.

1 THEORETICAL FRAMEWORK

1.1 Professional identity

Professional identity (PI) is seen as a personal as well as a social constellation or a combination of both, referring to the identity of a person related to their career or job. Ashforth, Harrison and Corley [2] distinguish both content and strength of professional identity, where content is about characteristics, behaviours and norms that form the professional identity and strength refers to the commitments to these components. Research shows that PI influences career choices positively in the sense that a clear and stable PI contributes to persistence in engineering [3]. Social interaction shaping the content of PI takes place during higher education, but also before entering a course in primary and secondary school and in the family context [4]. Research on the formation of professional identity does not usually focus on early childhood and teenage years, but is most often aimed at the period in which a student selects a course, the university years and the first years of the professional career [5, 6] assuming that formation of professional identity starts in this period. Cohen-Scali [7] though studies two dimensions of PI formation: socialization for work and socialization by work, the former taking place in a family and (early) school context, the latter in the professional context. How PI is shaped throughout life experiences that start taking place long before educational and career choices were made is explored especially in educational and medical contexts, but not yet for engineers.

1.2 Life history research

Narrative inquiry provides a framework to study the development of professional identity in an in-depth and interconnected way, not trying to predict and control reality, but to make sense of the complexity of human lives. In narrative inquiry, the focus is on stories told in order to reconstruct these stories and create meaning about how people interpret the events in their lives.

Life history research is a form of narrative inquiry that focuses on entire lives of respondents in order to “(…) be generative of alternative ways of seeing, knowing, understanding and interpreting life experiences” [8]. According to Cole et al. [9] “(…) life history inquiry is about gaining insights into the broader human conditions by coming to know and understand the experiences of other humans. It is about understanding a situation, profession, condition, or institution through coming to know how individuals walk, talk, live, and work within that particular context. (…) To understand some of the complexities, complications, and confusions within the life of just one member of a community is to gain insight into the collective" (p.11). Goodson [10], in his studies on the lives of teachers, argues that in order to unravel socialization processes contributing to formation of professional identity, it is necessary to cover the socialization process during its full span of life and work, as opposed to the training period only. As the goal of this type of qualitative research contextualisation is a contextualised understanding instead of generalisation, the number of respondents is small.

1.3 Research question

This research aims to provide a contextualisation of the study and career choices of alumni who recently finished technical degree programmes in higher education. As PI is shaped by experiences – socialisation for work – , it is relevant to find out what experiences are regarded as meaningful by the alumni. The research question is therefore:

What experiences in life stages preceding the first jobs of engineering alumni shaped their study and career choices?

2 METHOD

2.1 Design

This study is based on life history interviews. A total of eight were held with alumni of engineering degree programmes. With this type of interviewing, the number of questions is limited and respondents are asked for their stories on certain themes. In the case of this study, the alumni were asked to share stories on the following stages of their lives: early childhood-primary school, 12-18 years of age, their engineering studies, the transition from their engineering studies to their first jobs and the actual working life from the start to the moment of the interview. Although the interview schedule is very open and loosely structured, the criteria defined by Dollard, cited in Polkinghorne [11], are used to fully explore the stories of the alumni. The interviews took about 60 to 90 minutes each.

2.2 Respondents

The respondents of the study are eight male engineering alumni, four from a university and four from a university of applied sciences, both in the Netherlands. The engineering degrees they graduated from are Electrical Engineering, Industrial Engineering and Management, Mechanical Engineering and Technical Physics. They graduated between 1,5 to 3 years before the date of the interview and are between 24 and 27 years of age. All respondents are male.

2.3 Analysis

All interviews were recorded, transcribed and analysed according to the method described by Fraser [12], who describes seven steps of the analysis of narratives that are suitable for the purpose of the interviews.

3 RESULTS

The results of the interviews are described according to the four stages in the lives of the alumni between early childhood and current job. Quotations from the interviews illustrate the findings.

3.1 Childhood: 4 to 12 years

> I can hardly remember things. I was definitely not in the reading corner or anything. (…) I have not played with dolls or building blocks and definitely no Lego or Technic Lego. *(Robin[1], Mechanical Engineering, University)*

Robin makes clear that Lego and building were not his favourite activities in his early childhood. Most respondents do not have very clear memories of the kindergarten age, but they do mention playing soccer and doing other sports. Some of the respondents have vivid memories of doing little technical projects like taking apart appliances.

> [My dad] would bring typewriters home. Very funny, with all the tiny balls inside that you could play with. And computers. And once an old monitor, He likes old stereos and replacing amplifiers, speakers or an old DVD player and got me to look what is inside. It was fun to explore that. (Simon, Technical Physics, University)

Others have no experience at all in this kind of projects. All alumni describe a primary school period that was rather easy in terms of subjects, especially, but not exclusively, mathematics. They mention persons like teachers, siblings and parents. that are part of their experiences, but do not attribute a large role to them at this stage of their lives in influencing study related choices.

3.2 12 years till start of studies

At this stage, the trajectories of the alumni start to diverge. In the Netherlands, there are three different levels of secondary school (lower, intermediate, higher), lasting 4, 5 or 6 years and giving access to vocational education, university of applied sciences or university directly. Only one of the respondents started with the 4 years lower level education, three followed the intermediate level and the remaining five followed the 6 year secondary school that gives direct access to university. All of them choose for a math and science profile without considering other options, except for one.

> At that time everything was easy and I thought what am I going to choose? And yes, it needs to be as difficult as possible, because that will give me the best possibilities.
> *So what did you think was the most difficult option?*
> I my eyes that was the math and physics profile.
> *But if that is easy for you, it is the hardest option? It may be difficult, but…*
> Yes, but everyone said that the physics option is the most difficult one. This is also what school told us, look if you are a really good student, you can do this, but for others, the arts and humanities may be a more sensible option. So perhaps that was my biggest motivation, because it is the most difficult option. (Matthew, Industrial Engineering and Management, University)

At this age, a dichotomy in the group of alumni is becoming clearer. On the one hand, there is a group that describes hobbies like welding and soldering, taking engines apart and repairing mopeds and tractors. On the other hand, the other alumni do not describe this kind of experiences and refer to more general hobbies like sports, music and reading. They tell stories about more analytical experiences like detailed route planning for holidays. None of the alumni have a clear idea about future professions. Two have memories of ideas they had about their future. One of them wanted to be an inventor and the other a managing director of a company.

The dichotomy between the two groups is also visible in the process of choosing a university degree programme. The alumni who describe technical hobby projects and

[1] Names of respondents are replaced by pseudonyms

specific technical interest during their secondary school chose an engineering course, went to open days and confirmed their choice, without considering alternative options, inside or outside engineering. Their choice is seen as a logical consequence of interests and experiences. The other alumni did not have such strong feelings about the choice for a specific engineering course. They considered a range of options, both inside and outside engineering, like economics and econometrics. They went to open days of different programmes and looked for more information, or spoke with teachers, the student counsellor or older brothers to get some advice.

3.3 University period

About their time at university, the alumni depict study related activities as well as other activities like student associations, hobby activities and sports. When asked for important experiences in their first year, many stories are not directly study related. One of the alumni had some doubts about the choice he made:

> But at a certain moment I really started doubting my choice, is this the course for me? I like it, but it is not fantastic.
> *What made you doubt?*
> I think one of the programing courses, that was given so badly that I thought, this is really bad. Fortunately, I have not had any programming courses after that. (…). But I have always considered other courses that may have been interesting.
> *Like what?*
> Mechanical Engineering of Physics. And I spoke with teachers there (…), but in the end I stayed at Electrical Engineering. *(Luke, Electrical Engineering, University)*

The students who have doubts during their course are also the ones who have considered more options before they enter university.

The division between more practical and more theoretical students remains visible at university.

> […] as at Mechanical Engineering there were around 50% of the students who were really into Calculus, Statics, all the math, physics and chemistry that you get at Mechanical Engineering and the other 50% was really into technical hobby projects with bikes, cars and so on.
> *And you are the first category?*
> Absolutely! (Robin, Mechanical Engineering, University)

Robin explains this with an example:

> The design. I could not care less about the design. Things about pulleys and wheels. At the moment I had to calculate the size of the beam in order to touch the wheel, it started to become interesting again. Making calculations. (Robin, Mechanical Engineering, University)

At the other end of the spectrum there is Thomas, who wants to do very practical engineering projects.

> In the second year we had to design a device that would move cupboards. I did not like it. And exactly in that weekend my dad asked me (…) if I could make a wood splitter. I said I can do that. So I thought, perhaps I can connect that to my assignment. And I talked to me teacher and he said, that is fine with me as long as you pay the materials. So that was great fun and the machine is still being used (Thomas, Mechanical Engineering, University of Applied Sciences)

He also explains that

> (…) if you never felt the urge to tinker with something in your free time, then a technical course does not seem a good idea to me. (Thomas, Mechanical Engineering, University of Applied Sciences).

3.4 Transition to first job

For all alumni, the transition to their first job was a smooth one and the jobs related well to their engineering degrees. Half of the alumni were found by a recruitment company through e.g. LinkedIn. Two stayed at the company they graduated, one started his own company and only one actively applied to a job post he found. They are happy with their first jobs, but looking back on the recruitment process, they are critical:

> *So how do you find out if that job is actually suitable for you? If it fits you and the ideas you have in mind?*
> I don't know if you have that clear for yourself. I did not, and if I would apply again, I would have better ideas now.
> *What questions would you ask now if you'd do it again or what would you have done differently in the process?*
> Now I applied starting from the idea that I have to sell myself, but I think that is not the idea, I actually have to make sure they sell themselves to me. Why would you want to work here and what tasks do we have that fit you? Not only my sales pitch, but why I would be good for that company.
> *Did you have enough insight in the tasks that you would do at the company or would you say now….*
> No, I did not really know what I was going to do, which does not mean I am at the wrong place here. (…) Because in the end… I still do the things I like to do and that suit me (Robin, Mechanical Engineering, University)

At the moment, all alumni have a technical job in a technical company and most of them see themselves in a similar job in five to ten years. Most have not considered a non-technical job. Only Robin and Matthew thought about jobs in the financial world, but concluded that was not what he really wanted. Looking for the challenges of doing difficult things, he saw that he could also do that in an engineering job.

> Actually I was never interested in technical things.
> *OK, that could be a conclusion.*
> But in the end I ended up in the technical sector.
> *Do you think you stay there?*
> I have been quite indecisive. Also before I went to *[company X]*. I have applied at *[company Y]* and *[company Y]* is a trading company, a kind of Robeco, but a lot worse. So in the end I did not want to do that. I kind of see it as evil.
> OK.
> Making the orange a euro more expensive in China, get it here and grab part of the chain. But it is… You cannot get it more analytical… (Robin, Mechanical Engineering, University)

Most of the alumni expect to be still working in a technical company or technical job in five to ten years.

4 DISCUSSION

The analysis of eight life-history interviews, revealed the personal trajectories for study and career choices. Looking at possible people who have either influenced the interviewees directly by providing information or guiding them towards a certain study or career option or serving as a role model, parents, siblings, teachers and study counsellors are mentioned, but in none of these interviews there are identified as a decisive factor. Experiences they have gone through have shaped their study and career choices in a clearer way. One group of alumni tells stories about practical projects they were involved in at a young age; tinkering with cars, bikes, agricultural vehicles, welding, soldering and taking appliances apart were part of their daily lives and are serious hobbies. Also at university they enjoy being involved in this kind of activities. This type of alumni can be characterised as 'engineers', regardless of the course they did.

On the other hand, there are the so-called 'scientist', although coming from engineering courses, those who were not particularly interested in technical hobby projects and were looking for (mathematical) problem solving challenges that were difficult. They explain they just "want to do difficult things." For the engineers, the choice for a specific engineering course is obvious and they did not consider any other options, especially not outside engineering. When choosing a course, they visit open days of only one type of engineering course and enrol at that course. The scientists however, consider more than one course, inside or outside engineering sometimes doubt their choice during their studies. The specialisation they choose towards the end of their studies is not a straightforward choice and they tend to seek input from people around them to confirm their final choice.

The narratives of the alumni reveal that especially for the so-called scientists the experiences during their studies in a technical company are especially relevant for the final choice for a technical company or technical job. Being in a company context in a technical company shows that these companies offer the kind of complex problems that these students are looking for. Experiences have a more prominent role during primary and secondary school and during university than people in their environment. People like parents, siblings, friends, teachers and student counsellors are present in the narratives, but do not really appear as decisive.

The transition from studies to work is characterised by quick decisions. The alumni do not refer to elaborate processes to select their first job. The offer of the future employer seems to be more important than the professional and personal interests of the graduates. They refer to the choices they made as a logical continuation of the preceding phase as opposed to an explicit decision moment.

5 FURTHER RESEARCH

This study has been carried out with eight male alumni from technical degree programmes who are still active in a technical company and technical job. The question rises whether similar findings can be obtained with alumni who have left the technical sector and if they have similar narratives on their different stages of life. Another issue for further research raised by the findings of this study is the question whether similar patterns are verifiable for women who finished engineering degree programmes. To what extent do they recount comparable experiences in their early childhood, school career and university education? Future research in this project will focus on women in the technical sector and those who have left as well as male engineers who no longer work in the technical sector.

The deliberations of the alumni in the period of transition from studies to work, the contexts in which these are taken and the factors that possibly influence these decisions are currently, although of major influence on a career choice, rather indiscernible, both for the alumni, as well as for the universities they come from. More qualitative research on this transition period can help to understand the choice of the alumni for their first job and provide opportunities for interventions aimed at keeping technical graduates in the technical field.

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‘Comparisons are odious’: or are there lessons to be learnt?

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ABSTRACT

Engineering is taught in many ways and at different levels, hence are we being optimistic to try to learn from each other. Although there are significant changes occurring in engineering education, it is essential not to overlook some of the key aspects, which must underpin any education curriculum. Key common issues and challenges that are associated with two very diverse institutions, are discussed. While this is not a formal ‘cross-sparring’ exercise these issues highlight important common concerns, which include attractiveness, meeting changing student demands and expectations, responding to changing employer needs and to central government pressures in education and research.

Conference Key Areas: Engineering Excellence, Attractiveness of Engineering Education, Quality Assurance and Accreditation

Keywords: Attractiveness, Benchmarking, Quality

INTRODUCTION

Countless universities across Europe teach engineering, with a wide range of topics taught in diverse ways and at different levels. What can we hope to learn from comparisons, which cover all engineering disciplines and orientations; or, are there indeed common criteria that we can use for comparison? Recent publications [1], [2] would suggest that currently there are significant changes associated with engineering education. While this may well be correct, but in addressing such issues we would be wise not to overlook some of the key aspects which must underpin any education curriculum. To do this we draw on direct experience from two very different institutions, having different missions and located in two different countries. While there may be

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great differences in many things, there are also important features and challenges that not only are common to both, but should be also of general concern to all engineering educators. Although within the context of this paper we will not be undertaking a 'cross-sparring' exercise [3], as these are major benchmarking type of exercises in their own right, we are also aware of the power of such approaches.

1 INTRODUCTION TO THE INSTITUTIONS

We first give a brief portrait of the two institutions, both of which have very clear strategies [4], [5] that are reviewed regularly. Although both are higher education institutions, superficially it might seem that these two could have little in common. However that is very misleading.

1.1 Metropolia University of Applied Sciences

Metropolia is the largest University of Applied Sciences in Finland. It educates about half of all the Bachelor of Engineering graduates of the country and in addition offers Master of Engineering programmes. In the Finnish university system higher education in technology is additionally offered in science universities leading to Bachelor or Master of Science degrees. Last year there were 15 300 Bachelor students (with 3850 graduating of which 7% were international) and 1320 post graduate students (with 570 graduating with masters degrees of which 13% were international,). The total staff count was slightly less than 1000. Until the end of last year all the degree programmes had been free from fees for everyone. This is expected to change at the start of the next academic year for non EU/ETA area students.

The main goals of Metropolia are in the area of education, research, development and innovation (RDI) activities as well as societal impact and regional development activities. The engineering graduates are mainly employed by the industries in the greater Helsinki area. The instruction language is mainly Finnish however, there are 8 engineering programmes where instruction is in English. The focus of the University is on high-quality learning and professional life cooperation. The operating culture and expertise are renewed though digitalisation and campus development. In terms of RDI and business solutions, Metropolia is seeking growth especially in impact and external funding.

1.2 Imperial College London

Imperial College London is a science-based university located in the heart of London, committed to developing the next generation of researchers, scientists and academics through collaboration across disciplines. It is a multidisciplinary space for education, research, innovation, translation and commercialisation, aiming at to tackle global challenges. It has an international reputation for excellence in teaching and research and is consistently rated amongst the world's best universities. Excellence in education is at the core of Imperial's ethos and is reflected in both UK and international rankings. It also contains the greatest concentration of high-impact research of any major UK university. At various times Imperial has been home for 14 Nobel laureates and two Fields Medallists.

The origins of the institution can be traced back to the middle of the nineteenth century with the separate founding of the Royal Colleges of Chemistry and of Science, the Royal School of Mines and the City and Guilds College for engineering. These merged to form Imperial College. The nineteenth century also saw the creation of several different medical schools within London. In 1988 St Mary's Hospital Medical School became the first of these to merge with Imperial. Then in 1997 several other schools joined to make what is now the largest medical school in Europe.

Today Imperial is home to 15,700 students and 8,000 staff (2015/2016 statistics). Undergraduates are attracted from more than 125 countries. Fees are charged at one rate for UK and EU students and a higher rate for those coming from other parts of the world. The faculty of engineering includes 4060 undergraduates and 2763 postgraduates (2015/2016) with 381 academic staff and 830 research staff. The student:staff ratio is 16.9 and the applicants for student admission is between 7:1 to 8:1 for both undergraduates and postgraduates.

2 IDENTIFICATION OF COMMON THEMES

In their different ways both institutions face challenges associated with a range of issues. Both institutions get mainly young people to start university studies with great expectations of attractive and rewarding carrier afterwards. The challenge for the universities is to organise learning opportunities for the students to get the relevant competences and skills applicable not only at the start of a working life but additionally to enable them to continuously update of their market value. Furthermore both institutions receive some fraction of their financing according to the different indicators, which can broadly be captured within the following themes and quality metrics.

2.1 Attractiveness

What makes engineering education and the profession attractive might vary in different countries and different institutions. Branding both the institutions and the comparisons to describe their focused profile, would help the communication with different stakeholders. Furthermore the branding needs to be marketed though today’s more varied channels - social media - to reach the relevant target groups.

In Imperial College London the attractiveness might lie in the challenging theoretical thinking, analysing technical problems, creating new theories and inventing solutions to unsolved problems. However in Metropolia the attractiveness might be based on the work profile by combining and adopting methods and theories to new solutions, running, controlling and developing processes, building and managing products and systems.

Important for the successful recruiting of students is the correct kind of information about the studies; expected theoretical level, intensity, expected learning outcomes, the level of freedom in schedules, methods and content. Furthermore the need of creativity, business mind and entrepreneurship are forming the brand of the university.

The brand of a university also attracts potential companies to seek cooperation with the institution and recruit its graduates. However at the same time the companies involved are influencing the brand of the university and the employability of its graduates in relevant positions plays an essential role in attractiveness.

When students are choosing engineering education, tuition fees have started to play an important role. While in Europe some decades ago, most of education was offered free or almost free - since then in many of the countries the situation has changed. In England the turning point came in 1998 when the Labour government introduced yearly tuition fees of £1,000. That has now increased to the level of £9,000. In Finland all degree tuition is still free for EU/ETA students, but this year the first time students from outside the EU/ETA area will need to pay. The debate about the effects of this is very active. How fees are affecting attractiveness is another question - is expensive education more appreciated, will it attract better teachers, will the employers appreciate more the graduates from expensive programmes?

Comparisons between institutions and countries about the tuition fees and their influence could help future policy makers to develop payment strategies to a direction that best supports the universities to fulfil their mission.

2.2 Meeting changing student demands and expectations

The first impression of the studies is important as during the first semester they start to discover their own attitude and aptitude for studying and taking responsibility for their own learning. The University needs to be alert to guiding the students to establish their style, including result orientation and effectiveness. Once the students have started the studies they have already invested effort which should be proven profitable. However, growth towards being a professional engineer or scientist takes the whole of the time until graduation. Furthermore it becomes important for students to develop an appreciation that lifelong learning should continue though their career.

Today's students have lived their entire life in the digital environment having different manners of nature of communication than many of the staff members of the university. Searching for information, understanding the origin and reliability of it and expressing their own thought, ideas and deliverables have taken a totally new form. Importantly however this new format of information has not changed the fact that in engineering education the need for a sound understanding of mathematics and natural sciences continues to remain critical.

For students and potential students it would be helpful to get information about the comparisons of pedagogical methods and paradigms used in different universities, although this might be difficult to achieve. Furthermore, comparisons of the student experiences, future employability, working life cooperation and institution branding etc., would be appreciated when the place for studies is chosen.

2.3 Meeting changing employer needs

Employer needs are rapidly changing. Sadly enough, when employers are asked about the competence needs of their recruits, they tend to list skills which are needed immediately. Employers tend to not to notice the competences that create the base of understanding that underpins the continued development of knowledge. In other words, this can overlook or take for granted the fact that there is still the essential requirement for them to possess a sound grasp of their engineering fundamentals, otherwise the rest is just froth!

As mentioned in the World Economic Forum White Paper "On average, a third of the skillsets required to perform in today's jobs will be wholly new by 2020. [2] In that report there is introduced a framework for transforming education ecosystems with 8 collaborative action areas giving roles for both public and private sector. Although in many European countries educational policy, skill needs information is commonly used to inform curriculum development [6] there are still huge challenges in creating right skills. So while in one sense the WEF White Paper is correct it should also be remembered that this does not apply to the subject fundamentals.

2.4 Mismatch of expectations

Taking note of the previous comments one might come to wonder if there is a mismatch between how the young professionals of today, also known as the 'millennials' are attracted and how the employers want to attract them. Despite the importance of employees and how to motivate them and create an environment where they can thrive and fulfil themselves by contributing to a higher purpose, one has to keep in mind that the fundamental reason of companies is to create economic value for its investors. Over the last decades, a trend of job tasks becoming more advanced and demanding a higher level of knowledge has been evident. As people become more educated, and more companies apply a project or process-oriented structure, people are able to see how their role contributes to the overall business and value creation for the customer. This also affects how people can be motivated; for example – it can be seen that the millennials view and value internal rewards more highly than previous generations, indicating that this will become even more important for companies to deal with when they want to attract and retain talents. A common trend is that millennials strive for a job where they can contribute to a higher purpose, have opportunities for personal development and fulfil themselves via their work. It is a matter of a hierarchy of social needs among employees and what it is that drives and attracts people. In short, corresponding to Maslow's 'self-actualisation level of motivation', according to which people are driven by a chance to satisfy their higher level needs like self-fulfilment, self-control and professional autonomy and thus, 'participative management' style is optimal way to manage people within organization.[7]

One example of the new working style in cooperation with different stakeholders is Sandvik's Open Innovation portal that invites individual inventors, small business and listed companies to propose innovative solutions to a number of specific challenges. The company also encourages its own employees to use the portal for releasing creativity and utilising their collective knowledge on customer's applications and products. Pasi Kangas (Vice President and Head of R&D at Sandvik Materials Technology): "We are optimistic that open innovation will lead to new products and technologies that aren't otherwise possible. Great ideas really can come from anyone, anywhere. We want to find them and give them every opportunity to make it real – to make a bigger difference – for all our sakes as we look to shape a more sustainable future."[8]

These views differ greatly from the traditional stereotypical view of engineering work that might focus on one restricted problem individually or in a small team. Instead, adopting knowledge, networking and sharing but still carrying strong responsibility of the outcomes is based on deep understanding of science and the "big picture" in the contemporary world.

3 QUALITY

Quality within a University is a multi-dimensional issue. The focus might lay in system, management, enhancement, improvement, measurement, comparison, benchmarking, cross-sparring or ranking etc. The target can be the whole university or some functions or features of it, such as education, research, societal impact, employer satisfaction, student satisfaction, financing etc. Furthermore the level of the inspection might be the whole university, one faculty or department, one study programme or research group, or even an individual course. However, the viewpoint varies additionally by the viewer - whether the activity is for internal use or for marketing purposes.

It is essential to have a clear view what is the background and purpose of comparing universities. The value of indicators is totally dependent on the correct feature of the definition and its measurement. Otherwise the indicators might be totally misleading and one can prove whatever with them and thereby learn nothing. A misleading indicator can lead to partial optimisation and therefore instead of improvement cause disruption for the agreed bigger target.

In European countries financial incentives are widely used for steering decisions towards better quality in universities [9]. However, the discussion of quality can be entered at least from three different angles: rankings, quality labels and continuous development.

3.1 Ranking

There are many ranking lists of universities, with the best known international ones mainly focusing on research and publications [10]. Educational success is more demanding to measure and subjective, thus the rankings are not that popular. In UK the Teaching Excellence Framework [11] is introducing the list that aims to recognise and reward excellence in teaching and learning and help inform prospective students´ choices for higher education. Such list does not exist in Finland neither in wider international extent.

Although only few people appear to know the indicators behind different ranking lists, they have much power over the reputation of the university. The reputation might attract students and staff additionally to facilitating partnerships from working life.

3.2. Quality labels

In Finland the Finnish Education Evaluation Centre (FINEEC) is responsible for the evaluation of education provided by universities and universities of applied sciences (UAS). The three key evaluation types are the audits of higher education institutions' (HEIs) quality systems, thematic evaluations of the education system and engineering degree programme reviews. The Polytechnics (UAS) Act and the Universities Act obligate HEIs to participate regularly in the external evaluation of their operations and quality systems. After passing the audit, the HEI will receive a quality label valid for six years. The reports of each audit are publicly available in the www pages of FINEEC (https://karvi.fi/en/higher-education/),

In UK the Higher Education Funding Council (HEFCE) conducts regular teaching audits of all higher education institutions on a rotational basis, with the principal conclusions. (The 'E' indicates England as each of the individual regions have their own, broadly similar Councils.) Such audits, while conducted under the auspices of the funding Council who involve appropriate senior academics from other institutions. A synopsis of the audit findings are available on a public basis. New legislation currently being discussed within the Parliament would link the outcomes of such audits to the level of central funding received by institutions – probably in three banding levels – and also to the student fee level that can be levelled. This is a mixed blessing while on the one hand this can be seen as an important step in raising the importance of education in ALL academic institutions, on the other hand this can be seen also as a further step in the removal of autonomy from institutions and a greater hand of central government exerting increased control over them.

Becoming a 'Chartered Engineer' is an important step to full engineering professional status in the UK. As part of the criteria for this an engineer should have followed a degree programme recognised by the appropriate professional body. Hence for example, to become a chartered civil engineer it is first necessary to have followed an undergraduate programme to Masters level approved by the Institution of Civil Engineers. For a Civil Engineering Department to offer such a programme it's course must also be approved by the Institution. In a similar manner to the HEFCE reviews there would be a paper evaluation and a visit by an approval team. The composition of this team and the assessment criteria would be different from the HEFCE review in that there would be more emphasis on the suitability of the programme in laying the foundations of professional competence. As with the HEFCE reviews such reviews are repeated on a regular cycle, say every 5 years.

3.3. Continuous development

Continuous development is based on good knowledge of the present situation and clear vision of the desired condition.

Defining present situation starts by collecting existing facts and then executing a self-evaluation. The results of the self-evaluation can be analysed with the help of SWOT analysis or some other tools that assist on defining the most urgent and essential development areas.

According to a research done with ERASMUS+ financing [3] an effective method for identifying good practices and other ideas for the enhancement is to meet “critical friends” in a cross-sparring session focusing on the first priority development areas. These critical friends are typically from another university and having as their strength the areas which are the chosen development areas of the original university. The friends will introduce and share their good practises and give hints for enhancement. Vice versa the roles will be changed and thus such an activity helps both of the parties in a constructive way.

In continuous development it is important to make the decisions of the actions and also execute the follow up of the implementation. Update of documentation supports the share of right knowledge in the organisation.

In the open culture of development the documentation of the enhancement and current practices is available for the review of all the interested parties. Potential students, students, staff and other stakeholders then have an opportunity to compare and build their own understanding of the attractiveness of the institution.

4 SUMMARY

Engineering education in different countries and at different levels is in a key position to teach people to find solutions to the greatest challenges facing the world and hence advance the wellbeing of human life. The big issue for the profession and its educators is to make this fact better known and encourage talented students to find and choose the right type of studies. The engineering studies need to be strongly branded as the starting point for gaining the competences and skills for solving these problems. The key role in this branding is the trustable evidence of the strengths of each institution that are given visibility for comparisons by the quality documentation, accreditations and rankings. Additionally much knowledge about the job opportunities and achievements should be marketed.

Comparisons that bridge between diverse institutions can offer effective tools for improvements and help to attract appropriate students and other stakeholders to find right partners to cooperate in such activities. Comparisons between institutions and countries can be extremely beneficial, raising relevant information for different stakeholders, be they students, employers, financing bodies and to support the directions of internal development. However, as there is a huge variety of institutions and missions the comparisons need to be understood accordingly. Still in their different and diverse ways there are common themes that offer challenges and similar methodologies that can be adopted for their appraisal, development, branding and ways to increase their attractiveness.

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The Effectiveness of Interactive Lectures on Students' Knowledge and Attitude to Further Study

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ABSTRACT

One of the possible alternatives how to increase the chance of students` success in the STEM (Science, Technology, Engineering and Mathematics) study programme is to supplement their lack of knowledge by using specific learning activities with the aim to motivate and activate freshmen. In our paper, we present the results that we gained from a standardized Force Concept Inventory (FCI) after implementing the intervention tool, interactive lectures. The overall results from the analysis of the FCI test point out that there was the increase in the students` knowledge. Even better results were achieved when students had the possibility to watch videos and use video analysis with the program Tracker (video analysis and simulations (VAS) method of problem tasks) in lectures as opposed to the groups taught by traditional methods. We have investigated how this intervention tool, interactive lectures, can support the students who are at-risk. We point out the importance of such intervention and its integration into study programme because thanks to these interactive lectures we can manage to reduce the lack of students` knowledge and increase their chances to cope with requirements of university study programme and eventually reduce the dropout rate.

Conference Key Areas: Physics and Engineering Education

Keywords: STEM education, interactive lectures, video analysis, key skills

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INTRODUCTION

In recent years, a regional education reform has been implemented in Slovakia with two main aims, firstly to enhance humanistic and creative teaching approaches and secondly to concentrate upon the development of the student's self-concept in order to achieve higher efficiency of learning. However, looking back at the outcomes of this reform, it seems that humanities and social science subjects were more or less knocking STEM and technical subjects down because the number of their lessons increased whereas mathematics and physics suffered from the reduction of lessons. Another outcome of this reform was that higher education was transformed to a three-level system, which triggered the need to adjust the study programs of individual departments as well as the content of the relevant subjects. And again the reduction affected mainly mathematics and physics and their number of lessons even so that the importance of these two subjects for technical study programmes is indisputable.

Another aim of the education reform was to increase the number of people with degree. In other words, to get as many students as possible to apply and enrol at universities, no matter whether they are prepared for it or not. As a result, vast majority of technical universities are attended by students who come from the whole spectrum of schools - secondary grammar schools or secondary technical schools - and a glaring gap in their readiness for university-level work is breathtaking. Furthermore, there was also a change in the system of the secondary school leaving examination. Students attending secondary technical schools can choose mathematics or physics only as an optional fifth subject! This is one of the reasons why students` theoretical knowledge, skills and key competencies are at very low level when they enrol at university. As a result, universities across our country are forced to spend time, money and energy to solve this disconnect. We must determine who is not prepared for university and attempt to get those students up to speed as quickly as possible or we risk losing them altogether.

Today more than before, education should meet the needs of practice and the content of it should be based on professional high-level expertise, which can be applied in a wide range of disciplines. Universities should have the leading role in preparing graduates who will follow new development trends in their field of study and whose knowledge will be supported not only by field-specific knowledge, but also by a broad range of skills and knowledge in mathematics and physics. Therefore, if we want to prepare graduates who are able to work independently with a high degree of creativity, then apart from well-educated teachers, devoted scientists, study materials of high quality and scientific laboratory equipment, we should keep in mind that university teachers of mathematics and physics must take into account the specific needs and requirements of each faculty and prepare specific study materials supporting the specialization of these faculties.

Therefore, we place the emphasis on the synthesis of theoretical knowledge and practical experience in the given field when teaching mathematics and physics in new accredited study programs of both the first and second level of higher education. So the graduate is able to conduct research and use evidence-based analysis, to gain in-depth knowledge in the major and analytic, problem solving, and to apply the knowledge of mathematics and physics in real-world settings either in production technologies, in the process of production management, or in quality control of the final products. Moreover, we try to prepare our students for teamwork and collaboration with scientists and engineers, so they are able to work in interdisciplinary fields at the interface between physics and technical departments. As a result, we consider theoretical training not as the goal but as a means to an end, and therefore it should always be followed by practical application.

1 THE IMPACT OF INTERACTIVE LECTURES

As we have mentioned above, there is a glaring gap between students in their prior knowledge of mathematics and physics when they enrol at the Electrical Engineering Faculty. However, all of them have to attend and pass the examination from the subject entitled Introduction to Physics during their first semester if they want to continue in their studies and graduate successfully. To be more specific, they should acquire and understand the following topics: physics units, kinematics, dynamics, gravity, molecular physics, deformation, thermal physics, and thermodynamics that are covered during the lectures. However, most of our freshmen understand just the basics of these topics because their prior level of mathematics and physics knowledge is not always at the required level for STEM study programmes [1].

Therefore, we thought a lot about how to overcome this gap. We decided to support freshmen by interactive lectures using video and video analysis and find out whether interactive lecture are more effective in increasing students prior knowledge level of physics than traditional lectures.

At the beginning of the academic year 2016-2017, the Force Concept Inventory (FCI) was administered to students at Electrical Engineering Faculty to find out their prior knowledge level of physics. The FCI is a scientifically validated instrument that aims to measure students' conceptual understanding of Newtonian physics. The pre-test was carried out at the beginning of the semester during the first week and it was attended by 190 students. Post-test was carried out at the end of semester (the 13th week, after the semester course 'Introduction to Physics') and it was attended by 170 students.

The students were randomly assigned to two groups – the experimental (pre-test was attended by 98 students / post-test was attended by 75 students) and the control group (pre-test was attended by 92 students/ post-test was attended by 95 students). Only those students who participated actively in the lecture took part in the experimental group. The lectures for the experimental group were conducted in an interactive way aimed at clarity - using real-life videos related to the topic. All videos were analysed with the help of the program Tracker (using VAS method). In the control group, lectures were conducted in a traditional way. Students from both groups attended compulsory computational physics seminars. The subject 'Introduction to Physics' consists of 2 - 1 - 0 (lectures - exercises - labs) lessons per week, presence study. The semester consists of 13 weeks. Both experimental and control group had two lessons per week, that makes 26 lectures for each group per semester. The only difference between experimental and control group was that students from experimental group attended 26 interactive lectures while students from control group attended 26 classical lectures.

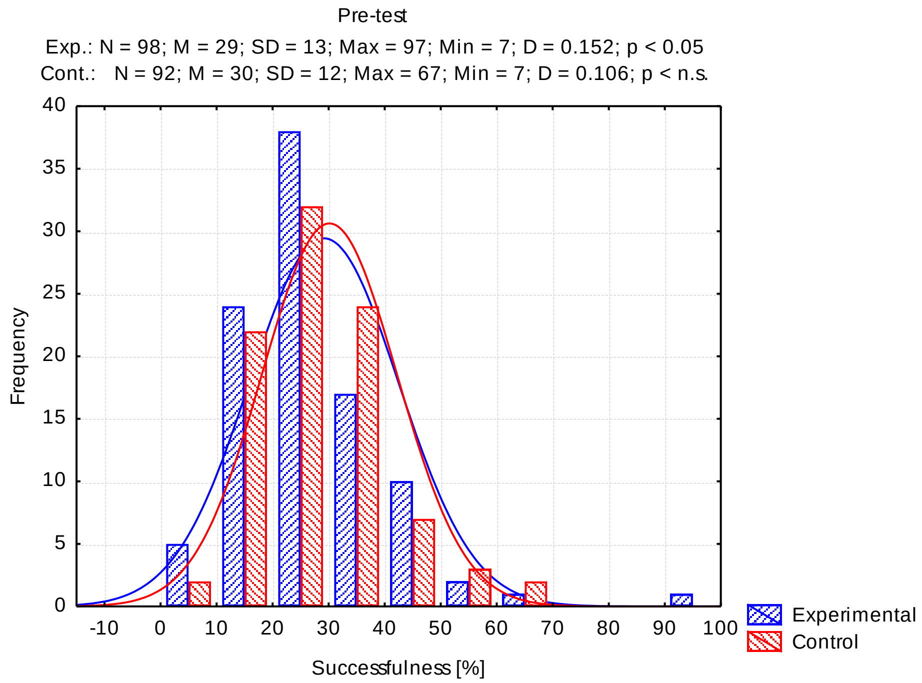

Fig. 1. Pre-test

Table 1. Pre-test - F-Test Two Sample for Variances and t-Test: Two Sample Assuming Equal Variances and Post-test - F-Test Two Sample for Variances and t-Test: Two Sample Assuming Unequal Variances

	Pre-test		Post-test	
	Experimental	Control	Experimental	Control
Mean	28.95	29.93	46.36	35.47
Variance	176.31	143.58	313.27	193.83
Observations	98	92	75	95
df	97	91	74	94
F	1.23		1.62	
P(F<=f) one-tail	0.16		0.014	
F Critical one-tail	1.41		1.43	
Pooled Variance	160.47		-	
Hypothesized Mean Difference	0		0	
df	188		138	
t Stat	-0.53		4.36	
P(T<=t) one-tail	0.30		1.24E-05	
t Critical one-tail	1.65		1.66	
P(T<=t) two-tail	0.59		2.48E-05	
t Critical two-tail	1.97		1.98	

These results (Fig. 1, Tab. 1) indicate that there is no statistical difference in the mean pre-test FCI score of the experimental and the control group at the beginning of semester. But results in Fig. 2 and Tab. 1 indicate that there is statistical difference in the mean post-test FCI score of the experimental and the control group at the end of semester.

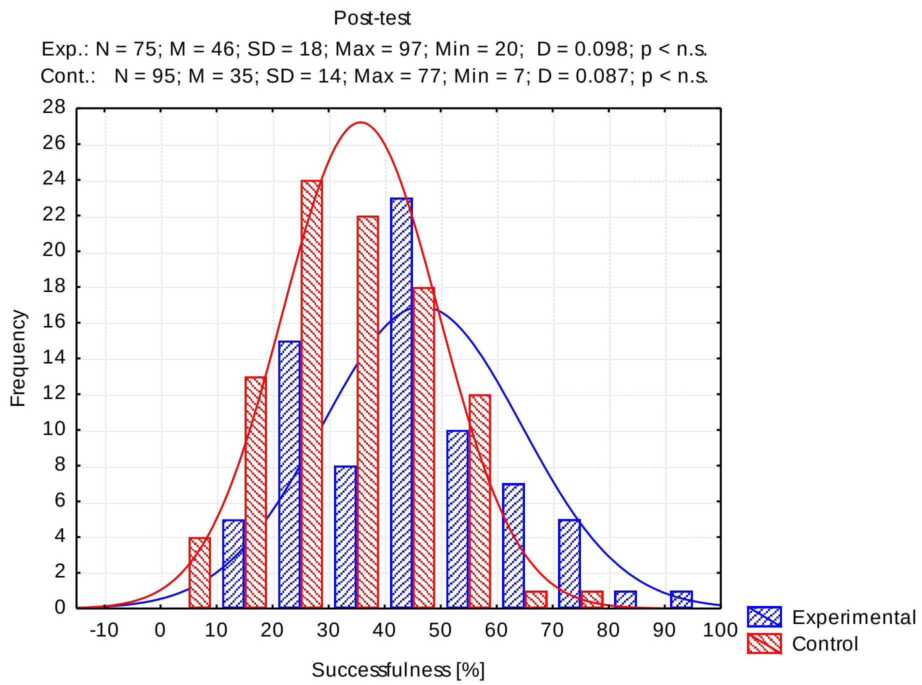

Fig. 2. Post-test

Then we evaluated pair Student's t-test for experimental and the control group. The final numbers of students in the experimental and the control groups were reduced to 58 and 84 – only answers of those students were used who took part in both pre- and post-tests plus answered all questions.

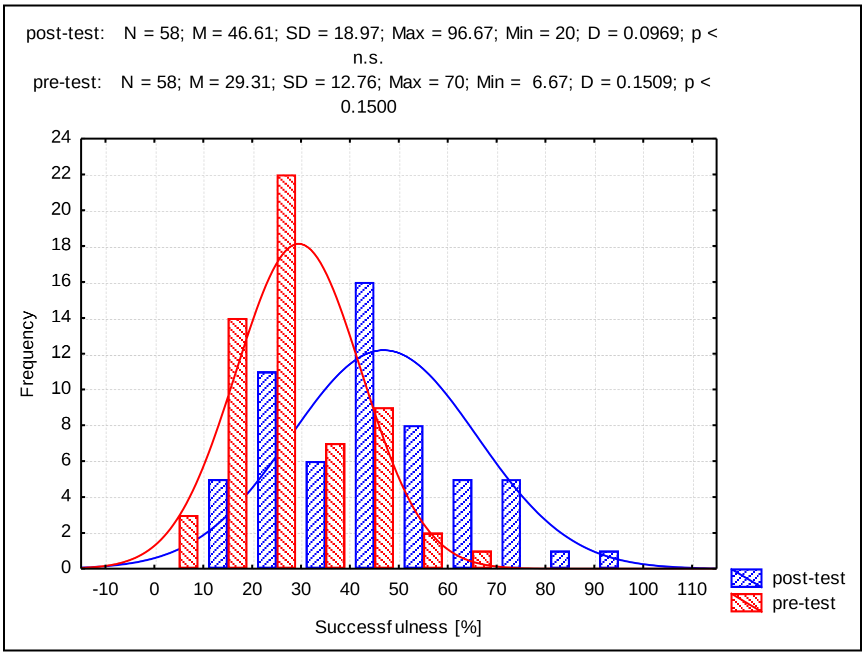

Fig. 3. Paired Student's t-test for the experimental group

Table 2. t-Test: Paired Two Sample for Means – the experimental group and the control group

	Experimental group		Control group	
	Post-test	*Pre-test*	*Post-test*	*Pre-test*
Mean	46.61	29.31	35.63	30.45
Variance	360.04	162.87	194.91	132.47
Observations	58	58	84	84
Pearson Correlation	0.69		0.65	
Hypothesized Mean Difference	0		0	
df	57		83	
t Stat	9.57		4.35	
P(T<=t) one-tail	9.30E-14		1.94E-05	
t Critical one-tail	1.67		1.66	
P(T<=t) two-tail	1.86E-13		3.87E-05	
t Critical two-tail	2.00		1.99	

The evaluation of post-test and pre-test of the experimental group at the beginning and end of semester (Fig. 3, Tab. 2) confirmed statistically significant difference between mean at the beginning and end of semester. The evaluation of post-test and pre-test score of the control group at the beginning and end of semester (Fig. 4, Tab. 2) confirmed statistically significant difference between mean at the beginning and end of semester, too, but p-value is lower in the case of the experimental group.

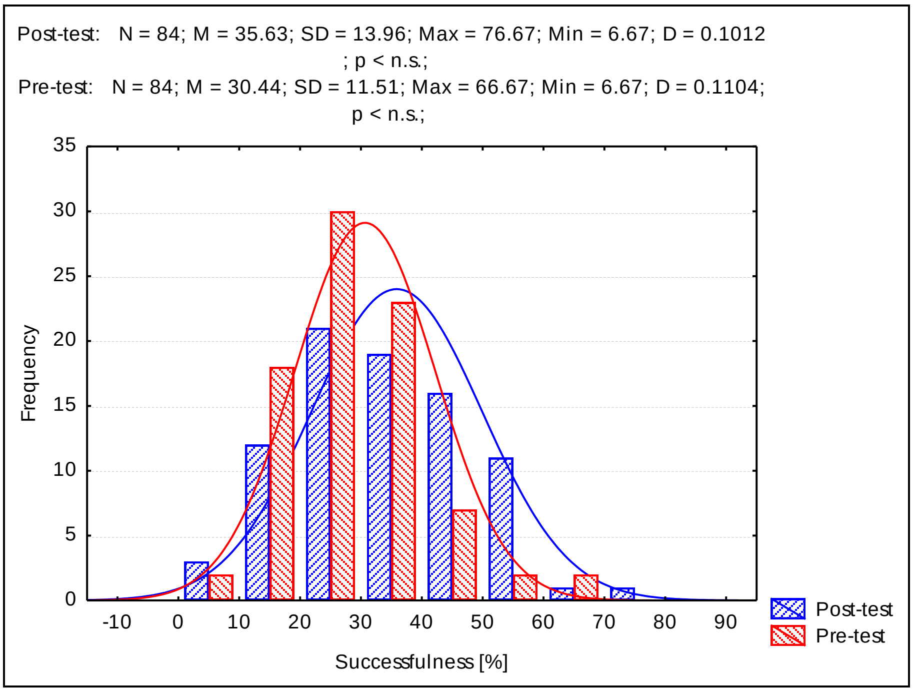

Fig. 4. Paired Student's t-test of the control group

Gain (Eg. 1) of courses was calculated in this way

$$g = \frac{\text{postscore\%- prescore\%}}{100 - \text{prescore\%}} \tag{1}$$

was g_{exp} = 0.22 for experimental group and g_{cont} = 0.08 for control group.

2 DISCUSSION

As the authors claim [2] it is necessary to point out that 60% of FCI test, for empirical reasons, is minimal threshold so that a student could continue in understanding Newtonian mechanics effectively. Below this threshold, a student's grasp of Newtonian concepts is insufficient for effective problem solving. Otherwise a student is not able to overcome difficulties which caused him/her misconception and thus s/he learns physics by heart. 80 – 85% FCI score represents the mastery level when a student thinks in terms of intentions and Newtonian physics. As the authors state such an outcome does not depend on what teacher, in what country and what kind of school s/he teaches [3 - 6]. The results of pre-test (Fig. 1) reveal that only 4(5)% of students (in the experimental/control group) reached the level of 60% or higher from FCI score and in post-test 19(2)% (Fig. 2).

The low growth of successful students can be caused by the fact that only one third of the total number of students attended lectures. In the experimental group final number of students attended lectures decreases to 60% in comparison with the beginning of semester.

The final successfulness of course 'Introduction to Physics' in academic year 2016/17 was 86% (45% of exam results was with the grade E); 70% of freshmen fulfilled the requirements of the subject „Mathematics 1“. Students who actively attended lectures of „Physics 1“ this semester after attending “Introduction to Physics” reached the level of 60% of FCI score in average [7].

3 SUMMARY

Student t-test confirmed statistical significant difference in knowledge and conception of Newtonian mechanics at the end of the semester in comparison with the prior knowledge level for both the experimental and the control group. However, our results also confirmed that there is statistical difference in the mean of post-test FCI score of the experimental group in comparison with the control group at the end of semester.

Watching real physics concept videos and their subsequent video analysis had a positive impact on the growth of knowledge and improving of conception of Newtonian mechanics at the end of the semester as was declared in previous studies by other authors [8 - 12].

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Using Service Learning for Improving Student Attraction and Engagement in STEM Studies

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ABSTRACT

Both in Europe and around the world, there is a lack of STEM (Science, Technology, Engineering and Maths) graduates. The Universities that offer STEM studies face two common problems, the first of which is the lack of technological vocation. Despite the need in Europe for more engineers, and while STEM graduates enjoy almost full employment, few students decide to enrol for these degree courses. The second problem is that engineering studies traditionally have one of the highest dropout rates in Higher Education. One of the reasons for this is that students perceive engineering courses as highly technical and difficult, and with little relation to social progress. They are not aware of the creative nature of such studies, or the contribution to human development made by engineers. In order to tackle these problems, we are advocating the use of Service Learning. The projects resulting from this initiative will be able show future graduates the importance of creativity and the important role of science and technology in the future welfare of society; two points capable of inspiring vocation and enhancing the sense of belonging to the STEM collective in the first STEM degree courses. In this paper, we present the project and describe some of the experiences we have identified at our university, with the aim of using them for student attraction and engagement.

Conference Key Areas: Attract youngsters to engineering education, Gender in engineering education, Sustainability in engineering education

Keywords: Service-Learning, Student Attraction, Student Engagement, Changing Society's Engineering Perception, Diversity in Engineering

1 INTRODUCTION

1.1 Europe and the STEM workforce

According to a report by the European Parliament Committee on Employment and Social Affairs (Caprile et al., 2015), employment of STEM skilled workers in the EU28 (the study was done before the brexit) was increasing in spite of the economic crisis, and demand was expected to grow. Since the beginning of the 2000s, the unemployment rate for this type of worker has been very low and clearly inferior to the total unemployment rate, even in countries particularly affected by the crisis, such as Greece, Portugal and Spain. In parallel, high numbers of STEM workers are approaching retirement age. Around 7 million job openings are forecast until 2025. A large majority of Member States have recently experienced recruitment difficulties in regard to STEM skilled workers. Challenges arise from the insufficient number of graduates and a lack of experienced staff.

Concerns about this situation arise from two facts: the proportion of students enrolling for STEM degrees is not increasing at the required level and the underrepresentation of women persists.

The proportion of university graduates in STEM at EU level in the period 2006-2012 remained basically stable, with a variation from 22.3% to 22.8%, while the demand for STEM professionals is expected to grow by 8% between 2013 and 2025 (Caprile et al 2015, Eurostat 2015). Furthermore, according to Burchell et al. (2014), STEM is male-dominated area: women account for just 24% of science and engineering professionals, and in 2012 only 12.6% of those who graduated in STEM-related subjects were female as compared with 37.5% of male graduates.

However, these figures are not evenly distributed across all STEM studies. While it is not expected employment grown on some STEM sectors, 674,000 new jobs are expected for 2020 in the ICT sector (Information and Communication Technologies), but a shortage of 756,000 jobs is also predicted. In other words, the labour market will be able to absorb 756,000 additional workers (Hürsing, Korte, and Dasja, 2015). In addition, according to the European Commission (2013) only 4 out of every 1,000 female tertiary graduates work in ICT fields, compared to 20 men (5 times more).

EU member states and other countries in the world are designing initiatives and programmes to tackle STEM issues at a national level by focusing on science education and attracting young people to science, with a special emphasis on girls.

1.2 Think globally, act locally

26,210 students enrolled at our University in the 2015-2016 academic year. Although it is a University with an international presence (3,126 students are foreigners - 11.9%) foreign students are mainly engaged in Master and Doctorate studies. Less than 5% of foreign students are doing degree courses, most of whom are first-generation immigrants who arrived with their families a few years before enrolling at university. Thus, in order to make STEM degree courses more attractive to students, it is necessary to focus on the potential local student population. Is the STEM workforce situation in Catalonia, our region, similar to that in the EU as a whole?

Catalonia has a population of about 7.5 million people. Compulsory secondary education in our country ends at the age of 16, at which point students may choose between leaving the education system, starting Vocational Education and Training courses (VET) or enrolling for preparatory university courses that last two years.

According to our Government Statistics (Generalitat de Cataluya 2016) only 12.7% of VET students choose STEM-related studies. Furthermore, while gender parity exists (50.9% women and 49.1% men) in all VET courses, statistics show that in STEM studies only 14.4% of students are female.

With respect to preparatory university studies, three categories exist: arts (7% of enrolled students), humanities and social sciences (46.4%) and science and technology (46.6%). While in the courses overall 53.5% of students are female, in science and technology this figure falls to 44.5%. Although these percentages show no appreciable difference, it should be remarked that the science and technology category includes not only STEM studies, but also life studies, so these figures for STEM are not an accurate reflection. If we consider enrolment at our universities in June 2016, only 24.6% of students joined STEM studies, and although 55.1% of new university students are female, this number drops to 30.3% in STEM studies.

In the case of ICT University courses, 10.1% of students enrolled for ICT in 2001, while in 2014 this figure was 4.9%. As regards gender distribution, 18% of ICT workers are female. Moreover, women account for only 11% of ICT university students, and less than 1% of female students choose ICT studies, while ICT represents 2.7% of current workplaces.

These figures lead to the conclusion that in Catalonia the problem is similar to that in the EU as a whole, and that similar measures can be applied in both cases.

1.3 Two problems: attraction but also retention

The problem cannot be reduced to the small number of students starting STEM degree courses. Traditionally, STEM and especially engineering studies have one of the highest drop-out rates in all courses. In our case, 20% of students ceased their studies because they failed the first year (our regulations require that students must pass all subjects in the first year in a maximum of two academic years). In addition, a further 17% of students dropped out before graduation. Thus, this is not only a matter of lack of vocation, but also about how to deal with those students who already have this vocation when they arrive at the university.

1.4 Catalan government plans and the role of UPC

In February 2017, Catalan government created a workgroup known as the STEMcat consisting of members of the Ministry of Business and Knowledge, the Ministry of Education and the Ministry of the Presidency, together with representatives from each of the regional Universities. The mission of this workgroup is to develop a plan for the promotion of vocation in STEM studies. Four working lines have been defined: a) Enhance teacher-training in STEM fields; b) promote STEM skills among students and develop tools to evaluate them; c) encourage the participation of STEM companies in school training; and d) promote STEM in society. Our university is the only technical university in the region. Other Universities have some STEM degree courses such as those in Mathematics, Physics or Chemistry, but ours is the only one that offers degree courses in Architecture, Civil Engineering or Chemical Engineering, for example. So our role in this workgroup acquires a special importance.

2 ATTRACTING AND ENGAGING STUDENTS

2.1 Student attraction

A study from “Science” (Tai et al 2006) shows that we should pay close attention to children’s early exposure to STEM at middle and even earlier grades. Universities make great efforts to attract students in higher grades, but this is really a question of marketing rather than awakening vocation. The study in “Science” shows that students graduating in STEM degrees have already decided to study physical science/ engineering degrees at the age of 13. The study stresses the important influence that mathematics and science courses taken at age of 12 and 13 has on the future STEM workforce.

There are several reasons that predispose young people to STEM studies (Orsak 2003, Laut, Bartolini, and Porfiri 2015). First, surveys show that children of engineers have a much higher likelihood of becoming engineers than those students without any personal connection to the field. Also all teachers are familiar with the question

"When am I ever going to use this?" In the case of STEM, do teachers, and society as a whole, have any meaningful answers? Real exposure to engineering is necessary to stimulate student attraction, but it is also important for young adults to learn about subjects that are fundamental not only for them but for society at large. Life sciences are considered important for the common good, but despite the importance of STEM in daily life, technology is regarded more from the user point of view than from the designer perspective. For instance, students are exposed to technology at school when learning about Scratch and Robotics, but the leading issues must be: What are programming and robotics for? How can I make the world a better place by using STEM? Stressing the importance of creativity and the vital role of science and technology for the future welfare of society is fundamental for awakening vocation, especially among girls and minority or disadvantage groups.

2.2 Student engagement

Two major variables are involved in the decision to drop out of university: academic performance and academic commitment (Wood, 2014). On the other hand, however, some studies show the relationship between both: the greater the academic commitment, the higher the academic performance (Boekaerts 2016). There is much discussion among experts, but the most prevalent conceptualization in the literature is that engagement consists of three dimensions (Fredicks, Filsecker and Lawson 2016): 1) *behavioural*, in terms of participation, effort and positive conduct; 2) *emotional*, focused on the positive and negative reactions to teachers, classmates, and school, but also on sense of belonging to and identification with the school or the studies themselves, and finally 3) *cognitive*, self-regulated learning using deep-learning strategies and exerting the necessary effort for the comprehension of complex ideas. STEM degree students are good at maths, physics and similar subjects, and are familiar with deep-learning strategies, making the required effort and having a positive conduct. Thus, it appears that the real problem resides not in the behavioural and cognitive dimensions, but rather in the emotional sphere.

According to Astin (1999), and Krause and Coates (2008), in order to engage first-year students emotionally, it is necessary to: 1) Encourage them to participate in challenging activities; 2) Show them that the knowledge they are acquiring is relevant for their professional future; 3) Convince them that the profession they chose has a real impact on the world, stimulating them to reach creative solutions for resolving real problems; and 4) Create collaborative activities to enable students cooperate both mutually and with the teachers in order to achieve a deep knowledge of their profession

Instead of being guided by these ideas, students often find themselves in what they perceive as difficult, boring and passive classes, where they do not understand the use of what they are learning, where no cooperation is encouraged and the only challenge they are faced with is passing the next exam. How may this situation be changed?

3 THE PROJECT

3.1 Service learning

Service-learning (SL) is an educational methodology that combines several processes related with learning. The Corporation for National and Community Service (1990) defines SL as a methodology by which students learn by performing a useful service to the community to which they belong, and by undertaking well-articulated and integrated tasks in the curriculum, all structured to stimulate thought and to expand what they have learned in the classroom. Robert Sigmon (1994) defines SL as an experimental approach in which mutual benefit occurs. According to the author, SL is distinguishable from other educational approaches by its intention to benefit both the supplier and the recipient of the service. Moreover, focus is put on both learning and service.

3.2 Why Service Learning?

For many years, our University has instilled a culture of cooperation and sustainability as its guiding principle.

As regards sustainability, UPC issued a statement of sustainability in 2008 as part of the 1st Sustainable UPC Conference in 2007. It has a doctoral program in sustainability, a UNESCO Chair of Sustainability and an Institute of Sustainability. Research groups exist within the UPC in areas of sustainability dealing with issues as diverse as construction, energy and information technology. These groups transfer the knowledge acquired during their research work into their teaching.

Where cooperation is concerned, we have a Centre of Development Cooperation (CCD), a unit of the UPC that was created in 1992. The aim of the CCD is to encourage the commitment of the university in cooperation for development and to support initiatives within this field among the UPC community members. The CCD also has the function of raising awareness and providing useful training, as well as debating and reflecting on cooperation and its related problems. The CCD is currently financing a series of cooperation projects using the funds collected by the so-called 0.7% campaign. Research and educational projects that received funds give 0.7% of them to the campaign. Furthermore, students can voluntarily make a donation when they pay their tuition fees, and the university staff can opt to give part of their salary to the campaign.

As for the teaching-learning process, the commitment of the UPC was explicitly stated when the adaptation of degree courses to the EHEA framework was defined. We set out seven generic (or professional) skills that all our graduates should acquire, one of which is "Sustainability and Social Commitment". Given this environment, Service Learning is a natural way of integrating research and cooperation into the teaching-learning process.

3.3 The goals

This is a work-in-progress project consisting of three steps.

- First, detecting Service Learning experiences that have taken place at our University. Some teachers have been using Service Learning for years, but on their own initiative rather than as part of an institutional plan. These experiences have not been publicized among our students, or among potential future students when deciding what degree course to follow. We wish to collect and analyse these experiences and use the acquired know-how to develop new ones, defining Service-Learning as an important feature of UPC defining spirit and encouraging teachers to use it.
- The second step is to use this information for attracting and retaining students by presenting engineering as a creative, challenging field where graduate work has a real impact on the progress of humankind.
- The final step towards this goal is to increase the number of Service Learning experiences in the first year of degrees at our University, since we have found that most SL experiences take place in the final semesters. Service Learning

can be of great help in student engagement, but clear action is required in the first semesters, which is when most students tend to drop out.

The project is being conducted by the Institute of Education Sciences, a unit of UPC, with a three-fold mission: 1) offer training in educational methods and tools to new and senior lecturers at our university; 2) offer training and advice on STEM issues to K-12 teachers, as well as stimulating STEM vocation among young people; and 3) promote Engineering Education innovation and Research among our academic Staff. This project has the support of the University Rector.

For research into Service-Learning experiences, we first asked the Centre of Development Cooperation for a list of lecturers who have been involved in the CCD-funded cooperation projects. Then we checked our publication database, searching for papers or projects connected with service learning, sustainability, education, cooperation, and so on. These two measures provide us with a list of lecturers who may be able to work (or may work in the future) with this methodology. The next step is to organize meetings on every campus (we have eight different campuses in six different towns and cities), issuing personal invitations to the lecturers on the list to attend the meetings, which are open and publicized to all the staff.

The purpose of these steps is to determine who is currently working on initiatives that are or can be easily be adapted to SL experiences. We also wish to encourage our lecturers to carefully consider the opportunities for SL, and to evaluate if they can combine their expertise in teaching and research to create new experiences. It is our mission to create the right environment to help these initiatives flourish, but also to use them to increase student attraction and engagement.

3.4 Some experiences detected

We were already familiar with some of the initiatives; some in fact have already been promoted by the CCD and the Institute of Education Sciences. We also found initiatives that we were not aware of before. One positive aspect is that they cover a broad range of typology and fields of knowledge. We have divided the experiences into 6 categories:

- Specific initiatives, which can be applied to very few subjects. These initiatives are confined to a very specific field of knowledge and cannot easily be exported to other subjects, even at the same school. One example is a topic at the School of Architecture, where students analyse building accessibility for people with disabilities moving about inside a building in a wheel chair or blindfolded and with the aid of a stick. They analyse public buildings or small commercial premises, and the resulting analysis and the solutions proposed are passed on to the owners of the buildings to help them adapt these spaces.
- Specific initiatives, which can be applied to several subjects in the same field of knowledge. One example is in the Eyecare Clinic, where students pursuing different subjects and degree courses at the Optic and Optometrist School can practice their skills; in particular, by offering the Clinic services for disadvantaged groups in society, such as children from deprived families. A further example is the refurbishment of old computers undertaken by Computer Science students for the subsequent donation of this equipment to NGOs and schools.
- Volunteer projects, based on service but with small learning component. One example is the ICT volunteer program in which students help non-profit organizations in basic technical problems; for instance, courses for the elderly to teach them how to use the Smartphone GPS and navigator, or how to use

Skype to talk with distant relatives. Although this is an important learning activity from the personal point of view, very little technical learning is involved.

- Medium size projects, oriented towards final degree projects or master theses, such as the development of support software for the refugee children vaccination program or the development of drones for the detection of anti-personnel mines.
- Application of basic research, such as the development of mathematical models to address challenges posed by malaria: understanding the dynamics of the parasite in the lungs and the dynamics of the epidemic in big cities.
- Applied research in projects, for instance, the development of a robotic pet to reduce pain and anxiety in hospitalized children. This began as a European-funded research project and has become a spin-off.

4 CONCLUSIONS AND FUTURE WORK

We have identified several initiatives in our university that are or can easily be adapted to Service Learning. It is important find local university initiatives, since students will not find attractive initiatives undertaken at the MIT, for example. It is important for them to engage in initiatives that have been carried out in or close to where they live, and by their (current or future) university teachers and classmates.

These initiatives can be used to increase student attraction: all of them focus on the creative endeavour of STEM professionals and their contribution to human development. The use of these examples in primary schools can stimulate new vocations. It is important to make pupils and students aware that science and technology are changing the world we all inhabit, and that a new generation of creative scientists and engineers is required to tackle these challenges. Schemes such as those described above bring young people into direct contact with the real-world problems STEM professionals are required to solve, as well as showing that the real challenge involved in STEM is not learning maths, but finding imaginative and effective solutions. By developing a vision of the future, they will discover that the ability to solve such problems is a matter of human creativity rather than gender, ethnicity or social class.

Engaging first-year STEM students in these or similar projects deepens and extends their relations with their teachers, their schools and their future profession, thus creating a sense of belonging and a greater emotional commitment to their studies, resulting thereby in a better academic performance.

At this stage of the project, the proposal set out herein is simply a work-in-progress. More work and research is required to determine the best way to use this information for stimulating a sense of vocation and increasing first-year academic performance. It is our aim to encourage other universities to put Service Learning methodology into practice, not only as a service to the community, but also to enrich the learning experience of students as well as providing them with local examples to enhance attraction and engagement.

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Course and campus choice in a multi-campus setting

Factors influencing study choices of (bio)engineering technology students

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ABSTRACT

As higher education institutions become more competitive in the recruitment of students, the need arises to gain insight into their study choice process. This is even more pivotal for multi-campus institutions, who are confronted with the added complexity of positioning campuses as well as courses. This study aimed to cast light on the factors influencing students' choice of a course and campus. To this end, a survey was conducted in a (bio)engineering technology faculty offering courses at seven campuses, yielding 1.064 respondents and a 94% response rate. Course content, expected career prospects, expected job security, and correspondence to prior education emerged as the most decisive factors for the choice of the course. Campus choice depended on the course offer and range, academic reputation and local scientific research, and geographical proximity. Students from all campuses valued similar course attributes, but different campuses did attract students for different reasons. The majority of students remained undecided until the last year of secondary education; many students even kept several options in mind up until their enrollment. Four information sources excelled at reaching prospective students: the university website, brochures, contacts with family and friends, and info events. Marketing and recruitment recommendations are provided.

Conference Key Areas: Attractiveness of Engineering Education

Keywords: study choice, multi-campus, information sources, recruitment

INTRODUCTION

The choice of a course and campus is a key decision for prospective students and directly impacts higher education institutions (HEIs), as their funding is highly dependent on student enrolment numbers [1]. As institutions become more competitive in the recruitment of students, the need arises to gain insight into their study choice process, so as to attract the right students to the right courses [2,3].

This is true for all higher education institutions but even more so for multi-campus institutions. As a consequence of mergers in tertiary education, multi-campus institutions are becoming increasingly common. These institutions are confronted with the added complexity of positioning not only their university and courses, but also different campuses. At present, nevertheless, not much is known about how students deal with this aspect nor have there been many studies on why students choose a course in the field of (bio)engineering technology.

This paper therefore aims to answer four research questions: (1) which factors play a decisive role in the choice of a course and (2) of a campus in a multi-campus (bio)engineering technology faculty, (3) when do students make the final choice, and (4) which information sources are most effective in reaching the current generation?

1 GAINING INSIGHT INTO STUDY CHOICES

The process of choosing a course and institution has been the subject of much scrutiny over the past decades, from different perspectives. One of the first articles on college choice warned practitioners not to assume a direct causal link between recruitment strategies and student enrolment numbers. The authors argue that college choice is affected by both individual characteristics and external factors, but mostly indirectly, by influencing the student's perceptions of college quality [4].

Further studies have identified a plethora of influences by elaborating on decision-making models from marketing and sociology. The resulting study choice models can be divided into three categories. A first group embraces economic and econometric models, which operate on the assumption that preferences are based on rational consideration of constraints and benefits. The second type are sociological models, focusing on contextual, cultural and social influences and influencers. The third category contains combined models, focusing simultaneously on rational and subjective forces [3,5,6,7]. A common element in all models is the premise that, after conscious or unconscious consideration of each option's expected costs, perceived benefits and chance of graduating, the aspiring student will choose the options with the best expected outcome [8]. Often cited influencing factors include course suitability, geographical proximity, academic reputation, self-efficacy, graduates' labour market prospects, family, peers, demographic attributes, financial constraints and application procedures [1,4,5,6,8,9,10,11].

The choice process itself has been segmented into three to nine stages [2,3,7]. Information sources relevant to choosing a college or course have been addressed as well, though with inconsistent outcomes [2,4,5,6,9]. For a comprehensive overview of literature on study choice, consult the article by Obermeit [7].

2 METHOD

In this study, all first year undergraduate students of the multi-campus Faculty of Engineering Technology at the KU Leuven university were asked to fill in a paper survey at the beginning of the current academic year ('16-'17). All seven campuses offering a bachelor program in (bio)engineering technology participated in the study.

The paper questionnaire was limited to two pages and consisted of three short sections. The first section focused on choice factors. Students were asked to indicate out of a list of nine factors those that had been decisive in their choice of a course, and to rate the importance of fifteen factors on their choice of a campus on a five-point Likert scale. Answer attributes were obtained from literature or suggested by the faculty board. The items were chosen to reflect different types of motivators: intrinsic interest, social and geographical aspects, educational considerations, and expected benefits on short and long term.

In the second section, a number of questions and statements intended to find out more about the choice process. Students marked which information sources had taught them about the existence of their course, and when they had made a choice.

Finally, background information was collected about their prior education and type of residence (living at home or at a dormitory).

3 RESULTS

A total of 1.064 students filled in the survey, yielding a 94% response rate. *Table 1* provides detailed information about each campus' sample weight and response rate.

Table 1. Number of respondents, sample weight and response rate for each campus.

	N=	n=	% of sample	Response rate
Aalst	32	32	3%	100%
Bruges	88	86	8%	98%
Diepenbeek	183	173	9%	95%
Geel	96	95	12%	99%
Ghent	233	197	19%	85%
Leuven	364	356	33%	98%
Sint-Katelijne-Waver	131	125	12%	95%
Total	**1.127**	**1.064**	**100%**	**94%**

Considering the high number of respondents and response rate, no additional checks were necessary to estimate the sample's representativeness for the total population.

The paragraphs below explore four research questions:

1. Which factors influence the choice of a course?
2. Which factors influence the choice of a campus?
3. When do students make their final study choice?
4. What information sources are most important to reach prospective students?

Additionally, differences in responses for students with different profiles are reported. The significance level was adjusted to .0045 according to the Bonferroni correction method, but this did not alter any conclusions regarding (non-)significance of results compared to a .05 level as all calculated values were well above or below the threshold.

Prior education was dichotomized into general secondary education (ASO) and technical secondary education (TSO), with a prevalence within the sample of 70% ASO versus 30% TSO. Type of residence was classified as students who live at home (61% of the sample) and students with residence in a dormitory (39%).

3.1 Choosing a course

The findings suggest that the majority of the students felt most compelled to pursue a study in (bio)engineering technology because of their interests and the content of the course, the expected job prospects and the expected job security (*Fig. 1*).

The match to prior education also proved to be an asset for students with a technical secondary education (TSO), but not for students from general secondary education (ASO) (indicated by 64% of students from TSO opposed to 33% from ASO; $\chi^2(1)=88.215$, $p<.001$).

Other factors, such as the university degree, expected salary and opinion of others were reported to have had less influence on respondents' choice.

Chi-square tests of independence showed only minor differences between campuses and no marked differences between the decisive factors for a course in engineering technology compared to bioengineering technology (p>.05).

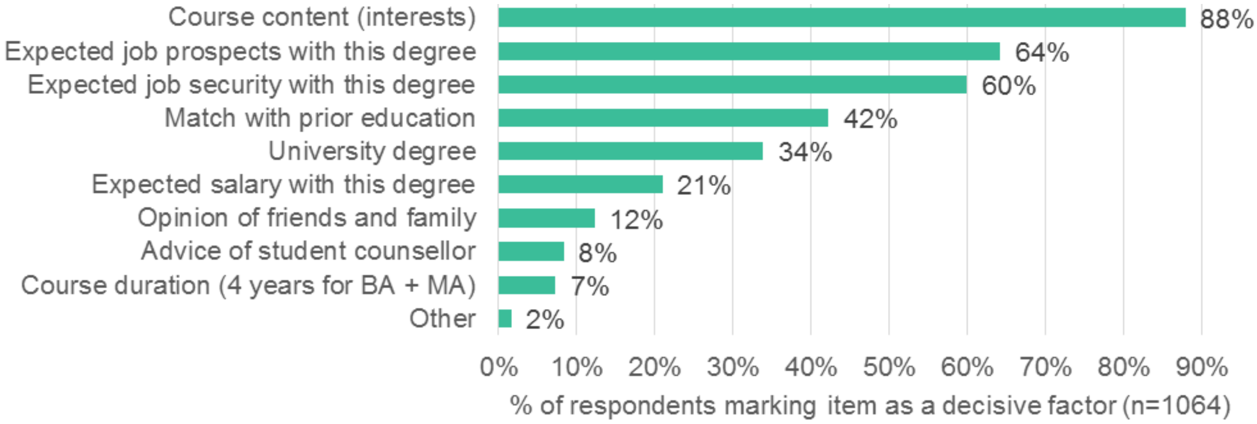

Fig. 1. Decisive factors for choice of course (multiple answers possible).

3.2 Choosing a campus

Fig. 2 shows influences on the campus choice. Most important on average was the possibility to take a specific course (M=3.58, 63%), followed by the range of courses (M=3.09, 40%), the campus' reputation (M=3.20, 47%) and its scientific research (M=2.79, 30%). The top five is completed by geographical proximity (M=2.73, 36%). Ranking items based on the number of students who scored each item as having a (very) strong influence presents a slightly different picture: in this case, city (M=2,64, 30%) gains importance to the expense of scientific research.

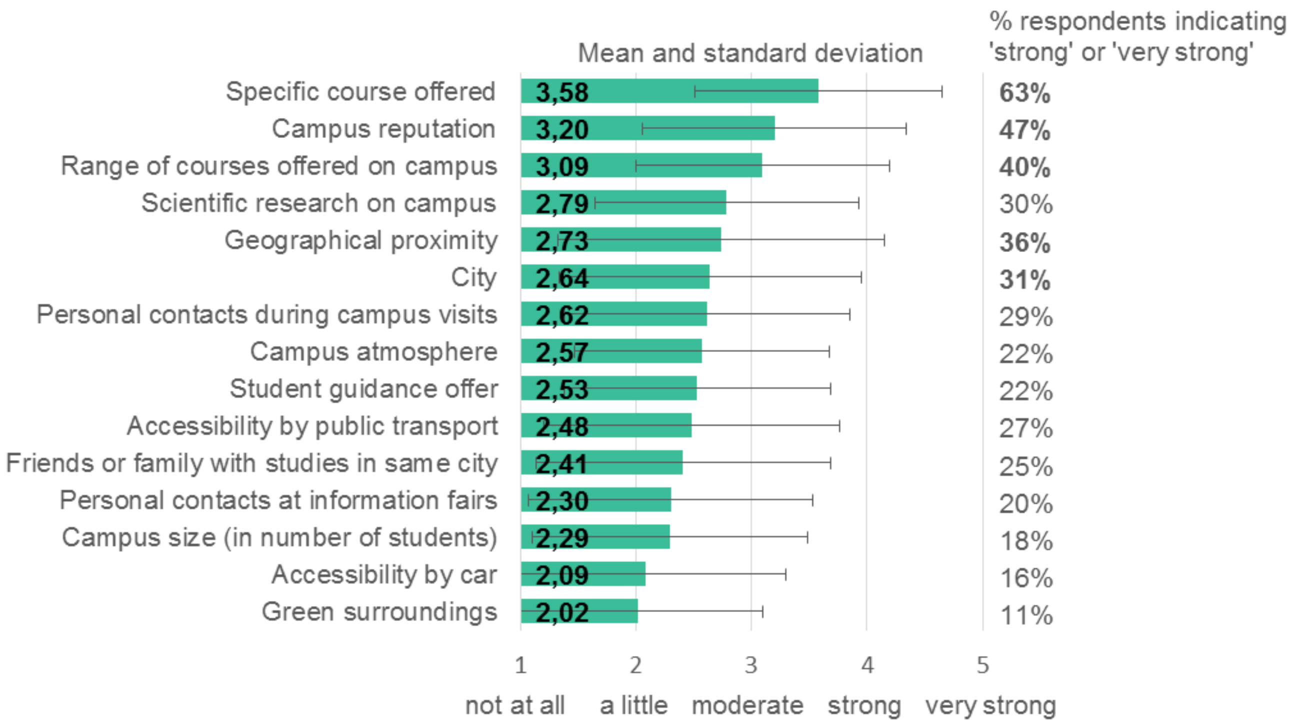

Fig. 2. Degree of influence on campus choice.

Looking at campuses' results in detail shows that the course offer is consistently the most important factor, but also illustrates strong differences in items' scores and ranking for each campus separately.

Independent-samples t-tests show only minor differences between students with different prior education, and predictable differences between respondents based on their type of residence. Students who live in a dormitory are far less concerned about proximity (M_D=1.93, SD_D=1.208; M_H=3.28, SD_H=1.287; $t(1033)=16.861$, $p<.001$), accessibility by public transport (M_D=2.21, SD_D=1.143; M_H=2.66, SD_H=1.333; $t(1035)=5.611$, $p<.001$) or accessibility by car (M_D=1.58, SD_D=.894; M_H=2.43, SD_H=1.278; $t(1033)=-11.870$, $p<.001$) compared to students who commute between their homes and campus, but they attach more value to study choices of friends and family (M_D=2.68, SD_D=1.299; M_H=2.23, SD_H=1.227; $t(1034)=-5.681$, $p<.001$).

The statement 'I chose a campus first, and a course next' elicited very strong responses from the students. The item was rated on a six-point Likert scale from 'strongly disagree' (1) to 'strongly agree' (6), and generated a mean score of 2,08 (SD=1,39). No fewer than 83% of all respondents declared they did not concur. Exactly 50% marked the 'strongly disagree' option, 22% opted for 'disagree' and 11% selected 'slightly disagree'. The percentages on the other side of the scale were 9% for 'slightly agree', 5% 'agree' and 3% 'strongly agree'.

3.3 Timing of the final decision

Most students (90%) did not make a choice until the last year of secondary education. One third (38%) chooses a course before the Easter holidays of sixth grade. Another third (32%) keeps different options in mind until the end of their final term, and the last third (30%) even up until their enrollment in the summer months.

A graphical representation of the collected data suggests a tendency for students from technical secondary education to make the final decision sooner than their peers from general secondary education (*Fig. 3*). A chi-square test of independence confirms this difference ($\chi^2(6)=20.083$, $p=.003$).

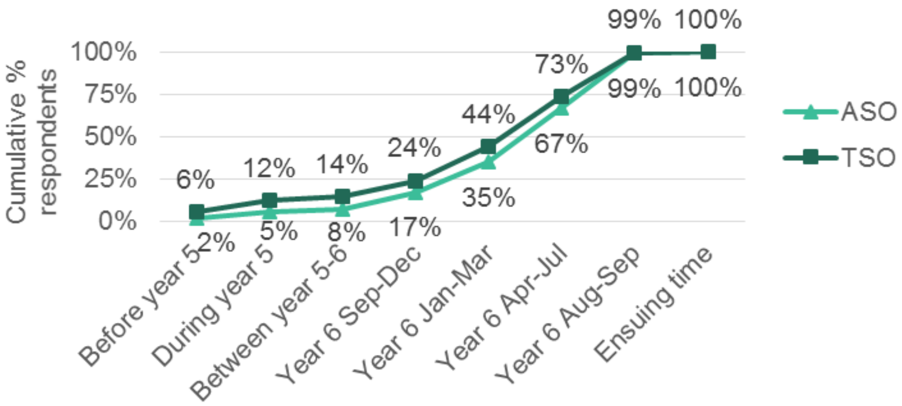

Fig. 3. Timing final study choice

There were no marked differences between students from (bio)engineering technology ($\chi^2(6)=5.324$, $p=.80$), nor between campuses ($\chi^2(36)=37.386$, $p=.41$).

3.4 Information sources

More than half of the respondents has learned about the course through info days or fairs, friends and/or family. Traditional information sources such as brochures and the university website also remain important (*Fig. 4*).

Less important but still worth mentioning are teachers and study counsellors, who generated awareness about the course and campus for one student out of five. The open course week, an annual event where prospective students can attend a number of classes, has a smaller effect but still manages to reach 14% of all students.

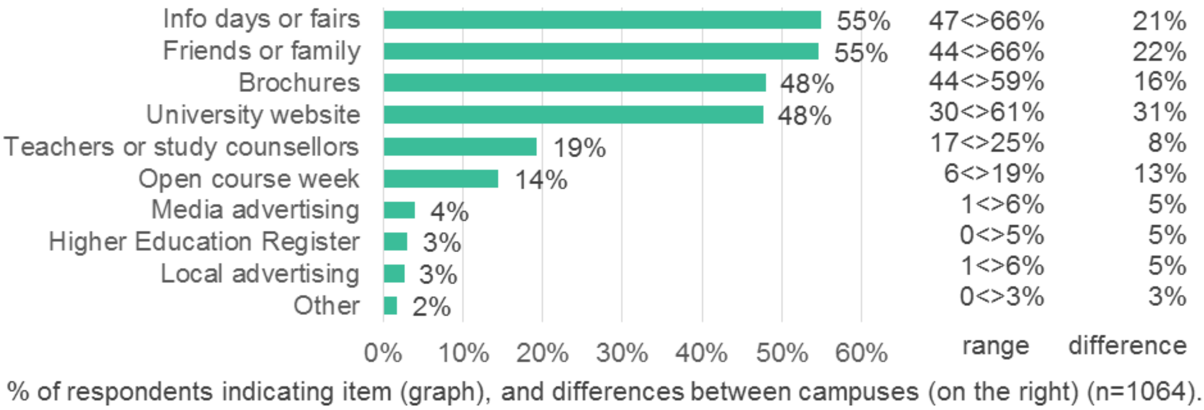

Fig. 4. Information sources relevant in finding out about course offered on campus (multiple answers possible).

One of the most striking observations, however, were the differences between the answers of students registered at different campuses (*Fig. 4*, on the right). This suggests that not all information sources had been equally effective for each campus. For several items the results varied by more than 15% between campuses. The difference was most pronounced for the university website, with percentages ranging between 30% and 61% depending on the campus ($\chi^2(6)=62.110$, $p<.001$). Moreover, the average number of information sources indicated by each student was similar for each campus, as was verified by a between-subjects ANOVA ($M=2.51$, $SD=1.282$; $F(6,1052)=1.194$, $p=.31$), eliminating this as an alternative explanation.

4 DISCUSSION

This paper intended to contribute to a better understanding of the decision-making process of students entering higher education, and specifically of those who wish to pursue a study in (bio)engineering technology in today’s multi-campus setting.

Marketing departments will benefit from insight in the study choice process by being able to select the most effective recruitment strategy to attract students to courses and campuses that offer the best fit with their preferences and needs. This in turn will help educational programmes improve retention rates. And faculty and university boards will find useful pointers in the results to keep their educational offer attractive even when presented with budget cuts and restructurings.

4.1 Summary, comparison to prior studies, and recommendations

The findings of our large scale quantitative survey show that course content, expected career prospects, expected job security, and correspondence to prior education were perceived as the most decisive factors for a course in (bio)technology engineering. Other factors, such as the university degree, expected salary and opinion of others were reported to have had less influence. This provides useful recommendations for marketing practitioners. Based on this study, marketing campaigns should be equally effective for all target groups and regions by highlighting these assets. The only exception is with regard to prior education, where it might be interesting to tailor the message so as to reach students from both general and technical secondary education in the most effective way.

The results are mostly in line with previous studies: in our study as well, intrinsic motivation was important, but so were labour market perspectives [2,6,9,10,11]. The opinion of others was considered less important than in prior studies [4,5,9]. Note that subscription fees and application procedures have not been included in our questionnaire, as higher education in Belgium is highly subsidized and the only requirement for admission to most higher education courses is to have obtained a secondary education degree. The fact that in our study intrinsic motivation was the strongest driver for the course is probably also related to this fact.

The strongest factors determining choice of campus were the campus' specific course offer and range of courses, academic reputation and local scientific research activities, and geographical proximity. In the minds of our students, though, the choice of a course trumped the choice of a campus. Students from all campuses valued similar course attributes, but different campuses did attract students for different reasons, in line with our expectations. This confirms that unique selling propositions do matter for recruitment. Our results correspond most to the college choice factors identified by Stanley and Reynolds [9]. Geographical proximity, which has often been identified as a major influencer [1,6,8], was taken into account by our students, but in comparison to a much lesser degree. This was interesting, as the course in engineering technology is offered at all seven campuses, allowing students to choose a campus based on the distance to their residence. On the other hand, the distance between any two campuses is less than 200 kilometres and Flanders has a dense infrastructural network, which perhaps makes distances irrelevant.

Marketing campaigns need to highlight the right information, but also need to reach students before they have made their decision. Based on the results from this study, the best time to start communicating to prospective students seems to be during fifth grade for students from technical secondary educational and during sixth grade for students in general secondary education. The most crucial moment to reach students is in the weeks before and after the Easter holidays. Even so, info events during the summer months matter as well and are recommended.

Personal contacts clearly played a major role in creating awareness about the course offer. Four information sources excelled at reaching potential students: the university website, brochures, personal contacts with family and friends, and info days or fairs. Contrary to some other studies [5,6], in our study both the website and brochures provided by the HEI had a strong impact. Marketing practitioners are advised to select a diversified communication strategy, as not all information sources seemed equally effective for each target group and region.

4.2 Strengths, limitations and directions for future research

One aspect to keep in mind when interpreting the findings is that all results were self-reported in retrospect. Students might have rationalized their decisions [8], been unaware of the impact of certain influences, or given a false account of their impact. In awareness of these potential limitations, the questionnaire was presented on paper and kept anonymous so as to avoid a social desirability bias.

Asking students about their choices at the beginning of the academic year allowed to take into account the final decision and the process right up until their enrolment. A limitation is that the sample was limited to those students who actually enrolled, a challenge addressed in literature [2]. This did not present an issue, however, because of the large sample and response rate and because the majority of all (bio)engineering technology students in Flanders were still included in this study.

This study extends upon existing literature by adding campus choice. Further research could validate the findings in other countries or fields of study. The author is currently investigating whether choice factors of prospective students match the actual strengths as identified by current third-year students. Additionally, a longitudinal study might be interesting to look into the relationship between choice factors, individual characteristics, study results and graduation rates.

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Not always a nerd: exploring the diversity in professional identity profiles of STEM students in relation to their career choices

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ABSTRACT

Although there is a high demand of highly educated professionals in the technical sector, only about 50% of the graduates from a study program in science, technology, engineering and mathematics (STEM) opt for a career in the technical sector. Professional identity has been shown to influence students' career choice. STEM students whose professional identity is more in line with their future profession are more likely to commit to a career in the technical sector. At the same time, stereotyping can lead less prototypical students to leave the technical sector. However, little is known about the diversity in STEM students' professional identity and how this is related to their career choices. Based on a survey-study among 743 STEM-students, we developed five profiles of STEM students' professional identity called the *nerd*, the *status seeker*, the *hipster*, the *security seeker* and the *loner*. These profiles were significantly related to the strength of identification with their future profession and intended career choice. Results indicate that while there is much variation between STEM students' professional identity, more stereotypical, male students are still more likely to aim for a career within the technical field.

Conference Key Areas: Gender and diversity, attractiveness of engineering education, continuing engineering education and lifelong learning.

Keywords: STEM students, professional identity, career choice, career commitment

INTRODUCTION

As the Dutch economy relies heavily on the technical sector, the economic success of the Netherlands is dependent on the inflow of highly educated science, technology, engineering, and mathematics (STEM) students. And while the number of graduates in technical study programs has increased in recent years, only about 50% of them continue to work in a technical profession after graduation [1]. This is even more remarkable as there are low unemployment rates in the technical sector and therefore many opportunities for graduates to find work. As of now, little is known about why so many STEM students opt for a career outside the technical sector.

One concept that influences students' career choice is *professional identity* [2]. Professional identity can be described as a set of personal traits, values, interests, and competences relating to that person's profession [3]. Research has shown that a strong and well developed professional identity increases the likelihood that students choose a job in their field of study [4]. Additionally, when the representations of a certain profession are more congruent with a student's professional identity, they are more likely to be committed to and continue on in a career in that profession [e.g. 5]. Therefore, it can be expected that students with traits that are more in line with the stereotypical representations of professionals in the technical field, such as being male, being a nerd, are more likely to aim at a career in a technical profession than their less stereotypical counterparts. Thus, presenting students examples of more diversity within the technical community and the professional identity of their (future) peers can increase their chance to take up and remain in a career towards the technical field. However, little is known about the diversity in STEM students' professional identity and how this is related to their career choices.

In the present study, profiles of STEM students' professional identity are identified to highlight the breadth of variety of professional identity of STEM students. Additionally, these profiles of professional identity of STEM students are linked to the degree to which they identify with their future profession and their intended career choice.

1 THEORETICAL FRAMEWORK

1.1 Professional identity

Professional identity has been described as the relevant traits, believes, and motives a person holds about themselves in a professional role. In this definition, there is a strong focus on the individual and his or her personal believes, which are presumed to be stable in a person's life [6]. Contrary to that, there are also researchers who support a more socially oriented view on professional identity. They define professional identity as "the degree to which employees identify themselves with the profession that they practice and its typical traits" [7, p.211]. This take on professional identity as the communality between individuals in a certain profession can result in stereotypes, for example that a typical STEM student is a white male, who is shy and highly intelligent. This process of stereotyping can have as a result that young people who are suited for a profession in the technical sector feel that they do not belong between their prospective peers as they do not possess certain stereotypical traits or values of a profession. Whether professional identity is seen as a personal or social construct, researchers agree that a distinction can be made between the strength of professional identity and the content. The content of professional identity contains five dimensions, namely an individuals' interests, competences, values, personality and goals. The strength of professional identity describes the degree to which an individual feels their relevant traits fit the traits of a certain profession [8].

Research on professional identity often focusses on how students or professionals develop a professional identity, that is to say how do students or professionals develop and shape their professional identity in time and which factors influence that process. Much less research is done on what the content of professional identity of students and professionals in a certain field is. Additionally, research on professional identity is most often performed in the medical or educational [3] field. However much less research has been done in the technical field and little is known about STEM students' professional identity. Moreover, research on the content of professional identity is often done in qualitative research on a small scale, whereby the content is measured in various manners. Large scale quantitative research that produces generalizable results on the content of professional identity of people in a profession is scarce [3].

1.2 Professional identity and career choice

Research shows that from a young age on, professional identity influences a person's life. Research on high school students shows that a well-defined strong professional identity improves students' school grades, their motivation to learn and how well thought out their career choices are [4]. In addition, research on STEM students has shown that university students who start their degree with lower levels of a match between their professional identity and their future profession or students with a strong but ill-defined professional identity (i.e. students who feel a strong commitment towards a certain profession without much knowledge of what that profession entails), are more likely to quit their studies. However, this need for a person's professional identity to be in line with the perceived characteristics and traits of a certain profession can pose a difficulty for people with less stereotypical traits of a certain profession. People who do not possess these stereotypical traits are much less likely to embark on a career towards a career in the technical field [e.g. 5]. However, the interest of less-stereotypical individuals in a career in the technical field can be increased when they come into contact with less stereotypical professionals who work in the technical sector. A study on university students showed that reading about a broad range of professionals in the technical sector with more or less stereotypical traits increased students' perceived communalities with professionals in the technical sector and increased the likelihood of choosing a path towards a technical career [5].

1.3 Research questions

Based on the literature review as described above, the goal of this research is to identify differences in the content of professional identity and to link these different profiles to the strength of identification with their future profession and their intended career choice. As such, three research questions were formulated:

1) What profiles of STEM students can be distinguished, based on their professional identity?
2) How do professional identity profiles influence the degree to which STEM students identify with their future profession?
3) How does professional identity influence STEM students' intended career choice inside or outside the technical sector?

2 METHOD

2.1 Participants

Last-year students from all technical study programs of two Dutch higher education institutions, one university, one university of applied sciences, were invited to take part in the study. About 3500 students received an invitation via email from their study advisor. In total, 816 students started to fill in the questionnaire (response rate 23.3%). Students with more than 10% missing answers, as well as students who indicated they were enrolled in a non-technical study program were excluded from data analysis. This resulted in the data of 743 students being included in the current study (34.2% female, 59.0% male, 6.9% unknown). The average age was 22.66 years old (*SD* = 2.78). Of the participants, 367 (49.4%) were enrolled at a university, while 338 (45.5%) were enrolled at a university of applied sciences (5.1% unknown).

2.2 Measures

To measure the professional identity of STEM students a new instrument, called the "Career Compass", was developed. Within the Career Compass preexisting, validated scales were used to measure the four dimensions of professional identity: interests [9], competences [10, 11], values and goals [12 - 15], and personality [16, 17]. This resulted in 178 items that were presented to the participants. Participants were asked via a 7-point Likert scale, ranging from 1= *not at all* to 7= *very much*, to what degree an item applied to them. Confirmatory factor analysis was performed on all five dimensions of professional identity. Model fit indices indicated sufficient fit for all dimensions of professional identity.

Next to the content of professional identity, the degree of identification with students' future profession was measured with six items [18], an example item being "*I feel good about becoming an engineer",* measured on a 7 point Likert scale. Finally, students' intended career choice was measured with two open questions, in which students were asked to name 1) an organization they would like to work for and 2) a job they would like to perform. Answers were coded by two independent raters as either technical (e.g., technical industry) or non-technical (e.g., hospital, financial industry). Interrater-reliability was assessed by the Cohen's Kappa which was deemed sufficient at a value of 0.68.

2.3 Analyses

In order to develop professional identity profiles of STEM students, k-means clustering was applied. ANOVAs were used to decide on the model best representing reality.

The professional identity profiles and career choices were related to the strength of identification using ANOVAs. Chi-square analysis were used to relate the professional identity profiles to the intended career choice.

3 OUTCOMES

3.1 Profiles of STEM students

K-means cluster analysis revealed five different professional identity profiles: the *security seeker* (24.2 %), the *hipster engineer* (22.5 %), the *nerdy enginee*r (21.4 %), the *status seeker* (16.6 %) and the *loner* (15.3 %). *Security seekers* are conscientious and conservative persons who values routine and structure and do not seek intellectual stimulation or challenges. They are organized, but score lower on analytical skills. *Hipster* engineers are very social, are interested in fashion and beauty. They find it important to have a purpose in life, to help others, want to live a healthy life and value their autonomy. They score high on design skills, working in teams and being internationally oriented. *Nerdy* engineers distinguish themselves by having strong analytical and research skills. They are conscientious and rational and find intellectual stimulation very important. They are interested in gaming, while scoring very low on socially oriented interests. *Status seekers* are very extravert, social students who are conscientious and rational. They score high on (self-) management skills and are very analytical. They value status and power and find money important. Finally, *loners* are students who are very introvert and agreeable. They find it important to have a comfortable life and value money, status and power only very little. *Loners* are mostly interested in gaming and score low on social activities, fashion and beauty. While estimating all their competences as quite low, they score especially low on managing others and collaborating with others. In Table 1, the distribution of all students can be found. The differences between men and women was found to be significant ($X^2(4)=121.089$, $p< .05$): male students were more likely to be classified as status driven, nerdy or loners, while female students were more likely to be classified as hipsters or security seekers.

Table 1. Professional identity profiles by gender

	Distribution of profiles n=			Mean strength of identification		
	Overall	Women	Men	Overall	Women	Men
Loner	114 (15.3%)	30 (11.8%)	78 (17.8%)	4.46	4.01	4.67
Security seeker	180 (24.2%)	98 (38.6%)	68 (15.5%)	4.53	4.35	4.72
Nerd	159 (21.4%)	16 (6.3%)	129 (29.5%)	5.08	5.08	5.08
Hipster	167 (22.5%)	89 (35.0%)	71 (16.2%)	4.70	4.64	4.83
Status seeker	123 (16.6%)	21 (8.3%)	92 (21.0%)	4.70	4.29	4.79
Total	**743 (100%)**	**254 (100%)**	**438 (100%)**	**4.70**	**4.45**	**4.85**

3.2 Strength of identification

Analyses of Variances (ANOVA) revealed significant differences between the profiles in the degree to which STEM students identified with their future profession, even after correction for demographic factors (gender, level of education, completed internship, and type of study program) ($F(4, 669)=4.15$, $p=0.00$). Nerdy students scored highest on identification with their future profession, followed by the hipsters and status seekers (see Table 1).

Also, significant differences were found between the degree to which male and female students identified with their future profession (again corrected for demographics). Male students scored significantly higher ($M=4.85$, $SD=1.03$) than female students ($M=4.45$, $SD=1.15$) ($F(1,674)=7.65$ with $p=0.006$).

3.3 Intended career choice

Chi-square analysis revealed a significant relationship between STEM students' professional identity profiles and their intended career choice within or outside the technical sector ($X^2(4) = 25.19$, $p< .05$). Students who are classified as *nerds* are most likely to pursue a career in the technical sector (64.7%), followed by *loners* (62.0%), while security seekers are least likely to aim at a career within the technical sector (40.4%). Because of unequal gender distributions over the profiles, separate analyses were carried out for men and women, showing no significant differences between professional identity profiles and intended career choice for either men ($X^2(4) = 4.04$, $p = 0.40$) nor women ($X^2(4) = 4.09$, $p = 0.39$). For a complete overview see Figure 2.

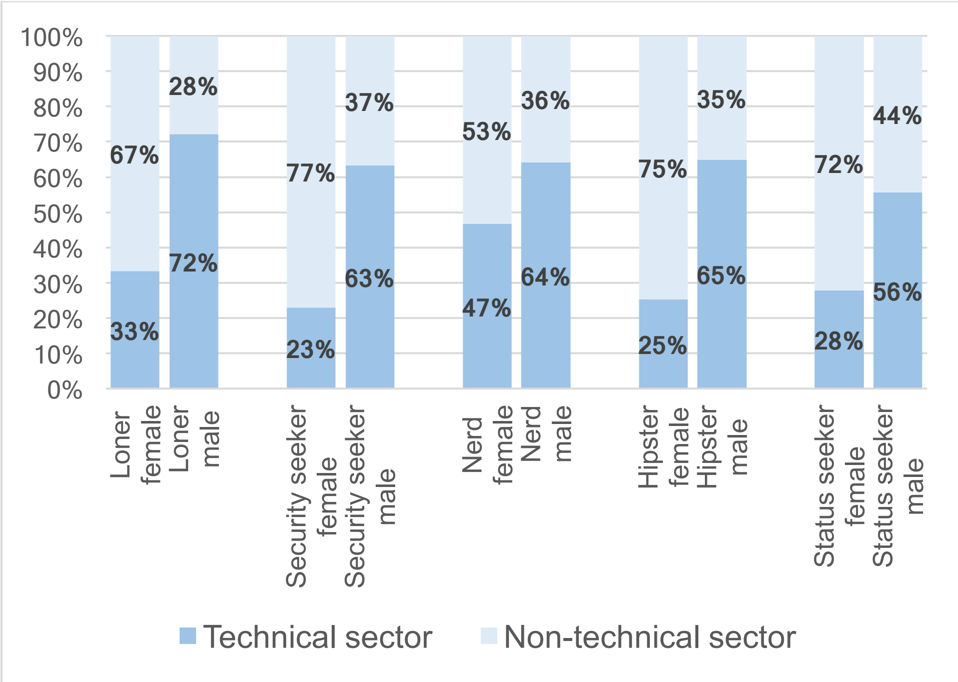

Fig. 2. Intended career choice per professional identity profile per gender

ANOVA showed a significant relationship between STEM students' strength of identification with their future profession and their intended career choice, $F(1, 601) = 59.10$, $p = 0.000$. Analysis of means showed that STEM students who aimed at a career outside the technical sector identified significantly lower with their future professions ($M = 4.43$, $SD = 1.05$) than their peers who aimed at a career in the technical sector ($M = 5.06$, $SD = 0.98$).

4 CONCLUSION AND RECCOMENDATIONS

The research at hand succeeded to identify five different profiles of STEM students, based on their professional identity, thus highlighting the diversity of that population. The profiles range from profiles with more stereotypical characteristics, such as the *nerd* profile to profiles with less stereotypical traits, such as *hipsters*. Further analysis shows that in line with expectations, professional identity does influence the degree to which STEM students identify with their future profession. Likewise, students' career choice is influenced by their professional identity: students with professional identity profiles that entail more stereotypical characteristics such as *nerds* or *loners* are much more likely to aim for a career in the technical sector than students with profiles with less stereotypical traits, such as *security seekers* and *hipsters*. However, the differences between profile in career choice evaporate completely when gender is taken into consideration. Conclusively it can be said that while there is much variation between STEM students' professional identity, more stereotypical, male students are still more likely to aim for a career within the technical field.

Findings from this study can be useful for (prospective) STEM students, educational institutions and organizations in the technical sector. STEM students may gain more insights into the diversity within the population of STEM students. This increased communality might help them to identify more with their peers and their future profession, which in turn can increase their motivation to study and decrease their chance of leaving the field. Another direction to explore, is how the identity profiles are related to different study programs. Do we see more variation in profiles in one study program and a more homogeneous group in another program? Educational institutions can use the findings to adjust the study program to the needs and interests of different profiles of STEM students. As an example, giving the possibility for more social types of STEM students to work together, or highlighting the benefits for society of working projects in order to motivate students with a *hipster* profile. Finally, organizations in the technical sector can use the developed typology to closely look at their workforce and recruit specific types of STEM students as job adds can be construed to attract specific types of STEM students.

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OPEN ASSIGNMENTS IN A FIRST YEAR STUDENT PROJECT

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ABSTRACT

Many universities offer projects to support students at the beginning of their studies in order to sustainably enhance the students' motivation or facilitate orientation and network building at university.

We introduced a new, open project format during winter semester of 2015/16. In this project, freshmen develop products for specified target groups. After establishing a close cooperation with the local association of the blind and visually impaired, a user-centered approach for product development was used for the assignment where students developed a new product to simplify the daily lives of that target group. Students derived a specific technical problem statement and discussed their understanding of the problem as well as their ideas for solving them with the future users. Results of this project were an inclusive version of the popular board game

"The Settlers of Catan", a tactile model of local main train station, and on the meta-level clear ideas for integrating this project format in the curriculum.
In this paper, we will show how different aspects of this project format can be developed, which special features need consideration when using largely ill-defined assignments, and what kind of support students need to successfully finish the project.

Conference Key Areas: Engineering Skills, Attractiveness of Engineering Education, "I want to contribute to solve local problems"

Keywords: First Year Orientation, Student Project, Open Assignments

1 INTRODUCTION

Beginning their studies at university poses large challenges for many freshmen. At university they are often confronted with a number of problems: Many of them move to a new city for their studies and as a result lack personal contacts and networks. The university itself is a new environment with its own rules, and being a student planning a future career, or even just having to organize a life without daily support by parents, is a new experience. In addition, students are now responsible for their own learning progress, generally with less support than in school if difficulties arise.

Universities are increasingly interested in supporting students during this transition phase. Besides other measures already in place at Hamburg University of Technology (TUHH), we developed a first-year engineering project which started in winter semester 2012/13. This project, the Interdisciplinary Bachelor Project (IDP), is designed to motivate students for their studies and is very well received. Student teams develop for example airship propulsion systems, urban wind turbines or photo bioreactors.

To develop this project further, we introduced a new project format – using open assignments – during winter semester 2015/16, which we present in this article.

1.1 First Year Student Projects

First year student projects are widely used in universities with various objectives, e.g. to familiarize students with the campus and people at the university and to encourage them to network with each other. Some projects aim to introduce students to the general topics of their profession or to concepts of scientific practice. For engineering students, we believe that learning through their own experiences in team work and project management prepares them for their later work as engineers. Since many students enjoy or need learning by practical experiences [1], also projects that integrate practical work are in place.

Our voluntary project allows students to build identity as an engineer right at the beginning of their studies. They, as teams of ten to twelve students of all study courses, are given a challenging engineering task which needs to be solved including all steps from conceptual work to a prototype. The project is characterized by a large degree of freedom regarding the project organization and the choice of material which is very motivating and rewarding for the students. For our project, we noticed that for some students it would be even more interesting if they could pursue their own ideas, especially with respect to defining the aim of their project by themselves. We therefore adjusted our concept and included an open assignment approach.

1.2 Open Assignments

When talking about "open" assignments, we mean that students are given a problem for which they can find any solution – and any way towards that solution – they like. The problem is broadly defined, in our case "find a way to support the visually impaired and blind in a task they would like to be supported in". We define a target group that we aim to assist, and we prescribe the solution must be "technical", because, after all, we are training future engineers.

We chose this form of assignment for several reasons, all ultimately aiming at increasing students' motivation for their engineering studies:

A) Experience what it will be like to be an engineer

Development of students' professional identity takes a lot of students' time and energy during their transition into university [2]. Many first-year engineering students wish their studies consisted of a better combination of theory and practice, not only dry theory, because in their eyes this does not relate to their future jobs as engineers [1]. By experiencing what it will be like to be an engineer, working on an authentic engineering task, a realistic view of a future professional identity is formed. This includes being confronted with others who are not interested in engineering but in something that only engineers can do: Create a technical solution.

B) Contact with professors, teaching staff, more senior students and peers

Supporting students especially during their first year of study is important because they often feel isolated and under extreme pressure [3] and wish for contact with instructors and feedback [4]. Therefore, we offer the opportunity to get in personal contact with professors, teaching staff, more senior students and peers. Additionally, working in teams and asking for help, which are a daily reality in engineering practice, is not often experienced or explicitly taught (and sometimes actively discouraged) at university which we aim to change.

C) Understand relevance of dry and/or boring subjects for their future as engineers

In order to guide students towards deep learning not only during the project but during their studies in general, it is important that they focus on wanting to master a task in order to pursue their own goals [5]. If their goal seems valuable enough, they will be willing to put in a lot of effort to reach it [6]. One important project aim is therefore that students independently identify problems and find ways to solve them, recognizing that even dry lectures teach them something useful to solve the problem at hand or problems they are likely to encounter during their future careers. This increases their motivation to attend, for example, mathematics lectures.

D) Experience competence and autonomy

Autonomy is an important motivator [7] that students typically do not experience much at university and that is therefore given in an open topic project where they not only chose the task they are working on but also how, when and where to work on it. However, being aware that failure can lead to frustration, it is important that students can succeed, which is made possible by offering mentoring and support by experts. But it is important that success is eventually attributed to students' own efforts [8] and hence that they experience competence [7].

E) Experience meaning

Engineering is not just about building things, it is about doing something good in the world, about accepting and acting upon the social responsibility one carries as an engineer. Meaning attached to a goal, for example helping people, increases the perceived value of mastering the skills needed for that aim, therefore students are willing to invest more in gaining those skills [6].

These reasons led to the development of an "open topic" project which we will describe in the following. Section 2 describes the projects' schedule we developed. Section 3 describes the approach used and presents the results of the project. Finally, in Section 4 we draw conclusions regarding the project.

2 PROJECT DESCRIPTION

The new voluntary project is offered to students of all study courses. They are supported by a team responsible for organizational aspects, a panel of experts who help on demand and tutors supporting the team processes. It has a duration of approximately one semester. The aim is to collaboratively develop a prototype of a product the user group needs. In the first run, about fifteen students took part.

The project is structured by only a few milestones in order to allow students to work largely self-determined (Fig. 1). However, in the weeks at the beginning a few workshops (e.g. basics of project management) and meetings ensure that students get all information and skills necessary to start.

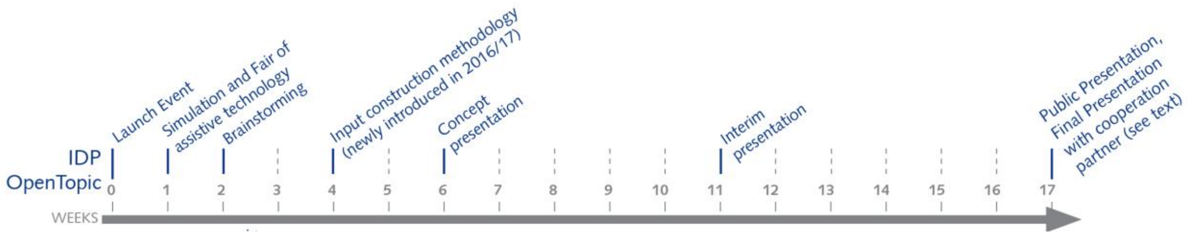

Fig. 1. Project schedule of the project format "OpenTopic" (IDP: Abbreviation for "Interdisciplinary Bachelor Project", the predecessor of the project described here)

Milestone 1 (Launch event) is an introductory meeting where students are familiarized with the ideas of the project and the people involved. Students also establish contacts to each other. A short teambuilding exercise supports them in this process. The next weeks up to the concept presentation at week 6 are used by the students to define their tasks. This involves several steps and is detailed in Section 4. At this stage, students would largely be organizing themselves with student tutors by their side, who keep the supervising team informed in case that team conflicts arise. For the supervision team, preparation of the concept presentation means to invite experts with different backgrounds such as electronics, informatics or mechanical engineering, since it is still unclear which expertise would be needed to support the students on their way.

At milestone "concept presentation", students present their concept and their ideas for realizing a prototype. They describe their planned team structure and allocation of tasks, propose a time line and a rough estimate of the costs and discuss all those aspects with experts from different disciplines and the supervision team. With an approved concept they start into the practical project phase.

During the following weeks, the student teams work largely independently. They have team meetings and keep contact to the cooperation partner. Materials are purchased and prototypes are realized in the university's student workshop [9]. The supervision team and experts may be approached if questions arise. For example, if students decide to use 3D printing and need help, a brief introduction on CAD programming will be made possible.

Just before exam period at week 11, an interim presentation takes place to ensure that students are not overwhelmed with their tasks and lose sight of their exams. Practical results are presented at a student projects' fair at university at week 17. Depending on the progress and scheduling issues of the project partner, the final presentation of the prototypes with all people involved in the project may take place a few weeks later.

3 INTEGRATING A CONCEPT FOR PRODUCT DEVELOPMENT FOR SPECIAL USER GROUPS

Corporate success depends to a large extent on the engineers and their ability to empathize with the problems and needs of the customer on one side and to design products solving them on the other side. From the product development point of view, our focus lies therefore on teaching students these abilities and giving them an impression of their future corporate work. For this task an open topic concept is a promising approach. Similar to the real circumstances, needs and requirements for the product development are largely undefined. Only the overall goal, to design an innovative product for a specific user group, is given, but all technical requirements, necessary for the product development, have to be defined by the students using their understanding of and empathy for the specific user group. To help students solving this challenging task, a user centered design approach is chosen [10].

In the project during winter semester 2015/16, the necessary contact to the special user group was made through the local association of the blind and visually impaired, so in effect we adopted a service learning approach [11]. The user centered design process conducted by the students in co-oporation with the users included direct and indirect aspects: First, students were sensitized to the special needs and problems of visually impaired through their online search, a voluntary visit of a fair for assistive technology, and a simulation carried out by the members of the association of the blind and visually impaired. Here, students were asked to perform different tasks, e.g. eating with cutlery or drinking from a cup, while wearing different glasses simulating increasing degrees of visual impairment.

Direct user integration was then used for a two-staged brainstorming. In the first stage of this method the students spontaneously gathered various ideas as well as problems and needs of visually impaired people without judging the ideas. Ideas were then collected and arranged in a mind-map. It was afterwards used in the second stage of the brainstorming as basis for discussion, selection and further elaboration in a team with visually impaired users. However, the mind-map and other visualizations of ideas were only helpful for the students as a basis for their explanations. The visually impaired, on the other side, had to imagine the students' ideas without any form of supporting tools. Clusters of ideas were therefore explained and discussed in detail one by one and results documented immediately.

Apart from the brainstorming method, direct user integration was also used for the further elaboration of concepts. For this purpose students independently held contact with the members of the association of the blind and visually impaired. They mainly shared and discussed their ideas over email. Furthermore, card board models and partial prototypes created through 3D printing were used to help understand and discuss alternative concepts during the development process as well as for evaluation of the final concepts at the end.

Of four ideas that resulted from the brainstorming, two were later realized: an inclusive version of the widely known board game, “The Settlers of Catan”, and a tactile part model of the local central station were to be designed. For the board game, board and tiles needed to be adapted which needed an elaborate exchange with the user group. Most parts were finally produced by 3D printing. Additionally, a podcast was produced comprising the rules of the game. The finished board game was handed over to the association where now members regularly meet to play the game. The group with the central station model worked out the suitable scale so that the overall model would be detailed enough for blind people and small enough to present the whole station on one large board. Staircases and escalators of the first prototype were easily recognized by the blind.

4 DISCUSSION AND CONCLUSIONS

Our experiences show that an open assignment with an external partner is worth all the effort it needs in preparation and support.

In order to evaluate the project, we asked the students in an anonymous questionnaire and we had a discussion to reflect their experiences. All of them said that the simulation as well as the brainstorming session with the blind people was most valuable for them to collect ideas for useful products. Students also remarked that the openness of the assignment was very motivating for them. As one student put it: “*This project taught me personally, what I am able to achieve in respect to being creative and finding technical solutions… This fact is very inspiring and motivating for me.”* All of them wish for the opportunity to participate in more of these open projects during their time at university. Generally, they agreed that their first year project was a good start into university, especially for getting to know staff and peers. Some of them still worked voluntarily weeks after the project to produce a product better than the prototype.

Working together with visually impaired users in a user-centered design approach was a major challenge to us. The product development process is characterized by several supporting methods and tools where usually different forms of visualizations are used to show complex structures and different concept ideas as well as to support communication in between the design team. In a user-centered design approach the special user group, in our case the visually impaired people, is also part of the design team. Switching to sole verbal and written forms of communication for the brainstorming method and the whole ideation process as well as using prototypes as a mean of communication during the elaboration of the concepts, worked out quite well for us. However, in future projects with the same user group more complex product ideas may force us to adapt the means of communication and collaboration even more.

If this project should be included into the curriculum, what does it mean from the teaching perspective? We learned that several things are important when combining an open assignment with the service learning approach: First, a close cooperation with the external partner including a careful planning of the project schedule where students are introduced to the project assignment and the needs of the potential user group. Second, at university, contacts to experts of various disciplines who are committed to the project are necessary. Overall, good communication of all people involved during the time of the project is essential for good results.

Additionally, if introducing a project into the curriculum, the specific circumstances of the curricular course require a number of adaptions. For example, in 2014 the study programme for mechanical engineering at TUHH introduced a mandatory first-year project that is based on our IDP (see Section 1). Now, each winter semester nearly 400 first year students develop airship propulsion systems in teams of 10 students. Based on our experience during this transition [12], we learned that the items to be addressed include

- The learning objectives and contents of the study course
- The number of participants
- The timeline of the course and the time effort planned for the students
- The available personal resources for organizational, technical and expert support
- The materials provided or the finances provided to purchase materials
- The availablility of rooms and workspaces
- The type of the exam

For all of these points, special solutions are needed. For an open topic project in a larger scale we would for example plan to engage well-trained student tutors, to introduce a project schedule with more detailed milestones, to – for the start – define a number of exchange dates with committed people from the project partner and to introduce formative assessment and reflection sessions.

In this article, we have described an open topic project for first-year engineering students. We developed a project schedule that integrates the step where students find their own project task based on the requirements of the cooperation partner. In the same way the base project was adopted as mandatory course into the mechanical engineering program at TUHH [12], we are now equipped with experiences and strategies to bring open topics into mandatory courses.

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The University Tutorial Action Plan

Experience in the School of Civil Engineering of the Universitat Politecnica de Valencia.

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ABSTRACT

The *Universitat Politècnica de València* (UPV), as part of the INTEGRA program, aims at reducing the impact of first-year students when joining the University life. One of the fundamental pillars of the program is PATU (University Tutorial Action Plan), which together with the Welcome Days eases the integration of new students into the University.

The main aim of this program is to help new students in their integration into the academic and social university life, as well as, to reduce the impact of access to the University, to inform students about relevant aspects of their studies, to increase student participation in the university life, and to advise students in a group and/or individual way about academic aspects or other, to help them to configure their formative itinerary and to optimize their academic performance.

This paper presents the organization, results and experiences of faculty-tutors of the Civil Engineering School at UPV, as well as the evaluation of the benefits obtained by the students of the Bachelor's Degree in Civil Engineering participating in the program.

Conference Key Areas: Engineering Education Research, Engineering Skills, Attractiveness of Engineering Education

Keywords: mentoring, first-year student, Civil Engineering degree, faculty-tutor

INTRODUCTION

The *Universitat Politècnica de València* (UPV) launched some years ago a mentoring programme for first year students known as PATU (The University Tutorial Action Plan) [1], [2]. The main objective of this programme is to make easier new students adaptation to the university context. This kind of initiative is common in many universities worldwide and its utility has been proved to smooth the beginning of first year students at the university [3], [4].

The program began to arise in 2000, within the context of the EUROPA Project (*Una Enseñanza Orientada al Aprendizaje*, A Leraning-oriented Education) of the Vice-Rectorate for Academic Coordination and Student Affairs. This project integrated five different programmes which aimed at adapting to changes in university education and to promote and improve the learning-teaching process between students and teachers. One of those programmes was AMA (*Ayuda a la Mejora en el Aprendizaje*, help for learning improvement), which aimed at helping to improve students learning, providing alternative tools and teaching methods to ease self-learning [5]. The sub-programme AMA3 was devoted to faculty-tutors and its objective was to promote students orientation through their studies. Indeed, it was recognized the convenience for new students to have a leading figure representing the institution to help them with studying techniques and to look after them from a personal and academic perspectives.

In 2004, the new Vice-Rectorate for Students Affairs and Campus Life launched the INTEGRA program, which main objective is to help students to integrate into academic and social university life [6]. The program is composed of three actions: Welcome Days (*Jornadas de Acogida*), different levelling courses and the PATU.

The Civil Engineering School (ETSICCP for the Spanish acronym of *Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos*) of UPV develops the INTEGRA programme for more than 10 years. The present paper presents how the PATU programme has been organized for the last editions, as well as presenting the results of a survey and questionnaire responded by new students who have participated in the programme during the 2016-17 academic year.

1 THE UNIVERSITY TUTORIAL ACTION PLAN AT THE CIVIL ENGINEERING SCHOOL OF UPV

1.1 Organization

All new students at ETSICCP receive information about the Welcome Days that take place in September (Fig. 1), just before the beginning of classes. Eventhough participating in the programme is elective, each new student is assigned to a faculty-tutor and to a student-tutor who will mentor him during the first academic year.

Fig. 1. Brochure of Welcome Days at ETSICCP-UPV.

During the 2016-17 academic year, each faculty-tutor had a student-tutor and, initially, a group composed of 15 first year students. This data varies from one year to another depending on the registration numbers and on teachers and students finally enrolled as mentors. The general organization of the programme is outlined in figure 2. The INTEGRA faculty member in charge of the programme at ETSICCP is the Vice-dean for Student Affairs.

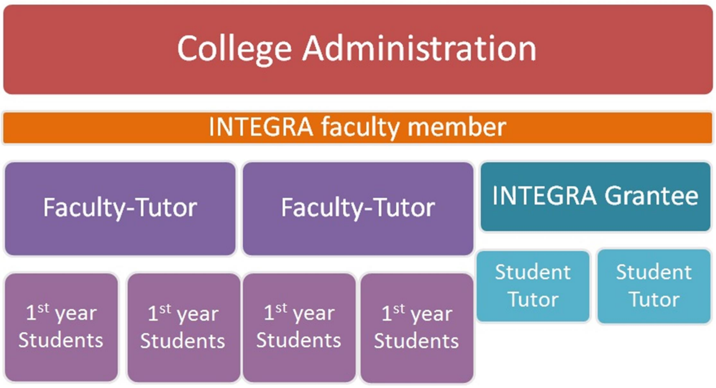

Fig. 2. General organization of the PATU programme (adapted from [1]).

To stimulate students to enroll, the school assigns 1 ECTS (equivalent to 30 student working hours) to the academic curriculum of new students that participate in the Welcome Days and that follow and complete the PATU programme. The requirements to get this ECTS are: to actively participate in at least 6 meetings (group or individual), to attend formative sessions organized by ICE (Institute for Education Sciences), and finally, to evaluate the programme.

If a new student does not participate in the Welcome Days, the faculty-tutor must contact him to call him to group meetings so that he can join the programme at any time. The Vice-Dean for Student Affairs suggests a minimum meeting calendar; participants might adjust this schedule depending on the circumstances and needs. The proposed calendar for the 2016-17 academic year is presented in table 1.

Table 1. Proposed minimum meetings calendar at ETSICCP.

Session	Day	Hours	Month	Organized by	Place
Session 1: Allocation Planning	September 1st	11:30 to 12:30h	SEPTEMBER	INTEGRA Responsible	Assembly Hall
Sesión 2: Information ETSICCP/UPV	September 15th	12:15 to 14:15h	SEPTEMBER	Student-Tutor	Computer class
Session 3: Learning strategies	September 22nd	12:15 to 14:15h	SEPTEMBER	Tutorial Group	Determined by the group
Sesión 4: Individual Tutoring	October 6th	12:15 to 14:15h	OCTOBER	Faculty-Tutor	Determined by the group
Session 5: Identify and solve problems	October 27th	12:15 to 14:15h	OCTOBER	Tutorial Group	Determined by the group
Session 6: Follow-up The End	February 2nd	12:15 to 14:15h	FEBRUARY	Tutorial Group	Determined by the group

As it can be observed, the main part of the programme takes place during the first term, especially during September. Although the reason for this is the need for tutorial action just at the beginning of their arrival to the university, students generally complain about the high number of meetings at that time.

1.2 Faculty- tutors experience

During the 2016-2017academic year, faculty-tutors authors of this paper mentored 20 new students and were coordinated with 3 student-tutors. In view of the surveys and the examination results, the balance is positive and the experience modestly contributed to improve the education system at ETSICCP (All but one of the students surveyed passed all subjects of the first semester). It also helped young new students at this new stage of their life.

In our opinion, the faculty-tutor must not be mythicized and the student must not see him as a person with answers for every question and with irrefutable opinions. Nevertheless, teachers that decide to take part of this programme must have some skills, like empathy, resilience, polyvalence, etc.; that, anyway, are likely to appear in teaching professionals [8].

For this reason it is important that the faculty-tutors are people capable of giving their time (little time) to meet students and listen to them, that they are mature enough to show possible solutions to problems that arise, that they show enough understanding and openness for the communication to be smooth and that they know their own limits to be able to indicate where students might find solutions in case of a problem being beyond the tutors reach.

All of this should be done without disrespectful confidence and without losing authority. The aim is to create a pleasant atmosphere where the student can feel comfortable, but the roles and the limits of privacy should be kept all the time.

1.3 Evaluation of the student benefits

To conclude the programme, which lasts one academic year, a survey and a questionnaire were developed. In addition with the students academic results during the first semester, this survey and questionnaire will let know their opinion and propose improvements for further editions of the PATU programme.

The survey is composed of 20 questions developed with the Likert technique [7] with five answer levels. Questions are grouped in 4 groups of 5 questions, related to the following dimensions: general assessment of the PATU programme, assessment of the relationship with the student-tutor, assessment of the relationship with the faculty-tutor and, finally, aspects to be improved in the future. Table 2 presents the survey.

Table 2. Survey to assess the students opinion on the PATU programme.

1	It was interesting to participate in PATU	TA	A	Ind	D	TD
2	I would recommend it to all new students at the UPV					
3	I would recommend it to all new students of the ETSICCP (even if it is not their first year at the UPV)					
4	PATU is only interesting the first year at the UPV					
5	All the information that PATU has provided me, could have been given to me in a talk in a single session					
6	The relationship with our student-tutor has been fluid					
7	It has been interesting to be able to speak with students of higher years					
8	The relationship with our student-tutor has facilitated my integration into the School					
9	The relationship with our student tutor has helped us to better prepare the exams					
10	I do not think there is a need for a student-tutor					
11	The relationship with our faculty-tutor has been fluid					
12	It has been interesting to be able to speak with a teacher of non-academic subjects					
13	The relationship with our faculty-tutor has facilitated my integration into the School					
14	The relationship with our faculty-tutor has served us to have confidence and to feel comfortable in the School					
15	I do not think there is a need for a faculty-tutor					
16	I would like the PATU program to continue in later courses					
17	All the aspects that have been discussed in the meetings seem interesting to me					
18	The PATU program only serves to channel the complaints and problems that arise in the classroom					
19	I would like the frequency of meetings to be greater					
20	If doubts or questions arise in the future, I will contact my faculty-tutor					
Totally Agree (TA); Agree (A); Indifferent (Ind); Disagree (D) and Totally Disagree (TD).						

In addition, the survey was completed with a questionnaire (Fig. 3.) where students may express in a more open way their opinion on the programme. Moreover, their academic results (marks) during the first semester were also asked in an anonymous format, to link them with the programme results.

Next section presents the results obtained with the survey and the questionnaire.

Please answer the following questions on this sheet:

1. Indicate the aspects that you most liked about PATU.
2. Indicate the aspects that you least liked about PATU.
3. Discuss the topics that you would like to see covered in the meetings.
4. Would you like to add something else? (Things that you would or would not include in the program, future needs that you think you might have aspects to be improved by faculty- or student-tutors, etc.).
5. Would you like to be a student-tutor? Why?
6. Indicates the grades obtained in the subjects of the first semester:

Drawing = Economics = Physics = Mathematics = Chemistry =

Fig. 3. Questionnaire to assess the students opinion on the PATU programme.

2 RESULTS

2.1 Results of the survey

Table 3 shows the results of the survey conducted to a 19 students pilot group mentored by 3 different faculty-tutors. This sample was selected amongst the 74 students of the Bachelor's Degree in Civil Engineering participating in the PATU programme.

To quantify the results of the survey, the following scores have been adopted: Totally Agree (TA) = 10; Agree (A) = 7.5; Indifferent (Ind) = 5; Disagree (D) = 3.5; and Totally Disagree (TD) = 0.

The first part of questions dealt with general aspects of the PATU programme. Surprisingly, students agreed more with statement in question 2 (You would recommend the PATU programme to new UPV students) than with the one in question 1 (It was interesting to participate in the PATU program). The reason for this result can be that although the participation in the programme is well valued, there are still aspects to improve which still produce a slight refusal (i.e., the excessive demanding during the two first months, at the beginning of the academic year). Nonetheless, the majority of the students recommend to participate in the programme, so we can conclude that they consider it a positive initiative to ease their integration into the University.

Table 3. Average and Standard Deviation for the survey questions.

Question	1	2	3	4	5		6	7	8	9	10
Average	6.34	7.50	5.89	5.68	5.21		7.03	7.76	5.50	5.37	3.45
Standard D	2.01	1.18	1.89	2.40	2.05		2.49	1.15	2.12	1.89	2.54

Question	11	12	13	14	15		16	17	18	19	20
Average	8.42	7.76	7.16	7.24	2.66		6.76	6.61	4.71	2.61	7.82
Standard D	1.71	1.64	1.79	1.84	3.14		2.12	1.98	1.22	2.13	1.69

The second part of questions focused on the opinion on the student-tutor. The most positive aspect ranked within the survey was the opportunity to meet and discuss with students studying the same Bachelor's Degree in higher years (question 7). It also has to be pointed out the positive vision of the relationship between new students and student-tutors (question 7). We have also to highlight that either in this part and in the next one, the formulation of questions 10 and 15 in a negative form has determined the kind of response given by the students. This is a point to be improved during the following years. Indeed, after analyzing the responses, the quantification performed for the data analysis is not adequate for this kind of formulation.

The third part, which aimed at knowing the opinion on the faculty-tutor, was the best ranked. Students gave scores over 7 for every question (except for question 15 for the reason explained before). Question 11 (the relationship with our faculty-tutor was fluid) obtained the highest score. The answers in this part show that faculty-tutors training as well as their motivation, make their participation in the programme successful.

Finally, the fourth part of the survey give interesting results regarding the continuity of the programme for upcoming academic years. Indeed, the majority of students would like the programme to continue during the following academic years. Finally, the application of the programme in the ETSICCP let new students to have a reference faculty during their first stepd in the University. Mainly, they will turn to him in the next future if they any doubt or problem arise, as answers to question 20 support.

2.2 Results of the questionnaire

General results of the questionnaire reveal that satisfaction of new students of the Bachelor’s Degree in Civil Engineering with the PATU programma is very high. Students appreciate accompanying done by faculty-tutors and student-tutors. They also highly appreciate to have a reference person to ask doubts or questions related to their new studies.

Regarding negative points of the programme, a generalized complaint is the high number of activities during the first weeks of the programme: a high number of meetings, the assistance to the Welcome Days and the training sessions organized by ICE. This initial concentration of activities has to be reconsidered for further editions. Advantages of providing a huge amount of information during these first weeks must be analyzed and reconsidered. Possible alternatives are to extend these informative activities all along the first four-month period, or let the students ask for information when it will be needed.

The mayority of new students who participated in the PATU programme will be trained to participate in the future as student-tutors. Nevertheless, this willingness is not necessarily altruistic, provided they will get from the school credits as a transfer for they participation in the programme. All but one of the students surveyed passed all subjects of the first semester. Nevertheless, we cannot identify a relationship between the academic results and the participation in the programme.

3 CONCLUSIONS

The analysis performed with the survey and the questionnaire hihlighted the following conclusions.

The best appreciated aspect of the PATU programme by new students is the assignation of a faculty-tutor. The majority has a positive opinion on the relationship between the student and the faculty-tutor.

The relationship with the student-tutors is good and new students of the Bachelor’s Degree in Civil Engineering are satisfied with the possibility of meet older students. Nevertheless, they are indifferent to statements like “the relationship with my student-tutor eased my integration into the School" or "the relationship with my student-tutor helped me to prepare my exams".

Three conclusions should be highlighted, (1) only one student was reluctant to contact with his faculty-tutor in case he will arise doubts or questions in the future, (2) the majority of students would like the programme to continue during next academic years, and (3) all new students who participated in the PATU programme and were surveyed agreed in recommending future new students to also get involved.

Finally, regarding points to be improved, there is a consensus on the high concentration of activities during the first weeks of the year (meetings, Welcome Days and training sessions). An alternative solution may be to spread these activities during more months.

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Since we are using double-blind reviewing process, also references revealing the identity of the author(s) should be made anonymous until the final paper.

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Assessing an ‘incentives-driven” approach to engage undergraduate engineering students in a developing Pacific country

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ABSTRACT

The unexpected and non-linear growth of IT products has challenged the way in which students have traditionally been taught in classrooms. Innovation in teaching has been the focus for many teachers who want to keep up with burgeoning IT tools and make their classes interesting. This study focuses on using an incentive-driven approach supported by technology-based teaching methods, used in one undergraduate engineering course at a university in a developing country in the Pacific region. Students in the course are not only from different pacific island countries namely Fiji, Solomon Islands, Vanuatu, Tuvalu, Kiribati, and Tonga where they had little or no exposure to technology support but come from diverse ethnic and cultural backgrounds. Data from students were collected using online forms and analyzed qualitatively.The findings suggest that students learned better and enhanced their skills when innovative methods like group learning, Facebook groups, Peer assessments and team work were introduced. Students are motivated to learn and participate in classroom activities when incentives encourage their achievements. Students’ wish for similar teaching methods to be used in other courses highlights the need for engineering teachers in any context to focus on innovation and incentives in classrooms and for policy makers in universities to encourage such approaches in order to provide a more relevant and effective learning platform for students.

Conference Key Areas: Engineering Education Research, Engineering skills, Attractiveness of Engineering Education.

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Keywords: Engineering education, diversity, incentive, assessment, creativity

1 INTRODUCTION

This paper describes and assesses the effect of an incentive-driven approach, based on various innovative strategies, in a computing science engineering course for a period of 13 weeks during semester 1, 2015 at The University of the South Pacific. Hence, we set ourselves the following research question: How do incentive-based innovative strategies used in engineering class impact these students?

The objective was to see if students in a new developing country context would find them useful and whether it would encourage engaged learning. Given the continuing advances in Information Technology (IT) and IT tools, teaching and learning methods need to change rapidly. The students are way ahead, with numerous gadgets readily available at their disposal. Based on our experience teaching undergraduate courses in Australia and India, we found computing students hard to motivate to attend lectures or other learning activities. Many participate in lectures or assessments only for attendance marks or if the lecture covers exam topics. They miss important concepts if they don't attend lectures or tutorials but if classes are not interesting there is little motivation to attend. The experience of using innovative methods with Australian and Indian computing students sparked this study to ascertain if they were also suitable in a diverse Pacific island context.

The University of the South Pacific, in Suva, serves students from eleven different pacific countries and some remote Pacific islands. Fiji has around 900,000 people in 2017 and is multi-racial and multi-cultural. Indigenous Fijians are the main ethnic group (54%) with Indo-Fijians around 40% and declining. The indigenous Fijians are mainly Protestant Christians; the Indo-Fijians are mainly Hindu, with small Muslim and Sikh communities. For various reasons, there is tension between the ethnic groups. This makes effective teaching, particularly in terms of inclusive teamwork, even more important. Moreover, a modern lifestyle and infrastructure pose challenges to students before they even start classes. Internet coverage is good in Fiji, but unstable in other Pacific countries. This study was based on student group that includes indigenous Fijians, Indian Fijians and students from other Pacific nations such as Kiribati, Tuvalu, Solomon Islands and Vanuatu. They are aged between 18 and 35. The average age of the participants was 22 and 30% of the respondents were female. The data were collected in the form of anonymous online survey towards the end of the teaching period and results were analyzed qualitatively.

Two terms are commonly used within this paper: approaches and methods. Approaches refer to general philosophies used in teaching while methods refer to the practical aspects of teaching. The findings indicate that these students benefited from the incentive-based approach using innovative teaching methods and IT tools and moreover, that they would welcome such strategies in other courses. The benefits include learning creative skills, benefiting from group learning, motivation to learn new skills and learning to work as team players. It justifies continuing to invest in and encourage teaching innovations in a developing nation context where there are so many other demands on funding.

In the following sections we review innovative approaches. We then describe the methodology, before outlining the findings, limitations and conclusion.

2 INNOVATIVE APPROACHES

The traditional (and still common) approach used a quiz, assignments and a final exam, which have the obvious advantages of being easier to administer and mark. The contrasts between the enriched innovative approach and the traditional approach are illustrated in Figure 1 below. The exponential growth in IT has created jobs that were not part of organizational structures a few decades ago [1, 2]. This has created new challenges for teachers, including how to establish the conditions to help students learn [3]. Researchers are now focusing on specific technological tools [4-6] such as how a participative learning setup, assisted by ICT, would help teachers to keep the learners interested and motivated [7]. Every few years a new disruptive technology emerges, i.e. something that fundamentally changes the way we do things [8]. For example, the Internet, mobile devices and Virtual Learning Environments, Smartphones, mobile devices and tablets have advantaged students who use them, for instance in catching up with any missed lectures [9]. They provide complementary support for students working in a second or other language, as it gives them more opportunities to listen and take meaningful notes or reflect on content. Tapp [10] found that podcasting helped students in this way. Teachers can improve student interest by introducing tasks that are imaginative and involve reflective thinking, fostering creativity and out-of-the-box thinking ideas.

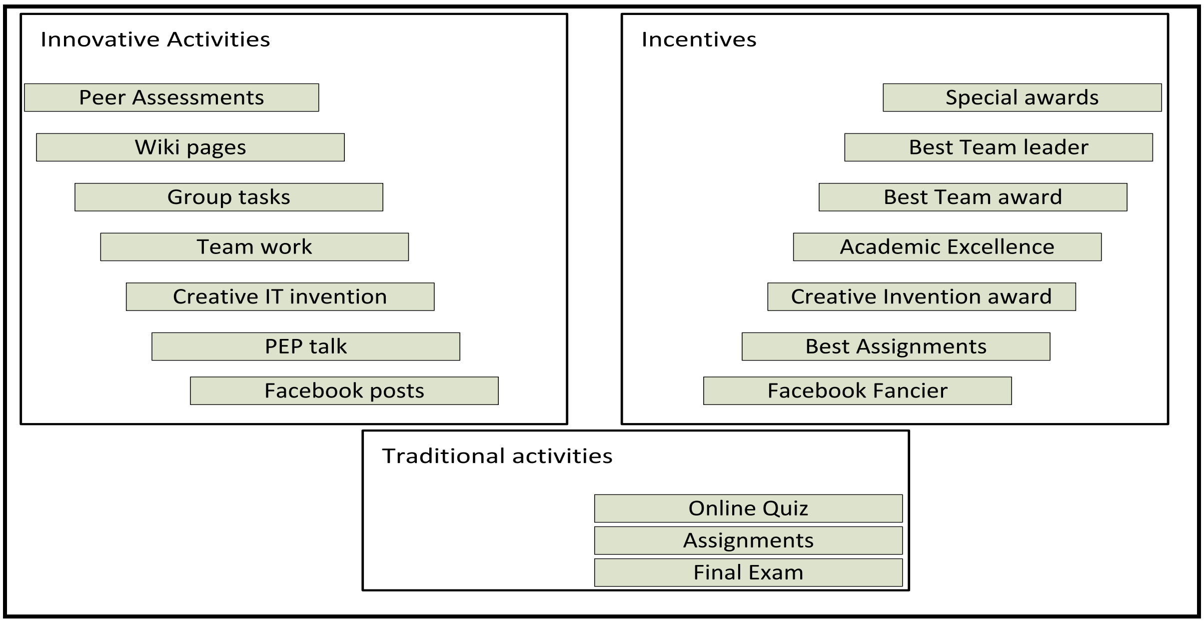

Fig. 1. Teaching model deployed in CS240

Innovative approaches [11] include the use of multimedia, a combination of different digital media [12], interactive applications and presentation tools. Humor has proven effective, as it creates a conducive environment for learning and communication [13]. A study by Missildine et al. [14] to test the effectiveness of a flipped class room approach – a pedagogical model where typical lectures and home work in a course are reversed, indicates that students managed to score higher examination grades. Student satisfaction was also higher than in traditional lecture-only approaches. Robson and et al [15] report that a case study approach to teaching innovation encourages students to participate actively in learning. Scenarios have been effective, especially for students from science and engineering disciplines, as they foster decision making [13]. Wilson's study on the implications of using evidence-based assignments in an undergraduate course indicates that students tend to gain more knowledge and are better prepared to identify problems in practice and understand them better in order to conduct systematic reviews [16].

Many studies reveal that higher education should focus on meeting the individual needs of learners [17, 18]. Innovation has also been used in giving and receiving feedback. Focused error feedback, peer evaluation, error logs, student goal setting and post-activity written reflections have been used by researchers to improve the teacher feedback process [19]. Informal, anonymous 'minute evaluations' for example, [20] can be used early in a course and the responses used to provide both students and teachers with rich, rapid 'feed-forward' to improve [21, 22]. This complements post-assessment feedback, which is useful, but often too late to enable constructive responses within limited time-frames.

Critical thinking and creativity are essential. Chan [23] showed that those who are part of an innovative learning group found that critical thinking and creativity were essential in connecting their learning to their field of study, as opposed to the standard groups. Educators need to be creative in designing courses that encourage active learning [24]. However both group work and confidence are essential to help students be expressive and creative. Lastly Chan [24] highlights the need for out-of-the-box thinking approaches to encourage students to learn new skills. Paper, chalk and print, use of projectors, educational toys, television and the basic technologies of writing were once termed teaching innovations. Teachers have extended these traditional teaching methods, using platforms like YouTube for discussions [25] and humor, games and peer teaching to make learning environments lively [26]. Teachers in varied disciplines use artistic work such as writing poems, role play, drawing and creating sculptures [27].

The digital revolution has changed the context of teaching and learning, so why not use its tools to provide the best learning experience for students? Any student in the age group 16-24 years should be an expert in exploiting internet resources. Blogs, podcasts, personal webpages, forums and social networks are increasing student participation and enhancing their participation outside the classrooms. Some projects have identified that allowing students to choose their own technologies has contributed to their progress in learning [28]. Moreover, when students find that learning paradigms seldom use technology, they may feel alienated. Institutions and teachers are responsible for minimizing the digital divide in classrooms. The less the divide, the greater the chances for students to engage with the learning pedagogies.

Few studies have used incentives as a form of innovation to motivate students in learning environment. An incentive based study [29] for performance on mathematical tests reveals that incentives have impacted on students' achievements. A similar study on economics students [30] revealed that their exam performance was boosted when they were provided with grade incentives. Similarly, children's engagement improved in a digital game-based learning experiment [31] on reading when rewards were introduced. Our study focuses on an incentive-driven approach in an interesting environment, a diverse undergraduate Computer Science cohort in a small developing country.

This paper outlines the results of data collected from the students in CS240 – a Software Engineering course during Semester 1, 2015 for the Bachelor of Science or Bachelor of Software Engineering stream. By the end of this course students should be able to understand the basic principles in Software Engineering. The innovative strategies used include Facebook, group learning and group presentations for team work, peer evaluations for assessments and preparation for public speaking. The incentive approach is described in Section 4.

3 METHODOLOGY

This is a work in progress, so the paper documents the 'initiation' stage of a Mixed Methods approach [32] identifying new perspectives and issues that can be complemented by deeper qualitative research which should shed light on the reasons behind student opinions expressed in these data. A Mixed Methods (MM) framework seemed the most appropriate for this work, given the diversity of the cohort and the need to be open to challenging researcher assumptions. Based on these findings, we will need to decide which qualitative methodology best suits this cohort, whether it is Grounded Theory, combined with an ethnographic approach, in which we need to research with students, not just 'on' them [33, 34]. We anticipate including a reflective aspect in student evaluations and/or assessment, which could be analysed using a tool such as N-Vivo.

An incentive driven approach guided and applied innovative methods as well as traditional course work activities (refer to Figure 1). Incentives were used to reward students upon completion of the innovative activities. However, traditional course work activities that were also part of teaching the course are included in the model such as online quiz, assignments and final exam. Students were informed during the first week of the semester about the study and the various activities involved. Participation was voluntary and any student could opt not to take part in activities. All of the students in the class (N = 50) opted to be part of the innovative learning experience and 70% responded to the survey that was posted online towards the end of the course. This high response rate may be due to the lecturer encouraging students to complete it and reinforcing its importance.

Every student was allocated randomly to a group of 6 to 7 members from diverse cultural and social backgrounds and they learned this course as a group in all instances. The terms teams and groups have been used interchangeably in the paper. An online survey consisting of 46 closed ended questions was provided to the respondents after completing the activities. The survey questions were designed to receive feedback from participants about the individual innovative activities and the overall experience about the course. The anonymous online survey was designed using the Moodle platform and distributed online. The responses were downloaded to a spreadsheet and the results were analysed quantitatively to obtain the results and draw graphical illustrations. The results of participants who agreed or strongly agreed to each item in the survey form are considered for analysis.

4 AN INCENTIVE DRIVEN MODEL

Before the activities were introduced, the students in the class were divided into eight groups. Each group had a team leader and teams were asked to choose a creative name. The following emerged: Team Heart soft, Team Code Chefs, Team US BE Engineers, Team Fusion, Team Prime Fusion, Team Software gurus, Team Oceania Software Engineers and Team AKAIANE. Each student participated in the innovative activities as part of a group. During the lectures and tutorials they were assigned to sit with their group and complete their tasks.

Teams were informed of the incentives that they would be entitled to after they completed the various activities. The incentives are listed below:

•Facebook Fancier – The best Facebook post would be chosen and the one who posted it would be awarded as Facebook Fancier. One student would receive a prize for this activity. Section 4 expands on Facebook posting.

•Best Assignments – The teams that did well in each assignment task would be recognized as the best team for each assignment. The course had three assignments and three points were awarded for the team with the best assignment score out of 100. Two points were awarded to the team with the second best score out of 100. One point was awarded to the team that had the third best score. A cumulative sum of the team scores for all the three assignments would determine which team receives the prize for this activity.

•Creative Invention award – Teams were asked to present a creative invention idea and the best idea was awarded at the end of the presentations.

•Academic Excellence – Students who performed well in the traditional coursework activities like the Online Quiz, Assignments and achieved higher overall coursework grade was recognized as the winners of this activity. The total coursework mark for this course was set as 50 and students with a higher score out of 50 will receive prizes in the activity. Top three scores were chosen and awarded first, second and third prizes respectively.

•Best Team – One team was chosen as the best team based on their performance in each of the activities. After every assignment each team would receive a point if they have been the top team for the assignment. Upon completion of the three assignments the team that scored the maximum points would receive a prize for this category. In case of a tie, the lecturer will decide the best team by factoring their scores in Online Quiz.

•Best Team Leader – Team leader of the best team was announced as the best team leader or project manager. The winner received a letter of recommendation from the lecturer for their excellence in project management.

•A special award was also given for a team that attended most of the lectures/tutorials.

5 INNOVATIVE ACTIVITIES AND THEIR OUTCOMES

The activities introduced to the teams are outlined below.

5.1 Facebook posts

Students were asked to use a closed group “CS240 Software Engineering,” created for the course in Facebook. Students would post an article (at least three articles for a week) that they had recently read about Information technology advancements and post them with comments. The student who posted the article would also talk about the post for two minutes in the classroom. Other members in the closed group would view, ‘like’ or comment on them.

5.2 PEP Talk

Students were given three minutes in every lecture hour to talk about any topic of interest in computing science. The topic should be in some way relevant to Software Engineering. Each team member took turns to present their ideas, based on a ‘one team, one week policy’.

5.3 Creative IT invention

Each team was given five minutes during Week 13 to present any idea that they thought could be introduced as a new product or concept in the computing science domain. They had to arrive at novel and creative idea that involved an out-of-the-box thinking approach. Teams were given five minutes to present their ideas.

5.4 Group Presentations

Every time a presentation is required for the course - be it the creative idea or the assignment presentation, teams have to present as a group. Other groups would be present and anyone could ask questions about the presentation, including the lecturer, who was present.

5.5 Team work

The participants in the course were divided into eight groups during week 2 and their learning for the course was with their team mates. The learning during lectures and lab sessions or tutorials would occur as team-work and not individually. Assignments in the form of a project were done as team work.

5.6 Wikis

Teams were assigned a separate workspace in the form of wikis in their course page in Moodle. All the deliverables and reference materials produced by each team were deposited in the wikis. Teams collaborate and share documents using the wikis.

5.7 Peer Assessment

Since most of the student tasks were based on group work, there was limited scope to judge the individual contributions of the individuals in a team. Hence, the assignments that were submitted as a team document were assessed for initial grades. The peer assessments of the team members by others in the team, namely the team leader or the deputy team leader, were taken into account before arriving at the final individual grades. A simple marking scheme was used to assess the individual contributions. The criteria gave a mark of 0, 0.25, 0.5 or 1 for each student for a week. After four weeks an average of the score was taken and then multiplied with the assignment marks obtained by the team to arrive at the grades for the individuals in each team.

The outcomes for each category used in analysing the data are discussed below:

5.8 Usefulness of various activities for the Course

Most of the respondents found the innovative activities useful. Team work and group presentations were the most popular activities (Refer to Figure 2).

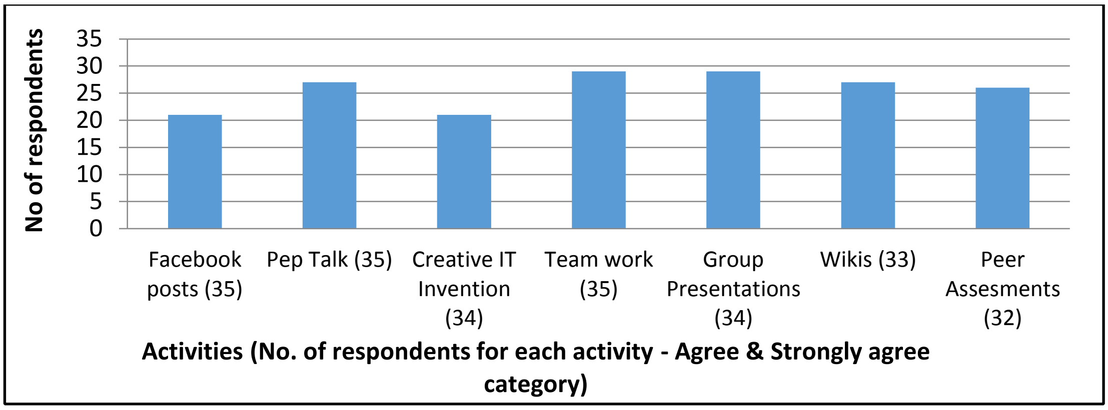

Fig. 2. Responses for the effects of innovative activities

While the teacher observed general enthusiasm in student participation during Facebook interactions, the activity appeared less popular among the respondents. It may be that given the need to use team building skills in industry, students realise that teamwork preparation is highly relevant. The group presentations were intended as a supplement to demonstrate their findings in the assignments and to build communication skills. The Pep talks provided good informal preparation for presenting. However the team members were observed to be less interested in the presentations in the class rooms, suggesting a need to prepare them and have trial presentations. Despite this respondents rated them highly.

5.9 Introducing similar activities would enhance learning in other courses

Most courses in this university are taught using a traditional approach, so the question arose, would these participants like such innovative teaching methods in other courses? As shown in Figure 3, many participants would prefer them, with team work, creative invention talks and presentations proving most popular. These students are clearly looking for their teachers to introduce team based activities and creativity based tasks.

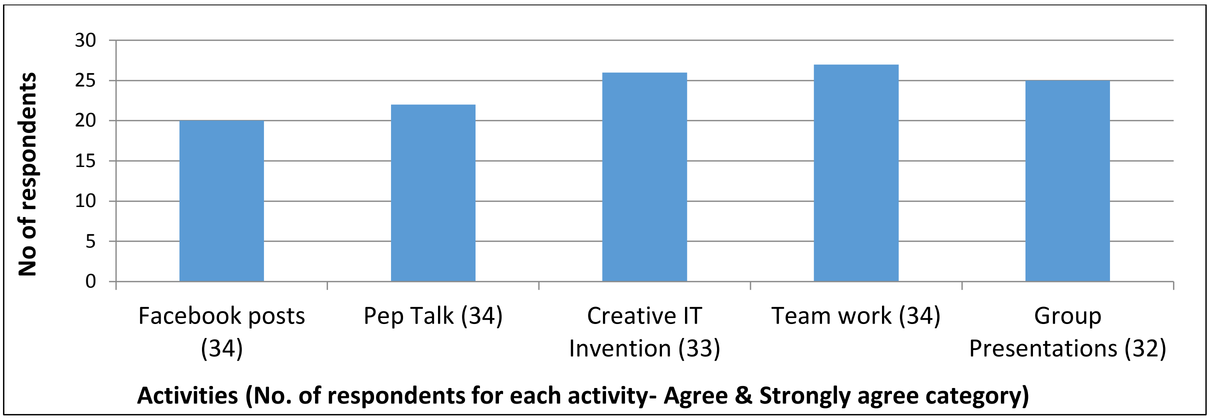

Fig. 3. Responses for introducing similar activities in other courses

5.10 Overall assessment factors for the course

Respondents were also asked about their overall assessment of the course based on the factors shown in Figure 4 below. Most agree that the learning was innovative and many believe that the methods used were different and more useful than those in other courses. They also believe that they would improve their learning skills if similar methods were introduced elsewhere. Interestingly, the respondents observe that they benefitted more from the team building skills aspect than the actual course itself. One of the course objectives is to contribute to software production in a team context. Hence, the results in this category show that an innovative approach to team building was well aligned with the course objective and the students found it useful.

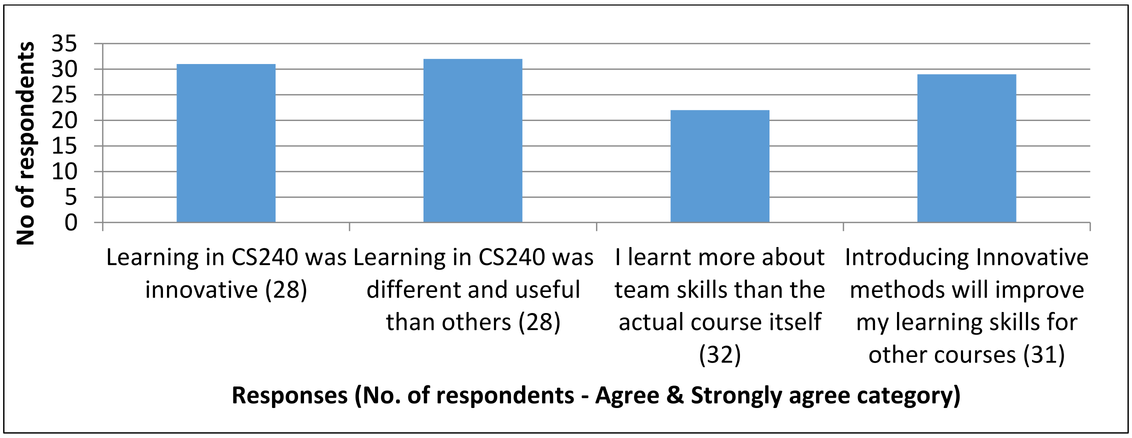

Fig. 4. Responses for overall assessment of this course

The following section lists the outcome of the responses for each of the activities in detail.

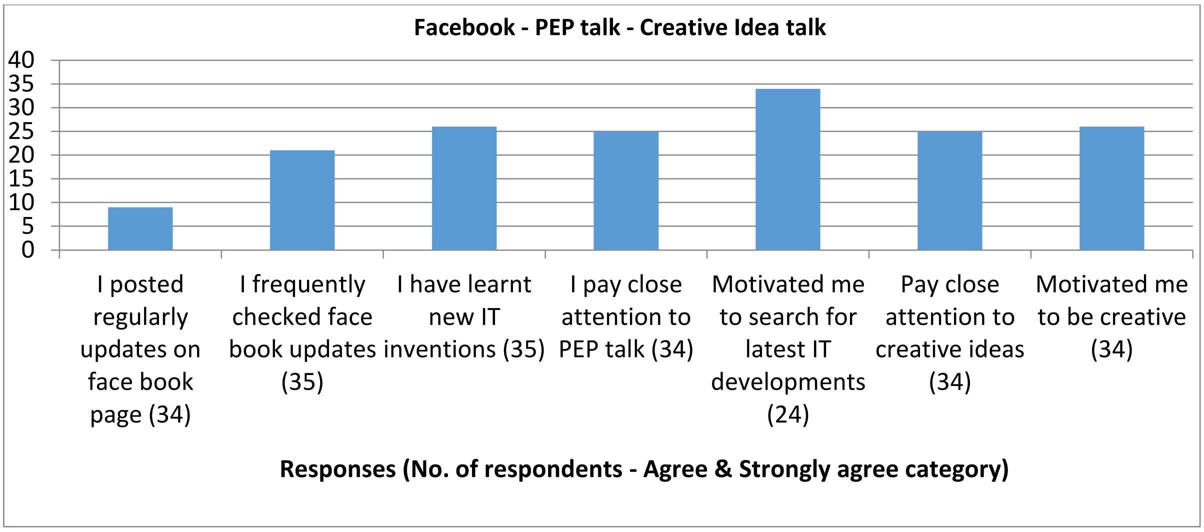

Fig. 5. Responses for use of some activities in the course

While many students remained active on the Facebook group during the course, not many were actively posting updates on the group page although they were actively checking for updates posted by classmates. The students were required to use the Moodle page as their primary source for course updates and university announcements. Not many students actively participated in the discussions posted on Moodle page but remained active on the Facebook group discussions. The findings raise questions about the data consumption patterns of the students and why they prefer to be active in a Facebook group rather than the Moodle Course page. Further investigation is required to answer these questions and this is beyond the scope of this paper.

Using a PEP talk (introduced earlier in this section) has been useful in helping students to learn about new inventions in the field of computing science. This activity motivated the students to search for new inventions and gain knowledge about them after their class hours. Even those who did not pay close attention in the classroom seem to have been motivated to search for new developments in computing. A similar argument applies to the creative idea talk activity (refer to Figure 5). Studies have emphasized the need for working in groups and their place in software industries [35-37]. Group-based activities have improved student participation in the classes.

Students have benefited from each other when working in groups. Group members who assisted others have improved their mentoring skills, by taking part in the “development of self by the mutual support of equals”[38]. Group presentations helped the students improve their presentation skills, communication and learning capabilities. The presentation aspect of the course needs to be improved by adding a practice presentation with formative feedback. This will reduce the fear of presenting and help students to develop the skill of providing constructive comments to peers. It may also address the next issue.

Not many students were willing to use or learn new software for their presentations during the course. The students seemed willing to actively use tools like Facebook, but the same students’ reluctance to use any new tools for their presentations raises an interesting question: Are the students willing to use only social media tools for learning? What lies behind their reluctance to use new tools? This will be the focus of further study and analysis. Group assignments have helped students to learn course concepts more easily. Group members assisted each other although some (about 12%) did not contribute equally to the assignment tasks. Non-contributing group members are a common source of friction and this needs further study.

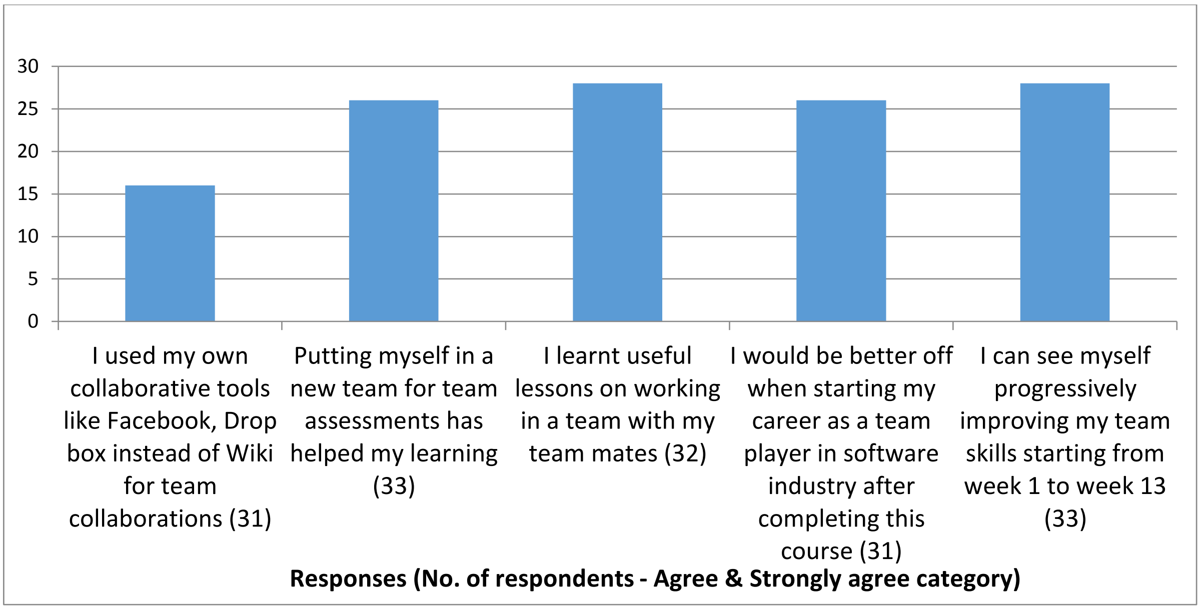

Fig. 6. Responses for Team work

As discussed earlier, students prefer to use tools like Facebook and Dropbox for team collaborations (refer to Figure 6) and are reluctant to use the tools available to them through the course page in Moodle (Wikis). Although students were reluctant to be part of a new team during week 1, they observe that they have been progressively developing their team building skills during the course of this class. This calls for better initial preparation for teamwork in the next course iteration, adapting the Teamwork Foundations strategies which have proved effective elsewhere [21]. These activities focus on supporting and developing intercultural skills as an essential preliminary aspect of learning effectively in groups. They have proved effective with engineering students at all levels in diverse classes in Australia [39]. They address the common initial reluctance of students to move outside their cultural or social friendship groups to form teams.

To conclude, the discussion is summarized below:

- Most of the participants in this diverse Pacific context found the innovative methods in teaching and learning useful.
- Incentives acted as a motivation for participants to engage with innovative teaching methods
- Most of them would prefer to learn in a similar way in other courses.
- An incentive driven model was well suited for this course, as was evident from the student participation and their competitive attitude during the group activities.
- Students are more interested and actively learn when tools and applications that they use in their day-to-day life are introduced in the class rooms, like Facebook, Twitter.
- When students work in teams and deliver tasks in groups their learning is more effective.

- Peer assessments are very useful to evaluate individual performance when tasks are submitted as a group artefact like a group assignment or group presentation.
- More studies need to be carried out to understand why students are reluctant to use online tools that were available for them through the Moodle shell, but prefer to use social networking tools.
- More study needs to be done to understand the outcomes of introducing similar methods in other courses and other disciplines in this developing country context.
- More attention needs to be paid to integrating the intercultural aspect of developing effective teamwork.

6 LIMITATIONS OF THE STUDY

The study and its findings would have been enhanced if more participants had responded to the online survey. Informal in-class minute evaluations at the beginning and end of the semester should provide increased and more detailed responses. If teachers respond to student comments early, students are encouraged to give feedback, as they trust that teachers are listening to them and acting on their suggestions. The innovative methods have proved well suited for a theoretical course like CS240 but it would be interesting to observe if they would suit a practical or more technical course with more laboratory sessions. Further, using the same model for Mathematics and other Engineering courses should also be investigated. Teachers face the challenge of finding time to focus on innovative methods due to the demands of course content as well as peer pressure to concentrate on delivering ‘content’. Active learning also challenges students to take responsibility for their learning. Despite the incentives, the teacher found it difficult at times to motivate the students, mainly because this work demands continuous attention and students are pressured to focus on their other courses as well as being comfortable with the simpler traditional assessment methods.

It is unclear if all the participants were active on Facebook, as some of the participants were reluctant to use Facebook posts. The teacher taught another course in semester 2, 2015 which is a follow up course (CS241) to the one used for this study. All the students enrolled for CS241 were part of CS240. It would be worthwhile to compare the effects of the innovative methods in these courses. Generally, students in the region view incentives as some form of reward and are motivated to attend workshops and social events. We introduced incentives in our teaching pedagogy with this idea in mind. However, we were not able to identify if the incentives have motivated students to actively participate in the innovative activities for the course. We will focus our future study on the ‘complementarity’ aspect of the Mixed Methods framework, in order to identify if there is a correlation between the incentives and their participation in the innovative activities.

7 CONCLUSIONS

Students were more excited and willing to be active participants in lectures and tutorials when incentive driven innovative methods were introduced. Since most of the students are familiar with the latest IT tools, they are well placed to use them for learning. An incentive driven model introduces a healthy competitive approach among students, motivating them to learn more and work together across perceived differences towards achieving a common goal. The activities and the skills they develop are not simply focused on essential course knowledge, which can become rapidly outdated, but prepare them for working in a globalized world. Team work and completing projects on time are basic skills in any software industry and the participants learn those skills by working together for a common goal. As evident from their responses, most of these participants expressed confidence that they would excel as team leaders in industry after their teamwork experience. This is a work in progress but the inference is that similar innovative approaches can be introduced in other engineering courses and that the students would be willing to participate. The findings also support the need for decision makers in higher education to continue investing in and supporting innovative teaching and learning approaches.

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10.

Physics and Engineering Education

ESPOL: a change exalted by our strengths.

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ABSTRACT

Education is an important factor in the development of countries, and universities are committed to train professionals whose skills enable them to contribute to such development. In this context, ESPOL has generated a competency-based and student-centred education system. This system uses methodologies based on active learning and a series of activities, formal and informal, that develop significant learning for a solid technical education, soft skills and a tendency to long-life learning.

Conference Key Areas: Engineering education research, Curriculum development, Skills and engineering education.

Keywords: Curriculum development, active learning, significant learning, integral education.

INTRODUCTION

ESPOL is a university that continuously searches excellency. Curricular reforms have been a standard practice that consider their auto-imposed challenging goals, international standards, and the Ecuadorian regulation. It is a process of evaluation,

[1] Corresponding Author (All in Arial, 10 pt, single space)
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updating, and contextualization of the academic activities of ESPOL, to promote the integral development of each student. The current reform seeks the generation of new knowledge and skills for students, promoting their adaptation to the demands of society, the innovations that affect the environment and the economic impulse that competent professionals give to a country, without neglecting our role of preparing future social leaders who are concerned about the collective benefit. In this context, the curricular reform fully implemented in 2017 will be described in this article.

1 EDUCATION SYSTEMS

1.1 Social constructivism and active learning

Active learning is based on the main principles of constructivism; however, they are not enough to explain it as the student-teacher interaction in a different way to create a student-centred classroom [1,2]. Constructivism was introduced by Jean Piaget and his followers, as a theory about the generation of knowledge, not only about learning or about education. It establishes learning as an interaction between the individuals who learns with the environment in which they develop [3]. Several experiences expect the apprentices to depart from what they know, and the teacher to guide the construction processes according to the collective knowledge.

Methodologies based on constructivism declare it is required to motivate students to analyse their experiences about the subject studied, also motivating them to propose a method for the learning of new knowledge according to their interest and capacities. The theory of constructivism also promotes that knowledge is generated in community, focusing on what students are capable to develop and the activities used by the teacher to stimulate and support the progress of students [4].

On the other hand, social constructivism of Vygotsky [5] indicates that cognitive development is influenced by the culture of the society and the strategies to solve problems through dialogue with other people from it, which concludes that knowledge is also the addition of knowledge of a person's own schema and its comparison with the schema of those surrounding him or her. This relates to a "zone of proximal development" (ZPD) which is the difference of what a student can do with help or without it. This theory says that abilities are more likely to develop by working with a guide or peer collaboration rather than a job on its own [6]. Therefore, the ZPD also depends on the scaffolding that supports a student supported by a tutor or by peers.

Since university students are not mere receptors of knowledge, modern universities work on the development of abilities related to the identification and problem solving, planning, auto criticism, and communication so that they support their opinions with evidence. Therefore, students are responsible of their own learning processes, empowered to learn out of classrooms, searching for information beyond what is presented to them. Consequently, universities educate professionals able to learn how to learn [7,8]. According to this, university students get involved in small groups working at their own pace, thinking about their own work, engaging in a creative and productive learning to solve problems, and guided by their teachers [9].

Significant Learning is a process in which students relate to new knowledge with information from their own, adapting and building over it [10]. Therefore, it occurs when students effectively relate their experiences with the knowledge received from lectures and applied it to solve problems of their professions. Active learning is a methodology that presents positive results to face the difficulties of learning [11]. However, master classes are still the predominant style even though they are inefficient to achieve significant learning. As expressed by Piaget, learning requires other pedagogical relationships, defining the active auto-regulation. Active learning develops in environments where students: actively listen, communicate, observe, write with a clearly identified objective, effectively read and dramatize reflexively [2]. Active learning impels the significant learning through aspects such as: an inductive instructional design, activities that motivate discussions, collaborative work, constant feedback, real-life examples, active students constructing knowledge, a teacher as a guide, a student-based learning, and an elevated level of comprehension [11,12,13].

1.2 The millennials as higher education students

An important factor for learning is the type of student that confronts the contents and the construction of knowledge. At ESPOL we consider our students are members of the Z generation, meaning the postmillennial. This generation grew surrounded by technology, lives in a digital world, and is accustomed to use emerging technologies in their everyday lives. They are connected to technology and have access to computers, laptops, smartphones, among others [14]. This generation do and learn in a different way, which motivates a disconnection with the methods used by lecturers.

2 ESPOL

ESPOL was established in 1958 at Guayaquil, Ecuador. Three major moments in its history are: inauguration of National Centre for Aquaculture and Marine Research at 1990, reinforcing its vision toward research; inauguration of Campus Gustavo Galindo at 1991, relocating around 3500 students and offering around 700 hectares for present and future activities; and, at 1997 doubling enrolment of students with respect to 1991. Currently, it has around 12000 students in 33 undergraduate programs and 1000 in 16 graduate programs. 70% of undergraduate students belong to science and engineering programs and the rest are from administration, economics, graphic design, video production, tourism, process auditing and nutrition.

The curricular reform process takes place in an institution awarded with the highest categorization within the National System of Higher Education, both in 2009 and 2012, as well as the accreditation for the programs of mechanical engineering and computer science by ABET. Accreditation processes continue for all undergraduate programs at accreditation agencies according to the corresponding degrees.

ESPOL establish its main objective declaring its mission: “to form excellent, socially responsible professionals, leaders, entrepreneurs, with solid moral and ethical values that contribute to the scientific, technological, social, economic, environmental and political development of the country, and to serve society by carrying out research, innovating, promoting technology transfer and providing high quality services.”

ESPOL established a goal to be part of international rankings, integrating undergraduate and graduate education with research activities. This requires strengthening the institutional research system, generating more graduate programs, and reformulating our undergraduate degrees.

2.1 Successful practices

As part of the analysis for curricular reform, four main successful practices were reviewed. The first one is declaring graduate programs and research as a suitable institutional environment. Another one is a solid base in sciences as background to develop further professional knowledge. The third one is our culture of continuous improvement: formally declared in 2005, reinforced in 2008 with the practice of assessment for learning outcomes, and consolidated during accreditation processes for all programs with international agencies. Finally, to relate its excellence to professors in continuous improvement: more full time members, with Ph.D. degree and experience in research projects.

2.2 The Ecuadorian context

Since 2007, Ecuadorian government guidelines have sought to strengthen national productive forces while promoting value chains linked to local endogenous development, integrating production processes with environmental factors and optimizing the use of renewable and non-renewable natural resources. In this context, current legislation is oriented to a humanistic, cultural and scientific education to develop integral, creative, responsible, critical, participatory and productive professionals. The system proposes to: a) promote academic quality and continuous improvement through evaluation and accreditation processes; b) contextualize education within the territories and their needs; c) impel creativeness, entrepreneurship, and bio-consciousness; and, d) strengthen the knowledge, application and research of science and technology.

The academic bylaws define education as diverse and integral, to provide an innovative, relevant and excellence-based service. Therefore, the programs offered by universities should meet the curricular requirements of our society, combining them with the soft skills required in the national planning documents. ESPOL also guided its curricular reform by advisory committees. Each program has an advisory committee with representation of its graduates and from employers, constituting a source of feedback for the program's curriculum and the student outcomes.

3 THE CURRICULAR REFORM AT ESPOL

ESPOL pursued a curricular reform to assure the deliverance of integral professionals with lifelong learning skills, as required in a world of constant and rapid changes [15,16] This need arises due to the geometric progression of scientific and technological knowledge [17]. For this, the reform settles a continuous monitoring of activities for students to experience a self-direct learning (in which they establish their goals), autonomous (in which they define how to govern their learning process), and self-regulated (with self-assessment and auto-corrective measures) [18].

ESPOL proposes a competences-based learning-teaching process with a student-centred focus, establishing reasoning as a fundamental characteristic of the cognitive process since *reasoning is a natural disposition based on the usage of language and […] the rational element is present in all our behaviours, becoming a part of our most minimal mental functions* [19]. This guided the inclusion of two language courses in Spanish and five in English in all curricula, and the commitment to develop this area throughout the curriculum of all programs.

Our learning-teaching process is based on competences, establishing seven common competences to all programs called the institutional learning outcomes which become the stamp of our education. The development of such competences is not the sole responsibility of one or two courses. All the formation, including the institutional learning outcomes, is responsibility of a series of efforts joining curricular and extracurricular activities to impart knowledge, apply it and develop it.

The reform process as shown in *Fig. 1* displays the procedure followed to develop the programs. The relevance analysis was a cyclic process during which the advisory committees gave periodic feedback for educational objectives, learning outcomes and the curricula as well.

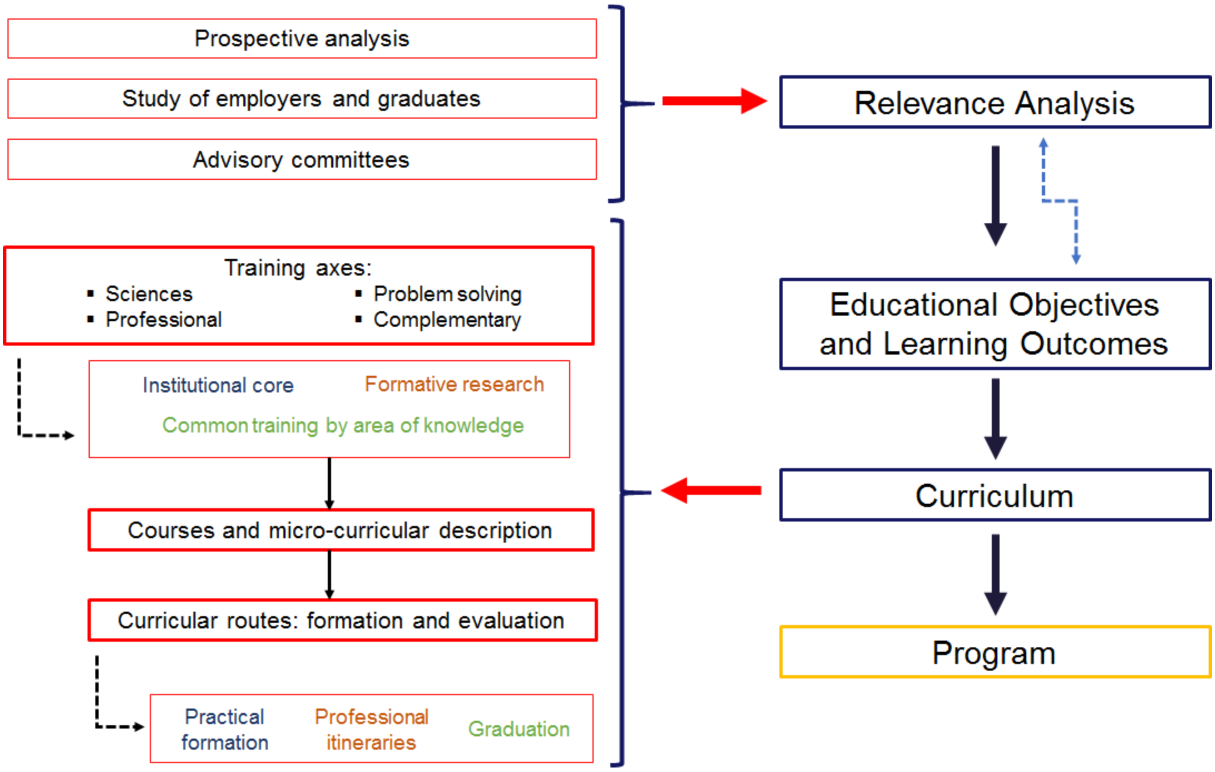

Fig. 1. Graphic representation of the curricular reform process.

The institutional core give a basis for ESPOL's distinctive imprint: reasoning, systemic thinking, bio-consciousness, entrepreneurship, problem solving and knowledge contextualization. It includes courses and activities such as complementary education including social and humanistic disciplines (psychology, history, politics, among others), arts (photography, music or body expression), and sports training (soccer, tennis, chess, kayak, among others). The seven institutional learning outcomes are related to: effective communication in Spanish and English, long-life learning, working in multidisciplinary teams, entrepreneurship abilities, understanding contemporary issues, and ethic and professional responsibility.

Development of formative research is part of the integration of undergraduate programs to research and graduate studies. This model provides students with basic tools and skills required for research (based on the scientific method), allowing them to identify and solve problems, oriented to the search for truth, forming them as high-level professionals [20]. ESPOL establishes a mandatory formative stage and a second stage based on a research itinerary that applies research-based learning.

The different areas of knowledge count with common courses ordered during the first year of the programs. Since Ecuadorian regulation requires a student to decide on a preferred program before entering university, common years are created to facilitate adaptation of new students and allow them to analyse their program choice, taking advantage of the institutional resources. Three general areas were designed for: engineering programs, arts, and social sciences. Due to particularities of their origins, undergraduate degrees for mathematics, nutrition and archaeology were excepted.

All programs offer projects, services and other activities to relate students with society. Students develop their pre-professional practices to apply knowledge in institutional, business or community environments, whether public or private. Their practices are monitored and assessed, providing feedback about student's abilities to explore, diagnose and experiment, as well as to intervene and solve problems.

Graduation process is based on capstone projects that validate knowledge, abilities and competences developed during programs. Within the projects, students work in groups, solving real problems framed in their professional practice. It is mandatory and it may include students from several programs to impel multidisciplinary teams. Another option is to participate in a research project leaded by Professors, and could be used for a special mention.

ESPOL plans master classes, practical work, laboratory sessions, field trip, autonomous work, tutoring activities, collaborative and cooperative work, pre-professional practices, and cultural events among others. They establish our philosophy: achievement of learning outcomes will depend on a combination of activities to empower students to develop knowledge, apply it and own it. Learning outcomes are assessed and valued through curricular routes. The routes establish the series of activities that show a formative contribution being responsible to instruct the different learning outcomes, as well as the ones used to evaluate them.

4 EDUCATIONAL ENVIRONMENT AT ESPOL

ESPOL visualizes the teaching-learning process as the execution of related activities. All activities are efforts for students to be recognized for their competence in technical areas, with solid humanistic foundation and able to continue learning. Assimilation of learning outcomes exceeds the responsibility of one or two courses, especially in outcomes concerning communication, teamwork, ethics, among others.

Several learning environments were created, based on learning strategies designed for specific objectives. The experience includes didactic material for key moments of the instructional process and moments to give feedback for students. Different initiatives include formal environments based on official evaluation of activities and learning outcomes, and informal environments which contribute to several outcomes (their contribution is measured but are not used to evaluate specific students).

The formal environments generated include aspects such as:

- Flipped classrooms: where lecturers do not transmit knowledge as done traditionally, but become facilitators in the construction of knowledge by students as collaborative researchers. Courses using this methodology are Physics (Peer Project Learning, PPL, and Research-Action Project, RAP), and English courses.
- Knowledge integration: where projects integrate knowledge, and assess learning outcomes. Each program establishes at least one course for each academic year so that several projects throughout the curricula challenge to integrate the knowledge of the different courses from those years and giving significant solutions to problems. A final integration course is the Capstone Course, in which learning outcomes are assessed and knowledge integration is monitored.
- Practical learning: where knowledge, abilities and capabilities are developed through activities such as laboratory sessions, field trips, or pre-professional practices. They focus on the implementation of analytical skills, decision making, as well as observation, diagnosis and group work oriented to collaboration.

Some formal initiatives are the *mini-businesses* within entrepreneurship courses to impel recognition of opportunities to add value to goods or processes; activities such as the BIDA fair (biology, research, development and application) within biology and environmental management courses to generate bio-consciousness; among others.

Informal activities focus their work to support formal activities to develop knowledge, abilities and capabilities. They are dynamic processes since they involve the direct participation of students from the beginning. Some examples are:

- Student clubs: multidisciplinary groups to develop within different areas. The diversity of clubs enriches the social, cultural and educational experiences.
- English clubs: informal environments to express freely while developing and improving communication abilities to speak, write, listen and comprehend.
- Writing centres: environments to enhance writing abilities in Spanish and English, focusing on the expression of proper reasoning through language.
- Ajá! Science Park: a park that offer stimulating experiences to explore science and engineering. The activities generate a fondness for the search of answers to question and the invention.

Another initiative is the Counselling system in which all students count with a lecturer as counsellor. This process allows a personalized monitoring of performance of students and give feedback for the programs. Also, affirmative actions are included to support minority groups, such as scholarships for low-income students or the development of specific activities for students with conditions like dyslexia, dysgraphia, speech apraxia, among others.

Professors and lecturers receive training to develop new curricula according to the reform guidelines. It begins with an induction process to understand the institution's philosophy, an accompaniment in classroom voluntarily requested, and a Teacher Training Program developed two years ago to improve pedagogical capacities. Currently the program includes eleven modules that cover: communication and reasoning process; macro and micro curricular planning; ethics; information and communication technologies; assessment and evaluation of learning; cooperative, collaborative and autonomous learning; research based learning, and entrepreneurship. More than three hundred teachers approved the program and around a hundred took some modules according to their needs. Another initiative is "Tertulias" which are cultural events such as cinema forum, read theatre, musical events, or conversation for a, organized by different departments to contribute to the integration of professors and lecturers.

The implementation of new curricula occurred in 2017, however, initiatives have been tested for a year or two. As preliminary results, it was observed that PPL methodology raised the approval rate of Physics C from 62.53 to 77.58%, while RAP methodology did it for Physics A and B from 44.35 to 78.55%. Standardized tests showed that students generated significant knowledge. Integration of undergraduate programs to research allowed 339 senior students during 2015 and 2016 in research projects, of which 93 did so as their graduation process. Also, capstone courses graduated more than 1600 professionals during the same period, representing 23% of the graduated professionals from 2012 to 2016.

5 CONCLUSIONS

The implementation of a student-centred education is a challenge for students and professors. However, the institutional support for the initiatives allowed access to resources and asses their effectiveness. Preliminary results, as well as the opinion of students monitored through counselling sessions and focus groups, show that new methodologies are appreciated not only for the improvement of approval rates but since they have a positive impact on students, improving their reading comprehension, communication abilities and analysis of information. Our future work includes a longitudinal study of the methodologies implemented and their effect on the knowledge, abilities and capacities developed by our students.

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Using Mission Analysis Software GMAT to develop skills in Astrodynamics

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ABSTRACT

Learning about the geometry and kinematics of orbital motion (or 'astrodynamics') is challenging due to its 3D nature. To address this, the University of Bristol have developed 3D orbit visualization exercises using a free NASA tool called 'General Mission Analysis Tool' (GMAT). The aims are to develop skills in manipulation of orbits and to focus on areas subject to common misconceptions. The skills targeted include: varying orbital elements and observing the effect, interpreting ground tracks, exploring features of sun-synchronous, Molniya and geostationary orbits, adding pro and retrograde burns and seeing the effects, performing inclination changes and Hohmann transfers. Common misconceptions include: confusing the orbital elements, thinking that satellites move faster in their orbits with increasing altitude, thinking that geostationary satellites are not moving (relative to stars), forgetting that Earth rotates when considering ground tracks, thinking that a Hohmann transfer is composed of one burn only, thinking that for a chaser spacecraft to catch up with a target in orbit, it must accelerate. Feedback from students is discussed, along with proposals for further work to assess the extent to which misconceptions have been addressed. Overall, GMAT exercises offer a promising way to visualise orbits and improve conceptual understanding of astrodynamics.

Keywords: orbit modelling, 3D visualization, astrodynamics, GMAT

INTRODUCTION

To understand the movement of spacecraft and the paths that they take around planets, students studying physics and aerospace engineering learn about the geometry and kinematics of bodies and their trajectories through space. This area is called ‘celestial mechanics’ or ‘astrodynamics’ or sometimes ‘mission analysis’ and it is one of the most challenging parts of such a course, due to the 3D nature of the learning. There are many excellent texts in this area to provide a strong theoretical grounding [1–3]. But 2D diagrams and descriptions in texts cannot fully describe the 3D motion of bodies through space. In exams and tests before this work commenced, students at the University of Bristol regularly showed evidence of misunderstandings and a failure to engage with astrodynamics. It was thought, therefore, to be an area very suited to the application of 3D visualisation and simulation tools. There is evidence from previous studies that simulation-based learning can potentially enhance motivation as well as enhancing understanding [4].

Fortunately, there are now several tools available, including ‘General Mission Analysis Tool’ (GMAT), ‘Systems Tool Kit’ (STK), ‘Orekit’, ‘Freeflyer’ etc. to build models of and permit the visualisation of spacecraft astrodynamics. These are based on numerical solution of the equations of motion and enable users to manipulate the views of the path of the spacecraft. It has already been shown that “user ability to handle technology in order to move around between different representations of mathematical or physical objects promotes conceptual growth” [5].

Previous authors have already looked at a number of specific examples of the use of these tools, including orbital elements, geostationary eclipse season, launch windows, reference frames, lighting, attitude, formation flying and manoeuvres [6]. Others have used them to reinforce satellite communications engineering concepts [7]. In other work, it has been maintained that the introduction of these tools at the expense of student exposure to the analytical basics of astrodynamics may lead to a reliance on simulation, instead of analysis, to solve problems [8]. These recommendations will be followed in this work.

Many research studies have demonstrated that “conceptions” are often highly resistant to traditional instruction, and despite passing examinations, students can still hold “misconceptions” that are at variance with formal science ideas [9]. Therefore, in this work, the aim was to improve student learning in astrodynamics through simulations which develop specific skills and address specific misconceptions. The simulation exercises were based on already established principles for effective simulation-based learning [10].

In section 1, the content of the astrodynamics aspects of the Aerospace Engineering degree at the University of Bristol is described, along with the most frequent misunderstandings and gaps in knowledge in the course and the choice of the astrodynamics tool. In section 2, examples of the exercises are presented. The feedback on the simulations and the limitations of this work are covered in the discussion in section 4. In section 5, further work is proposed and the conclusions follow in section 6.

1 METHODOLOGY

1.1 Content of Astrodynamics of Space Systems course

The University of Bristol has delivered a Space Systems course module as part of the 4-year Aerospace Engineering ‘Integrated Masters’ degree (Bachelor and Masters rolled in to one course) for many years. It is a compulsory course unit in the second year of Aerospace Engineering and is optional for students from the Engineering Design course. Cohorts are typically 120-130 students. It is worth 10 credits out of 120 credits for the year and currently comprises 24 hours lectures and 6 hours of computer simulation classes. Of the 24 hrs of lectures, 7 hours are used to cover a theoretical introduction to orbits, including: Kepler's and Newton's laws (and proving Kepler's laws from Newton); conic sections; 3D reference systems; orbital elements; ground tracks and different types of orbits; 2-body motion; The Kepler equation and the vis-viva equation; out of plane manoeuvres; Hohmann transfers; basic rendezvous principles.

1.2 Common misconceptions

In this course, the theoretical background of introductory astrodynamics is presented in standard lecture format. Before the simulations were developed, in end of year exams, coursework and mid-course tests, students regularly showed evidence of misunderstandings and a failure to engage with astrodynamics. Many able students avoided optional astrodynamics questions in exams and exhibited gaps in understanding. To address this, a list of desired skills and some of the most common misconceptions in introductory astrodynamics was assembled from systematically reviewing past exams and coursework (*Tables 1 and 2*).

Table 1. Basic skills required in introductory astrodynamics

No.	Skills
1	Varying orbital elements and observing the effects
2	Interpreting ground tracks
3	Exploring features of Sun-synchronous, Molniya and Geostationary orbits
4	Adding pro and retrograde burns and seeing the effects
5	Performing inclination changes
6	Performing Hohmann transfers

Table 2. Examples of common misconceptions in introductory astrodynamics

No.	Misconception
1	Confusing the orbital elements
2	Thinking that satellites move faster in their orbits with increasing altitude
3	Thinking that Geostationary satellites are not moving (relative to stars)
4	Forgetting that Earth rotates when considering ground tracks
5	Thinking that a Hohmann transfer is composed of one burn only
6	Thinking that for a chaser spacecraft to catch up with a target in orbit, it must accelerate in the same orbit.

1.3 Choice of Tool

There are now a wide variety of tools available for performing mission analysis and astrodynamics. The University of BRISTOL started out in 2011 using STK by AGI. When STK provider in Europe started charging for licences, another tool was required. The criteria for selection included: scientific credibility, ability to perform Low Earth Orbit, interplanetary, low energy and constellation missions, user support, documentation and a low licence fee. Based on these criteria, a free tool developed by

NASA Goddard Space Flight Center: ‘General Mission Analysis Tool’ (GMAT) was selected [11]. It has been extensively tested and verified and has been used for more than 9 NASA missions [12]. The system can display trajectories in space, plot parameters against one another, and save parameters to files for later processing. The trajectory and plot capabilities are fully interactive, plotting data as a mission is run and allowing users to zoom into regions of interest. Trajectories and data can be viewed in any defined coordinate system, and GMAT allows users to rotate the view and set the focus to any object in the display [11].

2 EXERCISES

2.1 Instructions

A set of step-by-step instructions through the exercises and tool menus was developed by the authors. These instructions also include explanations of the different commands and interfaces. The students are also required to answer questions as they progress through the exercises. It is worth noting that some excellent tutorials are provided by the GMAT developers, but they are aimed at allowing users to become familiar with the software itself, not at explaining or helping students to better understand astrodynamics theory. The students undertake these simulations during 3 computer laboratory classes of 2hrs each, just after the theoretical lectures. If the students do not complete the exercises during class time, they are asked to finish them in their own time. Although voluntary, these classes are attended at 90-95%. Staff and teaching assistants are available during the class to answer all questions. The worksheet questions are aimed at inspiring the student to explore and question what they see, e.g.: “*Sat01 has completed a complete orbit, as it starts and finishes at the periapsis, but there is a gap in the ground track on the plot. Why?”* The following sections describe the exercises covered in the instructions and their rationale.

2.2 Orbital elements

Textbooks on astrodynamics will usually list and define each of the 6 orbital elements (semi-major axis, eccentricity, inclination, right ascension of the ascending node, argument of periapsis and true anomaly are used here), with the aid of a labelled diagram. Understanding of the elements requires some spatial imaging skills and without practice many students do not understand them fully after learning the theory in class. To help students to explore these elements, 3 satellites are modelled with identical orbital elements. Then one element, e.g.: inclination, is varied for each of the 3 orbits so that the students can simultaneously see 3 orbits with 3 different inclinations. This 3D visualisation allows them to see how different values for the elements affect their orbits. The ability to zoom, pan and view the orbit from different angles makes it easier to see how the orientation of the orbit has changed. The students compare and explore the different elements one by one. This exercise addresses both the skills No. 1 and misconception No. 1 and 2 in *Tables 1 and 2*.

2.3 Ground Tracks

To address skills No. 2 and misconception No.4, an exercise on ground tracks is provided. Ground tracks are given as 2D plots based on a map of the Earth. It is challenging for beginners to understand even the simplest ground tracks, such as the sinusoidal pattern of an inclined circular orbit. Interpreting ground tracks is a skill which takes practice. Ground tracks can take on unexpected forms, such as loops, but the cause of these forms becomes clearer when they can be matched with the 3D view of the spacecraft orbiting above the rotating body. At the beginning of the laboratory a demonstration script shows 3 types of orbits with their matching ground tracks for the students to explore. The students are asked to compare the ground track with the orbit, to see how they link. For example, they are asked to work out the inclination of an orbit from the ground track plot only and then to look at the 3D orbit.

2.4 Special orbits

The selection of a satellite's orbit is driven by the mission it is required to perform, whether science, Earth observation or communications. A few orbits are particularly interesting for their features. They are: geostationary, sun-synchronous and Molniya orbits. To address skills No.3 and misconception No.3, the students are required to set these orbits up as simulations and are then asked to work out why they might be useful from their ground tracks and elements.

2.5 Pro and Retrograde burns and their effects

A prograde burn is a firing of the spacecraft main thruster in the direction opposite to the direction of travel, a retrograde burn is a firing in the direction of travel. To develop skill No. 4, students experiment with adding pro and retrograde burns to orbits. For rendezvous between a target spacecraft and a chaser spacecraft, if the target is travelling ahead of the chaser, then the chaser needs to drop into a lower orbit to allow it to catch up. In a demonstration simulation provided to the students, they can see how a chaser Soyuz performs 2 retrograde burns to drop into the lower altitude orbit and then 2 prograde burns to return to the target's altitude (see *Figure 1*). This is counterintuitive. Misconception No. 6 is to believe that performing a greater prograde burn (or '*flooring it*', according to one student) will help the chaser spacecraft catch up to the target spacecraft, whereas it will just raise the apoapsis of the orbit. Many students are startled to see this effect in practice and need to see the evidence both in 3D and in a graph of velocity and time, such as in *Figure 1*.

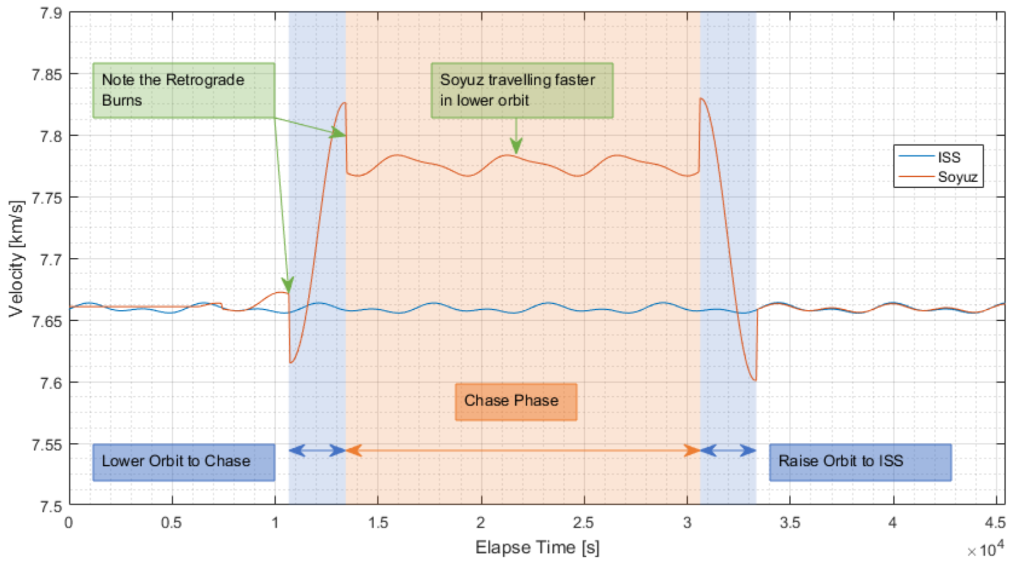

Fig. 1. A GMAT graph of the velocity of a Soyuz spacecraft as it performs a rendezvous with the International Space Station.

2.6 Inclination manoeuvres

An inclination manoeuvre is also called an ‘out of plane’ manoeuvre as it causes the orbital plane to change by changing its angle of inclination. Depending on the change of angle of inclination, it can be expensive on fuel and thus it is important that all such burns are considered carefully. To address skill No. 5, students investigate inclination burns, which are burns at an angle to the direction of travel. First, they perform theoretical calculations to work out the value of the burn elements, then they add the burn in to the simulation. They can then compare theoretical and model results.

2.7 Hohmann transfers

A Hohmann transfer is the most efficient way, in terms of fuel, to change the altitude of a circular orbit [2]. It is required skill No. 6. It involves two burns, the first to raise the apoapsis to the altitude of the desired orbit, followed by the second to circularise the new orbit. The students initially calculate the theoretical values of the two burns using standard theory. Students frequently forget the second burn (misconception No. 5). However, by seeing the result of modelling without a second burn, the students realise the necessity of two burns. They know from the instructions and the lectures that the finished mission should look like a version of *Fig. 2*. The students are also then asked to compare their theoretical results with the model results and to explain the difference.

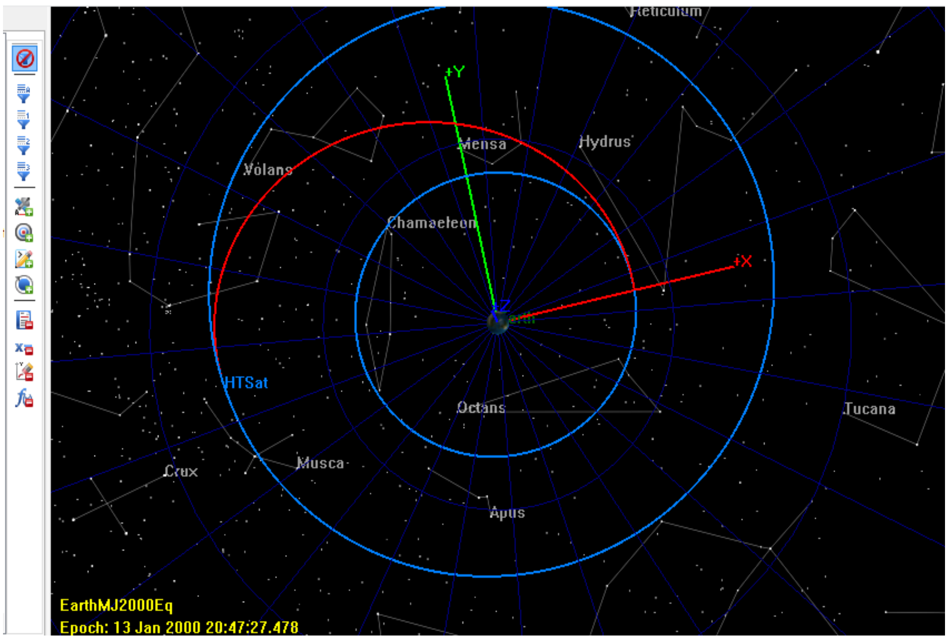

Fig. 2. The finished GMAT Hohmann transfer exercise

3 FEEDBACK

In 2015-16, at the end of the unit, students were requested to complete an anonymous feedback form on paper. In this they were asked: “*Rate each element of the course out of 10, including individual lecturers, the materials and the coursework*”. 54 students completed the feedback out of a cohort of 134. Of these, 90% rated the simulation exercises 7 or more out of 10. The students were also asked “*How did the GMAT labs help you in your learning, if at all?*” The responses included 26 variations on: “*Helped me to understand concepts that were hard to visualise*”. They also included helping them to understand orbital elements and Hohmann transfer. Three mentioned that "*It was quite fun and we all know that playing is the best way to learn*"! One pointed out: "*It helped having staff to ask questions to*". But also, negative ones included: "*I didn't find them that helpful. There were no clear instructions for how to do a Hohmann transfer, this was left for you to work out, which was hard*". Two people suggested: "*Maybe a longer lab time slot would give more time to understand what you are doing and what the results show*".

4 DISCUSSION

When setting the exercises, it was considered whether to set them in MATLAB, as this offers the familiarity of a known tool together with the satisfaction of developing the orbits from first principles via a numerical solution of the equations of motion. However, from a learning point of view, it was considered more important to have the 3D visualisation aspects provided by the GUI of the GMAT software. However, it is then a challenge to achieve a balance between helping the students to learn a new software and helping them to gain the desired skills. Another limitation of the exercises described here is that they are not open-ended, which is a desirable feature of simulation work [10]. It is challenging to provide sufficient support for open-ended exercises with cohorts of 130, but this is certainly a goal for future work. The ultimate question is whether the introduction of these simulation exercises has made any difference to student learning and understanding. It is difficult to assess this without conducting an experiment with parallel classes and comparing directly. But tests after the simulation based learning and the introduction of a compulsory astrodynamics question in the exam have aided in the assessment. Results in tests have shown an improvement in understanding of orbital elements and Hohmann transfers – a detailed discussion of this is beyond the scope of this paper. The feedback questionnaire indicates that the students find the exercises helpful although some students wished for more time in the class.

5 FURTHER WORK

As mentioned in the discussion and by the students, it would be desirable to reduce the scope of the exercises or increase the length of the class. One way of comparing student's understanding before and after the simulation exercises is by using "concept inventories". These are questionnaires put together by experts which can be used to probe students' understanding of scientific phenomena. The most well-known of these inventories is the force concept inventory [13]. It is proposed to develop a concept inventory of introductory astrodynamics concepts with a collection of experts via the Space Universities Network – a network of UK Space science and engineering University teaching staff. Analysis of the results of administering such a questionnaire could lead to a better understanding as to how effective the 3D exercises are.

6 CONCLUSIONS

In this work, the NASA 3D mission analysis simulation tool 'GMAT' has been used to develop important skills and to address common misconceptions in the field of astrodynamics. A series of exercises using GMAT have been developed to cover orbital elements, ground tracks, special orbits, Hohmann transfers, prograde, retrograde and inclination burns. Feedback from students indicates that they have found it rewarding and feel that their conceptual understanding appears to have improved. Further concept inventory work would enable rigorous testing to see if misconceptions have been addressed.

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Incorporating a Motion Analysis Research Laboratory into a Dynamics Course using Model Eliciting Activities

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ABSTRACT

Undergraduate dynamics is often one of the most challenging courses in an engineering curriculum. Creating meaningful assignments that provide engineering context is challenging, and problems often seem contrived and lack authenticity. To help motivate students, we try to bridge the gap between typical homework assignments and tasks that they may encounter in their engineering careers. One way to achieve this is through the use of Model-Eliciting Activities (MEAs). The Rowing MEA introduced students to the study of human biomechanics and allowed them to record motion data of a rower in the Cal Poly Human Motion Biomechanics Lab. In the MEA, a fictional gym equipment manufacturer wanted to improve the design of their latest rowing machine. In a post-activity survey, 83% of students agreed or strongly agreed that the Rowing MEA was more interesting and engaging than other in-class activities, 90% agreed or strongly agreed that they learned skills that would aid them in future real world applications of dynamics, and 77% agreed or strongly agreed that the MEA presented a realistic scenario that an engineer might encounter at their job.

Conference Key Areas: Engineering Education, Attractiveness of Engineering Education, Engineering Education Research

Keywords: Model-eliciting activities, dynamics, inductive learning

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1 BACKGROUND

1.1 Model-eliciting activities

The ability to assimilate different information and create usable models is a critical skill for engineers. Equally important is the ability to frame and solve ill-defined problems. A fairly new technique in engineering which evolved in the mathematics educational community attempts to address these skills by creating problem sets called Model Eliciting Activities (MEAs)[1]. Teams of students are provided with a client-driven problem, most commonly in the form of a request from a fictitious company. These problems are open-ended and force the students to fuse information in a way that is not typically encountered in homework problems. The process of working in a team-based environment, developing a systems-based approach to solving the problem, plus developing and refining conceptual models are all important skills that can be learned in an MEA (in addition to its technical content). Developing higher-order thinking and strong problem solving strategies are as (or more) important to a working engineer as their technical knowledge.

The MEA has several salient differences from other problem-based exercises [4]. Traditional exercises typically involve selecting the correct equations, applying a “cookbook” approach, and coming up with a correct answer. Laboratory exercises and creative hands-on exercises in engineering classrooms often have a similar approach. MEAs require students to develop a conceptual and/or mathematical model, then refine it by comparing it to the customer needs. This design, test, revise cycle is the crux of many undergraduate design courses. These MEAs can begin the process of developing strong open-ended problem solvers before students are required to complete a year-long capstone design project.

Diefes-Dux et al. [2] discuss a useful framework to use when developing an MEA. There are six basic principles that should be used [2,3].

Model Construction Principle: The MEA should require students to develop a process, description, and/or a mathematical model to address the needs of the client. This is not constrained to simply a mathematical equation – it may take the form of a set of procedures, an algorithm, a set of instructions, or graphical models. There should also not be one correct answer – students should struggle with the open-ended nature of the MEA. It can also be beneficial if a certain degree of discovery learning takes place in the process.

Reality Principle: A true engineering-based, client-driven problem should be motivational and realistic for the student. Placing lecture and textbook knowledge in an industrial or research context will help students realize how their skills may be used in the future.

Self-Assessment Principle: The MEA should include sufficient criteria for the student to test and possibly change their conceptual/mathematical models. This often comes in the form of sample data, or as in our Rowing MEA, students actually collect data to help them validate their models. Team members should be able to assimilate their previous knowledge to make some judgment on the quality of their solutions.

Model Documentation Principle: A deliverable product documenting student thinking should be produced at the end of the MEA. This is typically in the form of a memo to the company, but could also be in the form of a computer program, algorithm, or even a physical product. Their documentation helps students to review and reflect upon the development of their model, and allows the instructor to examine the students' conceptual understanding of the material and their problem solving strategies.

Generalizability Principle: A strong MEA requires the solution to be readily adaptable to similar problems or situations. In our Rowing MEA, students were asked to adapt their model to test the effects of different seat heights. Creating generalizable models is often difficult for the students, who tend to create very specific solutions for the exact problem they are given.

Effective Prototype: Student teams should be able to produce a solution that is "as simple as possible yet still mathematically significant."[2] The teams should be asked to revisit the model repeatedly as they progress, making sure that their models employ sound engineering principles. The MEA should also involve concepts that will be important in their future engineering classes and careers.

1.2 Context of study

The students were enrolled in an intermediate undergraduate dynamics course that also contains a significant Matlab programming component. The class meets for three 50-minute lectures and a 2-hour computer laboratory each week. The Rowing MEA was assigned in the middle of the 10-week quarter, and consisted of two different computer laboratory sessions. Approximately 30 minutes of the first session was used to familiarize students with the Human Motion Biomechanics Laboratory (http://hmblab.calpoly.edu/) and to collect data. During the second laboratory session, students worked on the assignment, primarily developing Matlab code to determine the kinematics of the athlete when using the rowing machine.

1.3 Human Motion Biomechanics Lab

The exerciser using the rowing machine was analysed in the Human Motion Biomechanics Laboratory (HMBL) at Cal Poly. The HMBL uses a series of 10 cameras, capturing in synchronized time at 150 frames per second, to collect motion data. Near infrared LED clusters surrounding each camera's aperture emit high intensity light at the capture volume within the lab. Retroreflective markers affixed to the subject and equipment in the capture volume then reflect this light directly back towards the aperture of the cameras. The video processing software Cortex, from Motion Analysis (Santa Rosa, CA), is used to collect and process data from the cameras in real time. Cortex locates the centroid of each marker's reflection, then calculates and displays the X, Y, and Z location of the marker for each frame of the video. Once the capture is completed, Cortex is used to post process data. Post processing includes naming markers, interpolating data where markers were obscured, smoothing data, and exporting in .csv format.

1.4 Rowing MEA

The memo provided to the students for the Rowing MEA is provided in the Appendix. As indicated previously, the memo is from a fictitious company that would like the students to (1) predict the hip marker location after a marker has fallen off using rigid body kinematics and to (2) investigate the effects of altering the seat height on leg kinematics. A picture of a subject rowing with kinematic markers is shown in Figure 1.

Figure 1. Subject using the rowing machine with kinematic markers on various anatomical landmarks.

The six principles of MEAs and how they are met in the Rowing MEA are provided in Table 1.

Table 1. How the Rowing MEA meets the MEA principles.

Principles	How the Rowing MEA Meets the Principle
Reality	A fictitious fitness company requests kinematic analysis of their product, and also asks about changing their design
Model Construction	Students develop a linkage model of the lower leg and a computer program to analyse the motion
Generalizability	The students create a model that allows them to change the seat height as well as the linkage lengths. This could be applied to any crank-slider mechanism.
Effective Prototype	Students can check their kinematics starting from the ankle to the knee, then progress to check the hip velocity. Rigid body kinematics are utilized in many engineering applications
Self-Assessment	Students are given position data for the first 2 or 3 seconds before the marker falls off, so they can check data against their kinematic calculations
Model Documentation	Students create a computer model, including an animation to help visualization of the motion. Additionally, they write a memo back to the client communicating their efforts.

The Rowing MEA fits under our classification of a Physical Model-Eliciting Activity, or P-MEA, where an actual experiment is used to either collect data and/or for utilization in self-assessment [5].

1.5 Research goals

Our goals were to (1) determine if the Rowing MEA increased student interest and motivation, (2) examine how well the assignment fulfilled the principles of an MEA,

(3) explore areas for improvement in future implantations of MEAs involving the Human Motion Biomechanics Lab.

2 METHODS

2.1 Subjective Survey

A subjective survey was administered to the students. Out of the 119 students who completed the assignment, 52 completed the survey. Students rated the following statements listed in Table 2 on a Likert scale: Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree.

Table 2. Survey Questions rated according to Strongly Agree, Agree, Neutral, Disagree, or Strongly Disagree

Question Number	Survey Question
1	The rowing lab presented a realistic scenario that an engineer might encounter at their job
2	The required deliverables were possible to accomplish in the time allotted
3	There are useful real world applications for the skills gained through the ME 326 rowing lab. (Matlab data processing, animations, etc.)
4	Compared to other labs, the ME 326 rowing lab was more interesting and engaging
5	This lab got me interested in applications of engineering related to biomechanics.
6	This lab got me interested in research
7	The rowing lab should be repeated in future sections of ME 326

In addition, students were asked two open-ended questions: (a) Do you have any suggestions on how to improve the rowing lab? (b) Any additional comments?

2.2 Student submissions

Additionally, student submissions were analysed to determine how closely they met the requests put forth in the client memo.

3 RESULTS

3.1 Survey Questions

Results from the survey are shown in Figure 2. Seventy-seven percent of the responding students agreed or strongly agreed that the lab presented a realistic scenario; 90% thought it involved useful real world skills. Eighty-three percent of students thought the Rowing MEA was more interesting than other labs in the course, and 87% recommended that the lab be offered in future sections of the class.

An additional interest of ours is to see if introducing students to the Human Motion Biomechanics Lab would help motivate student interest in biomechanics and in research. Fifty percent of the students agreed or strongly agreed that the lab helped them become interested in biomechanics, while only 25% reported that it helped them become interested in research.

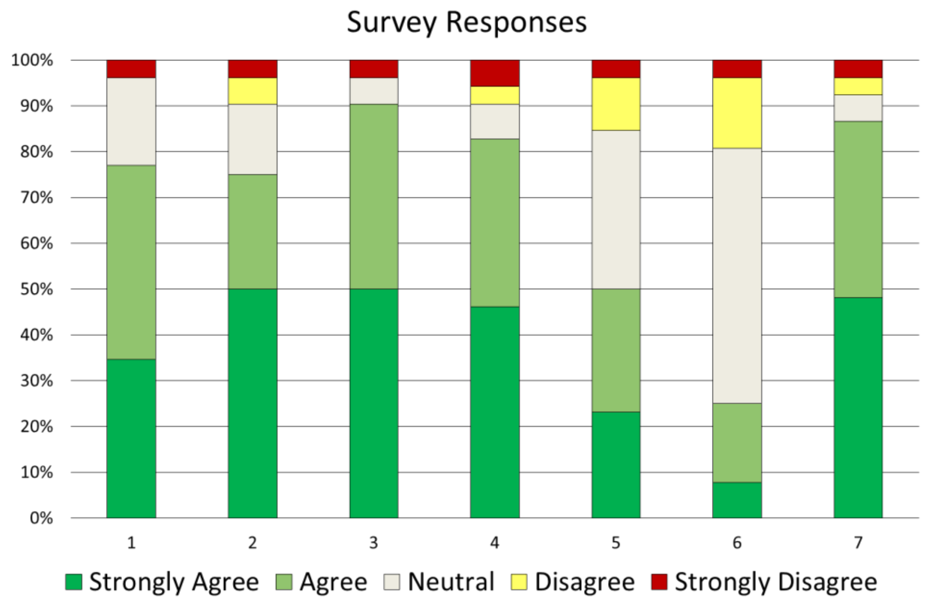

Figure 2. Replies to the seven questions from Table 2.

3.2 Open-ended Survey Responses

Eight of the 52 respondents commented that they would prefer having "better defined goals and deliverables" and "more organized deliverable requirements." Most students are not used to more open-ended projects and have difficulty discerning deliverables from a memo (see Appendix). One of the group data collection sessions did not work properly, so several students from that group commented on this as an area for improvement. Four students provided positive comments in the Additional comments section, indicating that "No drastic improvements, everything worked surprisingly well" and "I enjoyed it."

3.3 Student submissions

Most of the students were able to develop Matlab programs to analyse the kinematics of the rowers. Many struggled with creating animations of the motion, and commented that this was the most time-consuming aspect of the assignment. Although the majority of students realized that they needed to write their memos to the company, many turned in a typical lab report and did not consider their audience. There was also a great deal of variance in how students addressed moving the height of the seat. Some students performed some research into the biomechanics of the knee and injuries, while others did not put much thought into their interpretations of the knee angles. On the survey, one student mentioned that they thought the rehab company "would offer the specifications of what the flexion angle is and how much they want" and that this part of the lab felt a little contrived.

4 SUMMARY AND ACKNOWLEDGMENTS

A Rowing MEA was introduced into a dynamics course that uses Matlab for computer simulation of dynamic mechanisms. This provided a realistic context for why students might be required to perform this type of analysis in a workplace environment and exposed them to state-of-the art motion analysis equipment. One of our goals is to incorporate this research laboratory more into our teaching, and as an added benefit many top students who completed this activity applied to be research assistants in our Human Motion Biomechanics Lab.

The simulation also helped students recognize the time-varying nature of dynamics – all too often we only solve mechanics problems "at an instant in time." By solving kinematics of the linkage through several cycles and creating an animation, students obtained a better feel for how the angular velocities and accelerations of the knee and shank change as a function of time.

The MEA appeared to increase student motivation, as expressed in the survey. Students seemed to be engaged during the data collection, and appreciated seeing the application of dynamics in the research lab (several posters of different projects are placed throughout the lab). We were able to incorporate all six principles in the MEA (refer to Table 2), although not all students wrote strong memos directly to the client as part of the Model Documentation principle.

Although the lab was successful, several recommendations can be made for future implementations. As in many project-based assignments, students are often uncomfortable when specific lists of deliverables and instructions are not provided. Care must be taken when building the assignment, and often some online quizzes beforehand can be used to ask students to identify the customer, list the deliverables they identify from the memo, and to provide questions about the assignment. Classroom discussions can then be used to help clarify what is expected in the submission.

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APPENDIX

Memorandum

To: Biomechanics Engineering Team
From: Emma Williams, Senior R&D Manager at Rogue Fitness
Date: October 15, 2016
RE: Kinematics Data on Concept 2 Model D Rowing Ergometer

Hello Students,

My name is Emma Williams. I am an R&D engineer at Rogue Fitness, and am excited to be collaborating with your company to increase the efficacy of our Concept 2 Model D Rowing Ergometer. We have contracted with the *Cal Poly Human Motion Biomechanics Lab* to examine the motion of an athlete on our most current rowing machine. Over the past week, kinematic data from the athlete have been taken using the Concept 2 Rowing Ergometer. It will be your team's responsibility to analyze these data.

Unfortunately, the hip marker fell off of the athlete during the acquisition of the kinematic data. To avoid the cost and labor of rescheduling time with the athletes and the motion lab, we would like your team to develop a model of the lower body that accurately predicts the motion of the hip during rowing exercise on our device. We are certain that this is possible with your creativity and the kinematic data we were able to capture successfully. With the model your team creates, we ask that you provide a plot showing the velocity of the hip as a function of time. Your team should compare this model velocity to the velocity of the hip marker prior to it falling off. This will confirm the accuracy of the model. Also, with the model your team creates, we ask that you provide a 2D stick figure animation of the experimental data. This will allow our engineers to better visualize and interpret the analysis your team provides.

One of Rogue Fitness's main concerns with the rowing machine is ensuring that athletes are experiencing safe ranges of motion of the knee while using the rower. At Rogue Fitness we would like to be certain that our design is as safe and effective as possible. To do this we must ensure that our rowers are experiencing the proper range of flexion and extension in the knee while rowing, especially if they are recovering from injury.

Accordingly, as a part of your analysis, we ask that your team provide a plot of knee flexion/extension angle as a function of time for the rowing experiment. Finally, we are considering making some design changes to our rowers. We ask that your team analyse the effect that the moving the seat height up or down by 10 cm has on the range of experienced by the athlete on the rowing machine. From this analysis we ask that you compare the range of motion of the knee for various seat heights while using the rowing machine. Please also make any design suggestions that you have for protecting our customers, or for any variations on the design that you think might be innovative and help increase our sales.

I look forward to seeing the great work your team produces,

Emma Williams

Sr.R&D Manager
Rogue Fitness

Videos in physics theory and laboratory teaching: usage and retention analytics

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ABSTRACT

This paper investigates students' video usage in physics studies and differences in viewer retention. The educational videos are produced by the physics teacher team in Tampere University of Applied Sciences. A large enough number of video views is needed to provide a representative overview of the usage and therefore, only those videos which had over 300 views were included in this study, resulting in 50 video clips. The retention patterns differ between video categories: laboratory work instruction videos are watched differently than homework solution videos and theory videos. They are rewound and played many times to find advice for specific needs in relation to using laboratory instruments. Homework solution videos, on the other hand, have a higher watching at the end suggesting that students check the correctness of their own calculations. Even though this is a case study in physics, other disciplines have similar needs for video material. Therefore, the authors believe that the results are generalizable also to other engineering subjects.

Conference Key Areas: Physics and Engineering Education, Open and Online Engineering Education, Engineering Education Research

Keywords: Physics, Educational videos, Retention, Analytics

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INTRODUCTION

Contemporary pedagogical trends emphasize students' active engagement. Students who studied using interactive engagement methods reached better conceptual understanding [1] and better learning outcomes [2] than students using traditional methods. Some best-known activating methods in physics are Peer Instruction [3], Interactive lecture demonstrations [4] and Flipped classroom [5]. In those methods students need to be prepared to enable effective and active working. This can be achieved with the help of online videos. To add interactivity to videos PlayPosit and other similar tools can be used to attach automated multiple choice or open ended questions to any video [6,7]. With video instruction, it is possible to intensify physics laboratory work and shorten the needed laboratory time [7]. In general, educational video clips save valuable face-to-face time in classroom teaching and they are a necessary component of online courses. There are studies which show that the student's video viewing activity and final grade in a course have a correlation [8]. Some studies also have investigated viewer retention and retention patterns [9]. Viewer retention (audience retention) measures the ability of a certain video clip to capture and hold audience's attention throughout the video. Therefore, viewer retention data can help guide improvements for next videos.

1 EDUCATIONAL VIDEOS AT TAMPERE UNIVERSITY OF APPLIED SCIENCES

Students favour short videos over hour-long lecture recordings [10, 11]. Therefore, in Tampere University of Applied Sciences physics teachers have chosen to produce short, one-topic video clips themselves, rather than record lectures. This far, they have more than 1200 videos. YouTube is used for video delivery and links to the videos are in course's Moodle platform. This way, it is possible to investigate the video usage both using YouTube analytics and Moodle's log files. In Tampere UAS, videos are used for four different purposes in physics teaching and learning: 1) Present theory of physical phenomena. 2) Show lecture demonstrations and measurements. 3) Present solutions to homework exercises. and 4) Instruct laboratory work.

A snapshot of each type of video is shown in Fig.1. At Tampere University of Applied Sciences, videos presenting physics theories are usually constructed using MS PowerPoint with some animations. The PP-slides are narrated by the teacher and converted to videos. This way, the graphical quality is good and modifications are easy to make. The drawback is that this method is rather time-consuming and depending on the number of animated objects on the slides it can take several hours to produce a 10-min video.

Lecture demonstrations and measurements are recorded with a camcorder or smart phone by a cameraman while the teacher carries out the actual demo or measurement explaining it simultaneously. The same applies to laboratory instruction videos. The proper handling of laboratory instruments can be presented as videos. Also, instructions for data analysis and scientific reporting can be provided with videos. In a previous study, it was shown that with the help of pre-laboratory video instruction it was possible to remarkably speed up student working in an elementary engineering physics laboratory course [7]. Also, the time spent in laboratory was shorter.

Solutions to homework exercises are calculated with a marker pen to paper and recorded from above (Fig. 2). The recording device can be almost any recorder, but smart phones and tablets are very suitable for this purpose. The teacher's propagation speed is automatically similar to that of writing on blackboard. Therefore, it is easy for the students to follow this type of videos. Compared to mere written answer, this method provides the students with teacher's reasoning and explanation about the solution and its steps.

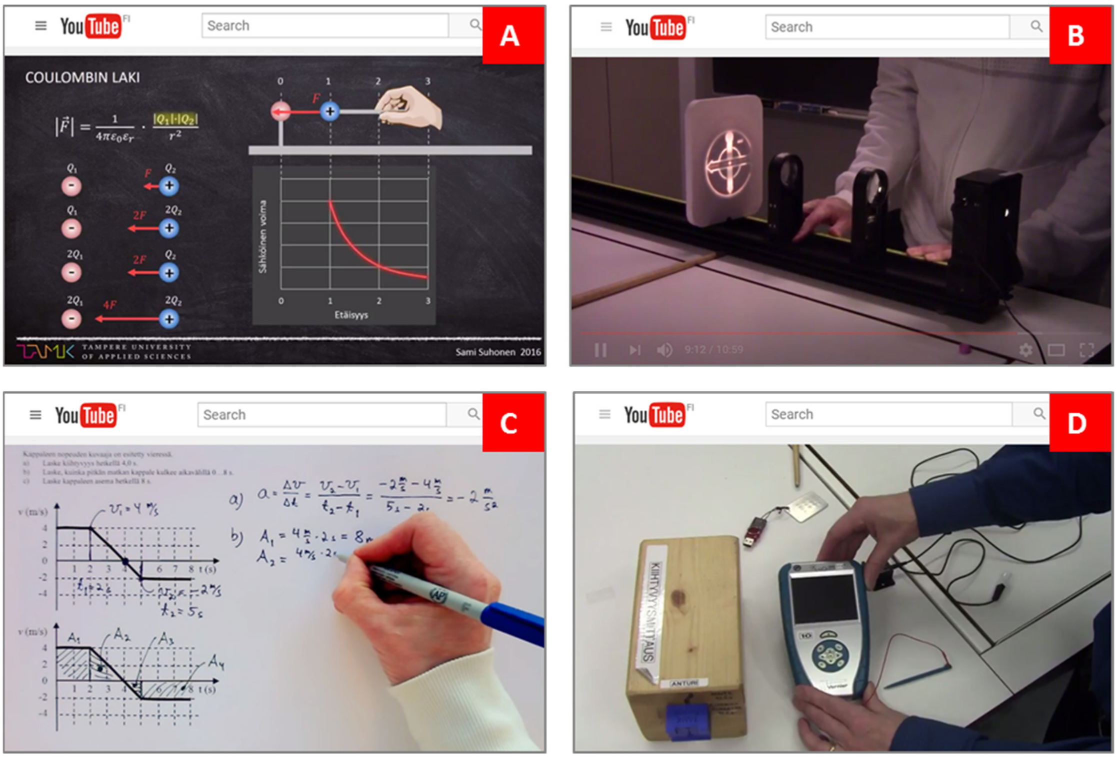


Fig. 1. In Tampere UAS, videos are used for four different purposes in physics teaching and learning: A) Present theory of physical phenomena, B) Show lecture demonstrations and measurements, C) Present solutions to homework exercises and D) Instruct laboratory work.

Short, individually streamable video clips have dramatically increased versatility and possibilities in teaching and studying over the last ten years. At Tampere University of Applied Sciences, the videos have been used in physics teaching since 2013. During this time, the main playback device has been PC-computers (91 % of watching), whereas tablets (5 %) and smart phones (4 %) form only a minority.

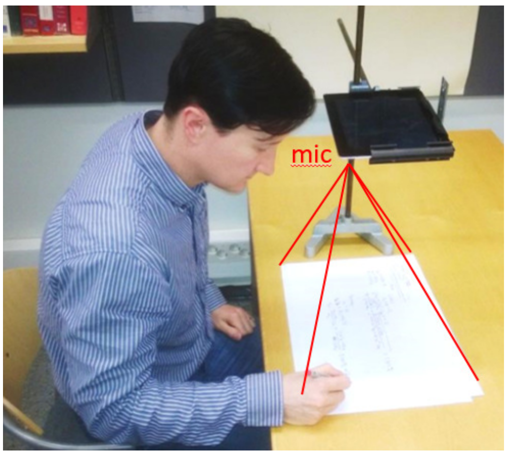


Fig. 2. Recording a homework solution video.

2 VIDEOS IN THIS STUDY

The physics team at Tampere University of Applied Sciences has this far recorded roughly 1100 short, educational video clips for physics teaching and learning. They have been watched 410 000 minutes and 125 000 times. This results in 114 views per video on average. However, the distribution of views is far from even. For this study, 50 such videos were chosen, which represented different categories and had 270 views at minimum. The authors believe that this number of views is enough to give a reliable average of viewer retention. A summary and characteristics of different types of videos included in this study are shown in Table 1.

Table 1. Characteristics of videos in this study.

Type of video	Number of videos	Average length	Average number of views	Average percentage watched
Theory	9	6:28	437	60 %
Demonstration	2	1:34	358	80 %
Exercise	30	6:45	573	55 %
Laboratory	9	11:40	383	52 %

A more detailed picture of the videos is presented in Fig. 3. It shows the length distribution of the videos. Based on table 1 and figure 3, it can be noted that the theory and the exercise videos have similar lengths, whereas the laboratory instruction videos tend to be longer. The demonstration videos just show one specific physical phenomenon and are therefore the shortest.

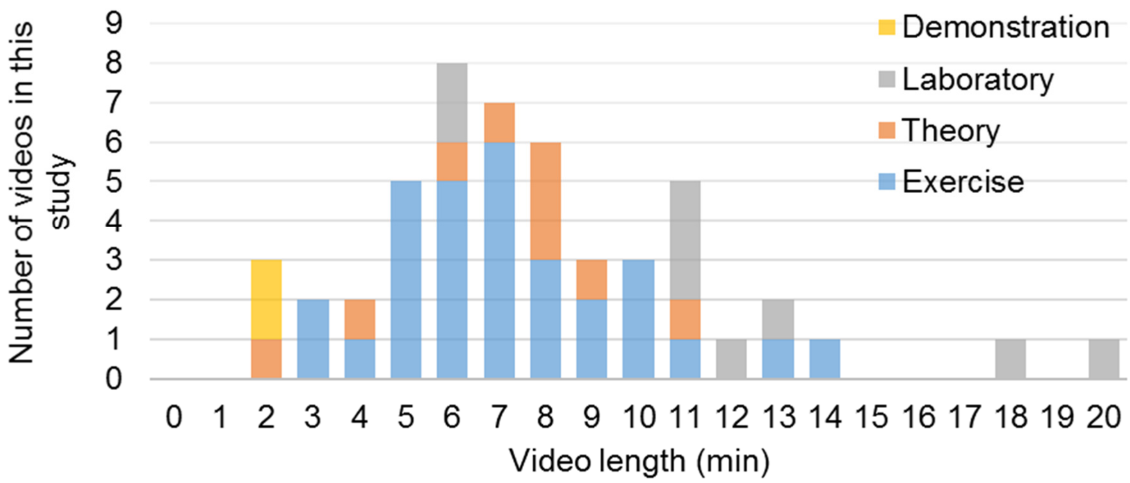


Fig. 3. Length distribution of different types of videos.

3 VIEWER RETENTION DATA

3.1 Theory and demonstration videos

Viewer retention can be analysed in YouTube analytics video-wise. Figure 4A presents the retention as a function of video position for all theory videos. Every video has a notch in the beginning. This means that watchers shut down the video within a couple of seconds after opening it. Similar behaviour is seen in all retention curves. These videos are “unlisted” in YouTube meaning that they are not publicly visible. Therefore, all the activity comes via learning management system. Therefore, it is likely that the notch is caused by accidental openings of (wrong) video.

The shorter videos have higher retention percentages in general, but the shapes of the retention curves are rather similar irrespective of the video length. This typical shape is presented in Fig. 4B. It seems that watchers lose interest rather evenly and the curve goes slowly down throughout the vide length.

Since there are only two demonstration videos, both very short, no generalizations can be made. The curves in Fig. 4C for demonstration videos both show some spikes. These videos were used to show measurements in an online course and the spikes represent time instants where the values can be read. It seems that students have rewound the video to retrieve the numerical values needed.

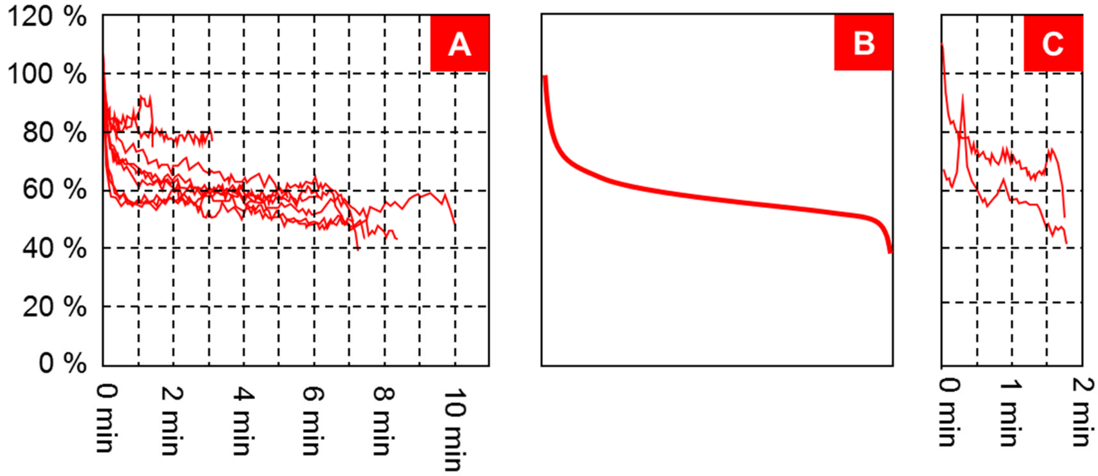


Fig. 4. A) Retention curves for theory videos. B) Typical shape, interpreted as an average of curves in part A. C) Retention curves for demonstration videos.

3.2 Homework solution videos

Figure 5 shows viewer retention for homework solution videos. Due to the large number of this type of videos included in this study, not all of them are presented. A characteristic feature is clearly visible even in this smaller data set – namely the rising spike at the end of the almost each video. In most cases these videos present algebraic solution and numerical answer to a homework problem. Reasoning and necessary steps are simultaneously explained by the teacher to cultivate students scientific thinking. Of course, students are encouraged to try to proceed as far as they can without watching the video for help. The spike at the end suggests that many students have actually managed to solve the problems and have watched only the last frames of the video to check the correctness of their own answers. To make this checking easier, the students could be provided with an additional snapshot image of the end of the video. These could be presented in the course's learning management system, together with the links to YouTube videos.

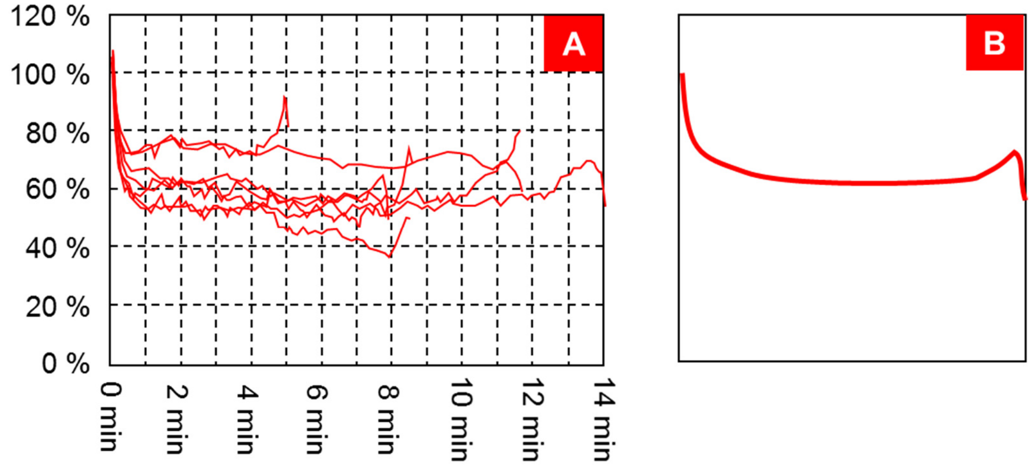


Fig. 5. A) Retention curves for homework solution videos. B) Characteristic shape.

3.3 Laboratory instruction videos

Retention curves for laboratory instruction videos are presented in Fig. 6A. The shape differs remarkably from those of all other types of videos. There are certain time periods that have been watched much more than other parts of the video. The retention percentages even exceed 100 % which means that the viewers have rewound it back and watched again. The shape suggests that the students have been seeking instructions for some specific actions to cope with the laboratory instrument. They probably have watched the videos before laboratory time, as supposed to, but needed to recall some aspects during the laboratory measurements. Authors suggest that to this type of videos list of content could be added to YouTube. It would help the students to find the parts they are looking for. An exemplary image of this table of contents is in Fig. 7.

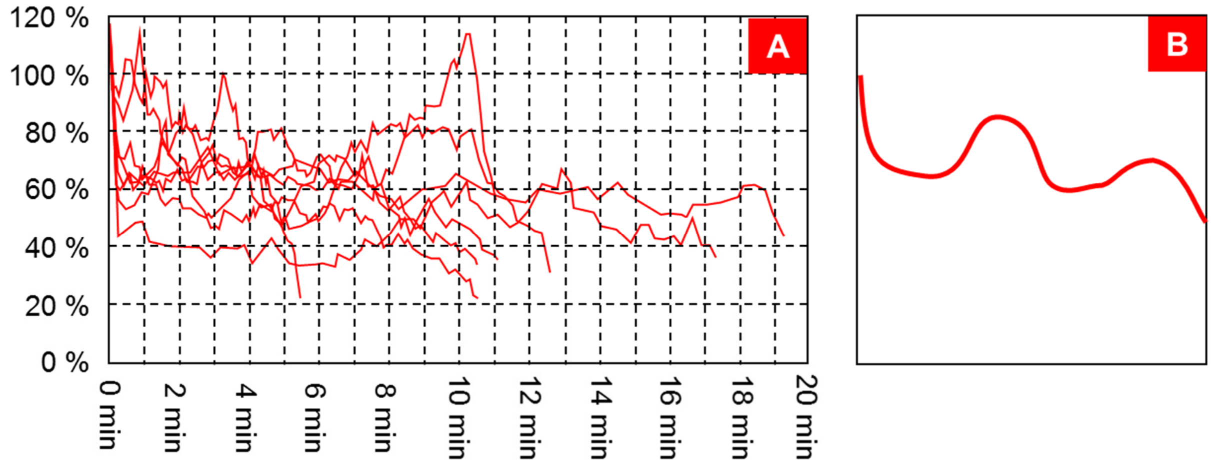


Fig. 6. A) Retention curves for the laboratory instruction videos. B) Typical shape, showing characteristics visible in part A.

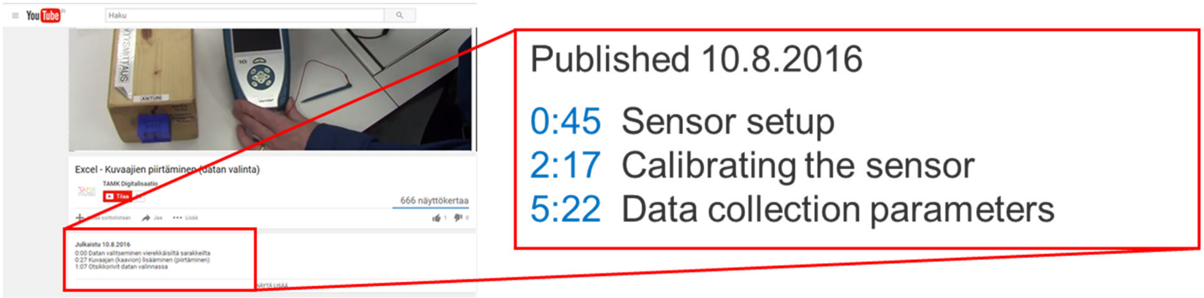
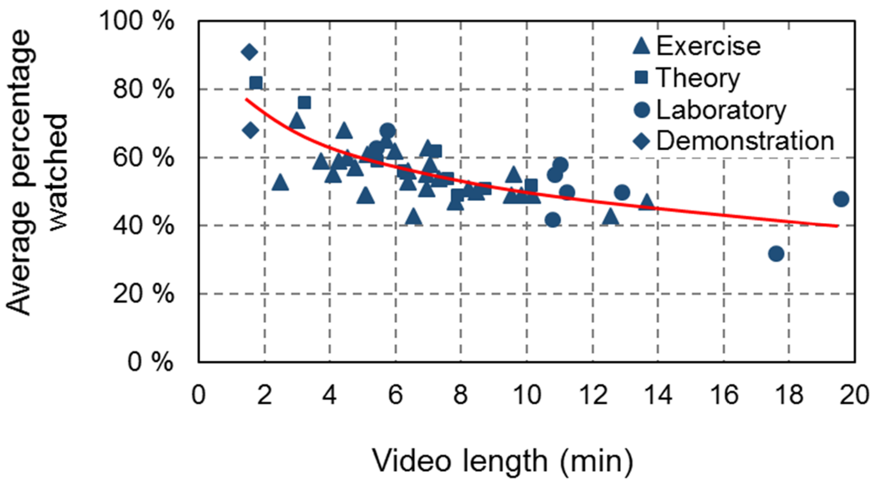


Fig. 7. Table of contents in a YouTube video.

3.4 Retention vs length

Figure 7 show the average watched percentage of each video as a function of video length for all video types. Regardless of the type, the longer the video the lower the average watched percentage. This result is in accordance with the findings in the literature [10, 11]. A large, 6.9 million video views study by Kim et al. showed that video length was by far the most significant indicator of engagement [12]. Students also engaged less frequently with assessment problems that followed longer videos.



4 SUMMARY

Watcher retention patterns differ among the video types Theory videos are simply watched through and the retention curves down as video progresses. Homework solution videos, have a spike at the end telling that students watch the last frames to check their answers. For this purpose, the students could be provided with a snapshot image of the end of the video - together with the actual video, of course. Laboratory instruction videos are rewound and certain parts are watched several times. Authors suggest that to this type of videos a list of video content could be added in YouTube. It would help the students to find the parts they are looking for.

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A Survey of Robotic Competitions and its Impact in STEM and Engineering Education

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ABSTRACT

Several studies point to the need to interest child and young students in the areas of science, technology, engineering and maths (STEM).

According to the National Research Council, out-of-school programs have been shown to contribute to young people's interest in and understanding of STEM, connect young people to caring adults who serve as role models, and reduce the achievement gap between young people from low-income and high-income families. The main criteria of programs that produce positive outcomes for learners are: they are engaging, responsive, and make connections.

Research also suggests that intellectually engaging STEM programs provide young people with first-hand, materials-rich, and place-based learning opportunities that involve processes of scientific or engineering investigation and practice.

Furthermore, today's students are active learners. They construct their own knowledge structures and learning environments through interaction and collaboration. Their approach to learning is highly nonlinear rather than following the sequential structure of the typical school curriculum. They are adept at multitasking and context switching. And they are challenging the teachers/faculty to shift their instructional efforts from the development and presentation of content, and instead become like mentors and consultants to student learning.

On a more advanced level, the Educating the Engineer of 2020 report states that engineering education must be realigned to promote technical excellence as well as understanding of work strategies, team, communication, ethical reasoning, societal and global contextual analysis skills in practising engineers. This implies that, to prepare professionals to communicate with the public, engage in a global engineering marketplace and become lifelong learners, humanities, economics, political science, language, and/or interdisciplinary technical subjects must be part of the undergraduate education.

To motivate engineering undergraduates to drive their learning process it is necessary to adopt interesting methodologies, *e.g.*, PjBL and autonomous teamwork, and problems, *e.g.*, finding solutions for the benefit of others. The desire to find together the solution for a real world problem drives students to search for knowledge, learn complex subjects and share their findings. Such design, build and test projects are intended to provide students with an experience that is fun, motivating and educational, increasing student self-confidence and interest in learning as well as in engineering.

According to Duderstadt's report Engineering for a Changing World: A Roadmap to the Future of American Engineering Practice, Research, and Education (2008), employers increasingly seek social and cultural skills such as the ability to communicate, to function in an increasingly diverse environment, to be committed to and capable of lifelong learning, and to not only adapt to but actually drive change. This will require that engineering education shift increasingly away from the lecture-laboratory approach of the sciences to more active learning experiences that engage problem-solving skills, team building, creativity, design, and innovation. Psychologists

and cognitive scientists have known for decades that the most effective learning occurs through the active discovery and application of knowledge, not through mere study and contemplation.

Still in the same report, it is stated that follow-up studies of student achievement following participation in projects such as the solar car race or autonomous vehicle competition reveal that student academic performance improves very significantly with such experiences, even though students may temporarily take reduced course loads to accommodate such demanding activities. This could be augmented with extracurricular experiences such as co-operative education, internships, study abroad, service learning, and team experiences such as the solar car race or autonomous vehicle competition.

Furthermore, Duderstadt's still argues that all institutions, programs, and roles must strive to provide exciting, creative, and adventurous educational experiences capable of attracting the most talented of tomorrow's students.

Similar objectives are stated in "The Green Report – Engineering Education for a Changing World", from ASEE. According to it, engineering education programs must not only teach the fundamentals of engineering theory, experimentation and practice, but be relevant, attractive and connected.

Also, as addressed by some institutions, namely ABET, that argues that faculty will need to evolve from professors to learning managers, by being collaborative, having broad knowledge, and integrating coaching and counselling into teaching formats while creating new ones made possible by the students themselves, students are given some project objective and they must, by themselves, define their detailed objectives, with the teachers working as tutors and not as problem solvers.

Robotic competitions are appealing for fulfilling these tasks. These competitions "capture" and interest lots of youngsters for the technical areas, are pleasant and join education with entertainment (edutainment). Moreover, some particular competitions can foster the advance the state of the art on some specific research and development areas.

Keeping these ideas in mind, this paper introduces several studies that point to the need to transform STEM, and Engineering, Education and the requirements that should be addressed to drive this change. Based on the survey of these sources it is then suggested that this change can be conducted through robot-based competitions and are introduced several such events, directed to distinct target ages and with different platform requirements.

Conference Key Areas: Attractiveness of Engineering Education, Physics and Engineering Education, Engineering Skills,

Keywords: Robotics, Competitions, Engineering, Education

Realizing an international student exchange program for Belarusian engineering students to Belgium

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ABSTRACT

In the framework of the Erasmus+ project "Improvement of master-level education in the field of physical sciences in Belarusian universities", 14 Belarusian students participated in a one week student exchange program to KU Leuven in Belgium. The training focused on a number of attractive engineering topics related to energy efficiency, clean energy and clean technology in general. This initiative aims to facilitate the modernization of the physics and engineering educational programs in Belarus including the integration of the European bachelor master degree concept. The overall satisfaction of the students as well as of the teaching staff about the training week is large. The present paper discusses the main goals, the practical realisation and an evaluation of the one week training program.

Conference Key Areas: Physics and engineering education, attractiveness of engineering education, skills and engineering education.

Keywords: international student training

INTRODUCTION

The Erasmus+ project "Improvement of master-level education in the field of physical sciences in Belarusian universities" is an educational collaboration between three European Union universities (Riga Technical University (RTU), University of Cyprus, KU Leuven), four Belarusian universities (Belarusian State University (BSU), Grodno State University (GrSU), Gomel State University (GSU), Belarusian State Technological University (BSTU)), the Ministry of Education of Belarus and two industrial partners [7].

The project aims to improve the relevance of master degree programs in the field of physics in Belarusian universities. This improvement includes the integration of the

European bachelor master degree concept at the Belarusian universities. A transition from the educational 5 plus 1 system to the 4 plus 2 system is an important goal. The bachelor program reduces from 5 to 4 years implying a challenge to prepare the graduated bachelors for the labour market in a shorter period of time. The master program increases from 1 to 2 years implying the need for new up-to-date course material.

At the Belarusian universities, an increase of the number of master students is expected and a larger part of these master students must be prepared for the industry i.e. not only to realize a PhD. This means the new master program needs a closer link with the labour market. Input is expected from the European partners to inspire and help the Belarusian academic staff when realising this modernization.

This modernization of the physics and engineering educational programs requires the implementation of innovative ICT based teaching methods, the development of innovative learning methods, the development of updated courses and teaching materials (including e-books). It is important the teaching of new and updated courses starts during the lifetime of the Eramus+ project with an adequate number of retrained teachers and students.

Exchanges to European Union universities of Belarusian teachers and students are needed. The experiences of these teachers and students are not only useful for themselves, their experiences need to and will disseminate in the campuses of their four Belarusian home universities [4]. As also mentioned in [3], "any student who is able to receive a better education or broaden his/her personal horizon due to participating in an exchange and scholarship programme is a huge plus".

Student training programs at KU Leuven, Riga Technical University and University of Cyprus have been planned. The present paper mainly focuses on a one week student exchange program, the first student training program of the Erasmus+ project, which has been organised in February 2017 to KU Leuven in Belgium. When organizing this event, the KU Leuven engineering campus in Ostend relies on a long standing tradition of international activities including the development of international curricula and organizing internationally oriented programs [6].

1 THE MAIN GOALS OF THE STUDENT EXCHANGE WEEK

The training program focuses on a number of topics related with energy efficiency, clean energy and clean technology in general. These academic and technical state-of-the-art topics cover a broad range of interests as reflected by the different professional orientations of the participating students and the modern multidisciplinary industrial reality.

The goals of the student training week are much broader than just the teaching of state-of-the-art technology to Belarusian students. Integrating research in all its aspects in an educational program is a major concern at the Faculty of Engineering Technology of the KU Leuven. This concern is reflected in the training program by visiting two research laboratories (lighting and Electro Magnetic Compatibility) and presenting research results of a Belgian PhD student (wind impact on dunes).

When considering the educational objectives of the Faculty of Engineering Technology at KU Leuven, application oriented engineers are educated. This application oriented approach is reflected in the exchange program by visiting an international industrial company (producing agricultural machines and having connections with the Commonwealth of Independent States (including Belarus)). Since the new Belarusian master program also prepares to employment in the industry, such a company visit is mandatory. It is also useful to demonstrate how the Belgian research laboratories cooperate with the local industry.

Intensifying the contact between the European Union and Belarus is also an important goal of the Erasmus+ project. From this point of view, the stay of young and promising Belarusian students in the European Union, Belgium and Flanders is important. Besides having important personal relationships and personal development, obtaining familiarity with the European Union and Belgium has been stimulated by:

- a session comparing the energy policies in Belgium and Belarus,
- cultural historical activities including the visit of Medieval cities like Bruges and Ghent,
- obtaining familiarity with the Belgian climatic conditions and nature (e.g. the formation of dunes at the Belgian coastline).

Increasing familiarity with the English language, the main lingua franca in the scientific world, is important. English is the official language during the entire week and a dedicated course on general and scientific English has been included. The training week allows to realise informal and formal English practicing.

2 REALISATION OF THE MAIN GOALS OF THE TRAINING PROGRAM

The practical organisation of the training week is a result of a decent communication between all European Union partners (including the receiving KU Leuven campus in Ostend) and the Belarusian partners at the management meetings of the Erasmus+ project. The needs and suggestions of the Belarusian partners have been taken into account at an early stage of organization [1] in order to satisfy their expectations.

The student training week focuses on a well-chosen number of topics related to energy efficiency, clean energy and clean technology in general. More precisely, the training program contains sessions on:

- energy supply and electrical energy generation in Belgium and Belarus,
- solar energy in combination with energy storage and fuel cells,
- optical communication,
- energy savings in lighting technology and innovative lighting,
- innovative material properties,
- the use and production of biodiesel,
- Electro Magnetic Compatibility and the design of reliable electronics,
- wind speed measurements and wind impact on dunes.

These topics are closely related to courses taught in the bachelor and master programs at the KU Leuven campus in Ostend (Belgium). These topics reflect the know-how at the campus mainly originating from social, commercial, purely academic and industrial oriented research.

The training week contains a combination of theory sessions (PowerPoint Presentations), laboratory sessions, practical demonstrations, a company visit, visiting research laboratories and cultural activities. The combination of this broad range of activities will inspire and help the Belarusian teaching staff and student population to organize modernized master programs which have a closer link with the Belarusian and international labour market.

By focusing on attractive topics like energy efficiency, clean energy and clean technology, the attractivity of engineering and engineering education has been emphasized. As explained further on in the paper, the participating students appreciated such an approach. By including laboratory sessions, a broader range of engineering skills have been addressed.

3 PROFILE OF THE PARTICIPATING STUDENTS

Although the size of the visiting group of students is rather small, the group represents a large diversity in many aspects. The group is composed of 14 persons (very similar with [8]) originating from four different Belarusian universities (BSU, GrSU, GSU, BSTU). Each university selected three or four students. This limited number of students allowed the Belarusian universities to choose highly motivated students. All students are volunteers and they are also strong promising students.

Fig. 1. Visiting group of students

The visiting group is composed of two professors having a PhD, 4 PhD students, 1 master student (still studying the 1 year master program) and 7 bachelor students. The diversity is also emphasized when taking in mind the different professional orientations of the students. More precisely, the professional orientations include chemistry, nuclear physics, computer science, physics, metrology and electronics.

Also when considering the prior knowledge of the English language, there is a large diversity in the group. In general the participants are rather familiar with reading English texts and understanding spoken English. When considering the ability to write English and especially to express themselves orally, there are large differences between the individual participants.

Based on the evaluations performed by the students and the teaching staff, it is possible to conclude that the general scientific training of all students allows them to understand the sessions on clean energy and clean technology. When considering the English course on general and scientific English, the teaching professor focused towards a medium prior knowledge for the students.

4 EVALUATION OF THE EXCHANGE WEEK BY THE STUDENTS

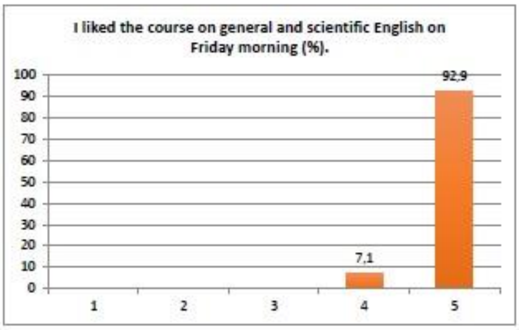
At the end of the week, two self-designed questionnaires containing positively defined statements have been offered to all 14 Belarusian students. Although the questionnaires are inspired by pedagogical science [2] and practical experience [6] available at the KU Leuven campus, the questions are adapted to the practical realisation of the training program.

A first questionnaire evaluates the general appreciation of the week including three main topics.

1) The general objectives of the week have been evaluated (including exercising the use of the English language, obtaining an introduction to the culture and the history of Europe and Belgium, learning the importance of international contacts and collaboration).
2) The program of the activities has been evaluated (including the scientific and technical content of the lectures, the clarifying nature of the laboratory demonstrations, the ability to perform experiments, visits to local companies and research laboratories, getting familiar with a virtual learning environment).
3) The accomodation and the hospitality of the KU Leuven staff has been evaluated.

In order to obtain an adequate dispersion of the data, a five-point Likert scale was used in the questionnaire. At the end, a limited number of students also mentioned an open statement concerning their experiences.

The general satisfaction of the participating students was very high on all topics. When considering the general objectives of the week, on average 73.2% indicated the highest score 5 (ranging from 71.4% to 78.6%) and on average 25% indicated the score 4. On average, 98.2% of the indicated scores are 4 or 5. When considering the evaluation of the program activities, on average 61.9% indicated the highest score 5 (ranging from 35.7% to 85.7%) and on average 29.8% indicated the score 4. On average, 91.7% of the indicated scores are 4 or 5. Especially the possibility to carry out practical experiments in a laboratory environment (technical hands-on sessions) is extremely appreciated.



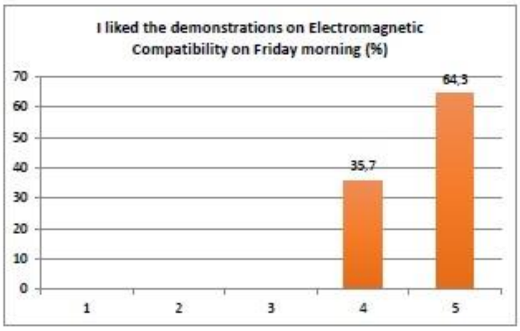


Fig. 2. Detail of the student questionnaire results

When evaluating individual sessions by a second questionnaire, all individual appreciations are really high. Figure 2 gives an excerpt of the results of the questionnaire giving the appreciations of the sessions on English and Electro Magnetic Compatibility.

The laboratory session of making biodiesel and the touristic visit of the historical city of Bruges both got the maximum score of 5 by all students. An interactive session on general and scientific English obtained a score of 5 by 92.9% of the students (7.1%

gave a score of 4), a more theoretical but also interactive session on energy and fuel cells obtained a score of 5 by 85.7% of the students (14.3% gave a score of 4). At their home institution, students do not lack traditional "ex cathedra" courses. The evaluation demonstrates that the students enjoy interactivity when realising an international training week. This observation is important when organising the future student training programs and when developing new teaching and learning methods in Belarus.

The overall satisfaction of the participating students will encourage them to maintain contacts with foreign countries in general and the European Union in particular. When focusing on the current Erasmus+ project, the satisfaction related to the first training week will encourage other Belarusian students to participate in other international weeks which will be organised in Riga and Nicosia.

5 EVALUATION OF THE EXCHANGE WEEK BY THE TEACHING STAFF

At the end of the week, a self-designed questionnaire containing positively defined statements, has been offered to the teaching staff realizing the individual sessions. Also this questionnaire contains a five-point Likert scale and formulating open statements concerning their experience has been stimulated.

In general, the satisfaction among the teaching staff is also large since they are satisfied about the organization of the international week (62.5% gave a score 5 and 37.5% gave a score 4) and they have the opinion such a student training is worth repeating (50% gave a score 5 and 50% gave a score 4). Despite this satisfaction there are a number of stimulating conditions which are not always that easy to fulfil. The teaching staff finds it important that:

- The teachers have sufficient information about the prior knowledge of the studens which allows them to build upon this prior knowledge (see the results in Figure 3).
- The students have a sufficient knowledge of the English language since during the entire week the English language has been used. It is also important the prior knowledges of the students are more or less comparable.
- The diversity in the student group is not too large (concerning prior scientific technical knowledge).
- The students are motivated to participate and to acquire scientific technical content.

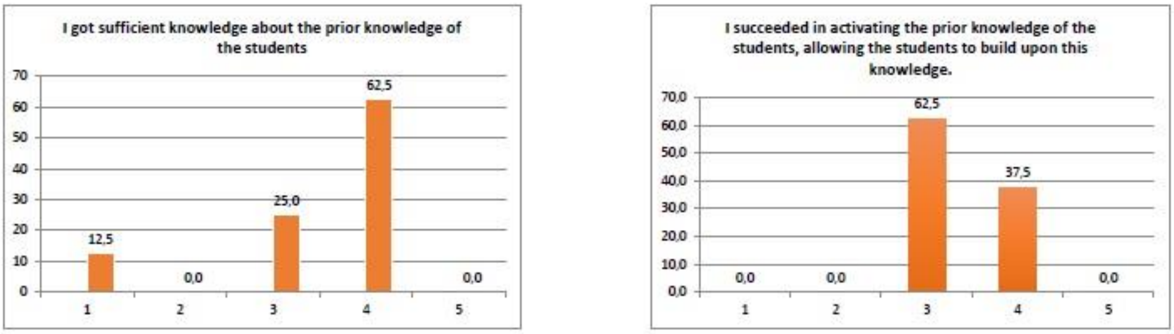


Fig. 3. Opinion of teaching staff concerning prior knowledge of the students

Obtaining sufficient information about the prior knowledge of the students, when considering scientific technical subjects and the English language, is a common challenge for the sending Belarusian universities and the organizers of the receiving university (see the results visualised in Figure 3). Decent communication about that topic has to be a concern when organizing the next student training programs at the Riga Technical University and the University of Cyprus.

A more or less homogeneous group of students is to some extent obtained by the general scientific training all participating Belarusian students have. However, a student group which is composed of

- students of different universities,
- bachelor students, master students, PhD students and participants who already finished their PhD program,
- students studying different professionel orientations

inherently implies a diversity. It is a challenge for the receiving teaching staff to face this situation.

During the student training week in February 2017, there were absolutely no problems concerning a lack of motivation of the participating students. The Belarusian universities have selected strong promising students which were all volunteers to participate. These promising students are able to disseminate their experiences at their Belarusian home universities [4, 5] and the local industry.

Due to the general satisfaction of students and teaching staff, it is clear that future international weeks can be organised based on a similar philosophy. When considering the international weeks which will be organized in Riga and Nicosia as part of the current Erasmus+ project, the teaching staff of Riga Technical University and the University of Cyprus will take the suggestions into account formulated by the KU Leuven teaching staff.

The visiting Belarusian students were not able to participate in regular classes with European students. Due to practical reasons, the training program has been organised during a holiday week of the local Belgian students (similar with the situation discussed in [8]). When organizing future training programmes, it can be useful to include contacts (scientific and personal) between the incoming Belarusian students and the local European students.

6 SUMMARY AND ACKNOWLEDGEMENT

In order to integrate the bachelor master degree concept at Belarusian universities for physics and engineering students, collaboration between Belarusian universities and universities in the European Union is very important. From this point of view, a student exchange week has been organised which allowed Belarusian students to get familiar with the educational system of the Faculty of Engineering Technology of the KU Leuven in Belgium. The student training week focused on topics related to energy efficiency, clean energy and clean technology but also linguistic and cultural aspects were considered. Based on a final evaluation among the participating students and the teaching staff, it is clear that the overall satisfaction is large. This satisfaction will encourage other Belarusian students to participate in similar student training weeks which will be organised to Riga and Nicosia as part of the Erasmus+ project "Improvement of master-level education in the field of physical sciences in Belarusian universities".

The present work is supported by the Erasmus+ project "Improvement of master-level education in the field of physical sciences in Belarusian universities" having the grant Nr 561515-EPP-1-2015-1-LV-EPPKA2-CBHE-JP-ERASMUS+.

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Inciting a Cognitive Conflict: A Challenge to Students in Introductory Mechanics

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ABSTRACT

The concept of force is a key concept in any pre-university physics course, but nevertheless it is well known that many students face severe problems because of misunderstandings within this subject when enrolled at an engineering program. The direction of the friction force in different settings is one example that often puzzles the students. Using a cylinder pulled by a force on a horizontal surface is a well-suited situation that can be studied at class with or by the students to gain detailed understanding of the forces involved.

In this work-in-progress, we present an extension of the standard treatment of the pulled cylinder found in the literature. We focus on modelling the induced friction force when the cylinder is pulled at different angles to horizontal and letting the pulling force attack at different heights of the cylinder. As a consequence, the analysis leads to several conclusions that we find very useful when teaching introductory mechanics. From previous investigations, we know that these conclusions are counter-intuitive to our first year engineering students, and thus the pulled cylinder may serve as a prime example to create a cognitive conflict at class. As suggested by other authors, inciting a cognitive conflict can be a very fruitful starting point for deep learning.

In addition, we present a setup for a demo experiment that illustrates qualitatively the features of the friction force on the pulled cylinder predicted by the dynamical model. Finally, we discuss different approaches to the topic at class in order to optimize the learning outcome.

Conference Key Areas: Physics and Engineering Education / Engineering Education Research / Engineering Skills

Keywords: Friction force, pulled cylinder, discrepant events, demo setup

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INTRODUCTION

There is a range of sources that explains why mechanics is often seen as a difficult subject. Among them are the material being abstract, the necessary precision required, and the intense use of mathematical descriptions within the subject. In this paper, we focus on another source of difficulty, which is the presence in mechanics of inherently difficult *conceptual primitives*. These primitives consist of *specific primitives* (or *key concepts*) like mass, acceleration, force, momentum etc., and *generic primitives* (or *fundamental theories and models*) such as Newton's laws, conservation theorems etc. [1]. Many students struggle with understanding these concepts at a qualitative level, but the difficulties may go undetected in traditional problem solving because the student with superficial knowledge and formula manipulation techniques can mask the misunderstanding of the underlying qualitative concepts [2]. The basic misconceptions are highly resistant to change and as discussed by Clement [2] they are remarkable similar to misconceptions treated as early as in the 17th century by Galileo!

During the past seven years we have used a student response system ("clickers") and peer instruction quite intensively in our introductory mechanics classes. Some of the problems described above become clear when looking at the data gathered by the response system. Of particular interest in this context is a multiple choice question where the students were asked what will happen when a cable reel on a horizontal surface with plenty of friction is pulled by a force a shown in *Fig. 1*.

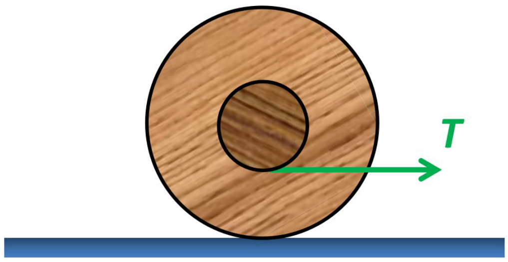

Fig. 1. Illustration to clicker question: In which direction will the cable reel move?

The students answered the question by themselves anonymously, and after seeing the distribution of answers they discussed in small groups before giving in an answer again. Results for the same question during the five year period 2011-2015 are given in *Fig. 2*. The data has been collected for ten classes with a total number of approximately 350 students. It shows that only a relatively poor number of students have the correct answer, and moreover, the students cannot in general increase the number of correct answers significantly by discussing in groups since most of the data points are close to or below the dotted line in the figure. This is in contrast to a previous study where we found that peer instruction is very likely to improve the students learning outcome, and even in cases where all students have severe difficulties with a certain question the peer discussions might increase the ratio of correct answers to as much as 80% [3]. Hence, pulling a cable reel or a cylinder on a horizontal surface is what González-Espada et al. have called a discrepant event [4]. Such events are powerful possibilities to stimulate interest, motivate students to challenge their misconceptions and promote higher-order thinking skills. When exposing students to evidence that directly contradicts their ideas a cognitive conflict is created, and this can be utilized in the teaching [5, 6, 7].

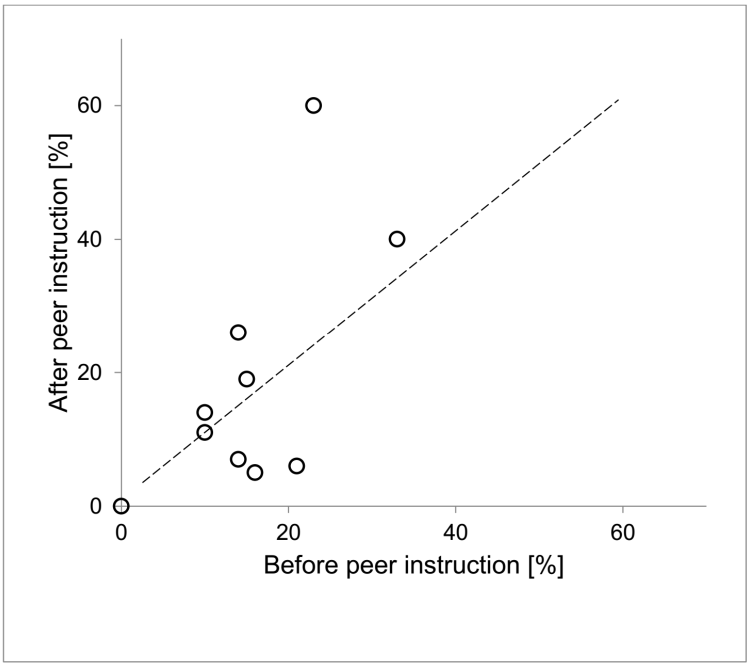

Fig. 2 . Percentage of correct answers to cable reel question

Some of the difficulties in the example with the pulled cylinder are due to the relation between force and acceleration, and it has been addressed by a number of authors by studying a rolling cylinder on a horizontal plane. To demonstrate the direction of the friction force on a rolling cylinder Shaw [8] proposed an experiment where he also measured the friction force when the cylinder was pulled at two different heights. A similar, but slightly simpler, setup was described by Salazar et al. [9] where they argued that most students consider the direction of the friction force on a rolling cylinder a paradox. Pinto and Fiolhais [10] have presented a systematic study on the friction force resulting from a horizontal pull at various heights of the cylinder and derived the conditions for the static friction coefficient to ensure rolling with and without slipping. A dynamical model for the rolling cylinder based on the exchange of linear and angular momentum between the rolling body and the underlying surface was described in a paper by D'Anna [11]. In addition, she presented a simple idea to illustrate experimentally the difference in the cylinders interaction with the surface and thus measuring the direction of the friction force.

A common feature in all the work mentioned above is that the cylinder is pulled by a horizontal force only. The angle dependence for a pulled cylinder has been studied by Mungan [12] but with a focus on the acceleration of the cylinder and deriving two critical angles where the cylinder slips on the surface without rolling and rolls without slipping regardless of value of the static friction coefficient. Carvalho and Sousa [13] reported on an interesting study about a number of conceptual problems involved in rotational motion, one of them being the pulled cylinder. They included a brief analysis with conditions for the direction of friction being in one direction or the other and useful comments on teaching approaches as well. In the present paper, we model not only how the friction force depends on the height of the pulling force but also how friction depends on the angle of the pull. In addition, we describe a simple setup for demonstrating the findings.

1 THE DYNAMICAL MODEL

1.1 Free body diagram

We look at a cylinder of radius R on a horizontal surface with sufficient friction to provide rolling without slipping. The cylinder is pulled by a force T at a distance r from the center of gravity G and at an angle θ to horizontal.

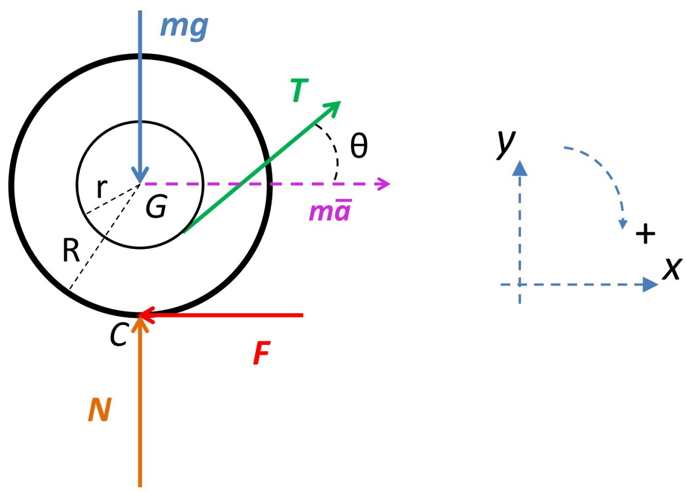

Fig. 3. Free body diagram

In addition, we have gravity acting at G and a normal force N and friction F acting at the contact point C.

1.2 Equations of motion

Applying Newton's 2nd law along the x-axis gives

$$\sum F_x = m\bar{a} \quad \Rightarrow \quad T\cos\theta - F = m\bar{a} \quad \Leftrightarrow \quad F = T\cos\theta - m\bar{a} \tag{1}$$

while for motion along the y-axis we find

$$\sum F_y = 0 \quad \Rightarrow \quad N + T\sin\theta - mg = 0 \quad \Leftrightarrow \quad N = mg - T\sin\theta\,. \tag{2}$$

Since we assume rolling without slipping, Newton's 2nd law for the rotational motion yields

$$\sum M_G = \bar{I}\alpha \quad \Rightarrow \quad -T\cdot r + F\cdot R = \bar{I}\cdot\frac{\bar{a}}{R} \quad \Leftrightarrow \quad \frac{F\cdot R^2}{\bar{I}} - \frac{T\cdot r\cdot R}{\bar{I}} = \bar{a} \tag{3}$$

where $\bar{I}$ is the moment of inertia for the cylinder about the center of gravity.

1.3 The friction force

Substituting *Eq. (3)* into *Eq. (1)* gives

$$F = T\cos\theta - \frac{m\cdot F\cdot R^2}{\bar{I}} + \frac{m\cdot T\cdot r\cdot R}{\bar{I}} \tag{4}$$

and solving for the friction force we get

$$F = \frac{T\cos\theta + \dfrac{m \cdot T \cdot r \cdot R}{\bar{I}}}{1 + \dfrac{m \cdot R^2}{\bar{I}}} \tag{5}$$

Setting $\bar{I} = \frac{1}{2} m R^2$ (i.e. we use the moment of inertia of a solid cylinder, which is a good model for the experimental demo presented in the next section) this equation reduces to

$$F = \tfrac{1}{3} T (\cos\theta + 2\frac{r}{R}) \tag{6}$$

From *Eq. (6)* it is easy to determine if the friction force might become zero:

$$F = 0 \quad \Leftrightarrow \quad \cos\theta = -2\frac{r}{R} \tag{7}$$

where we have neglected the trivial solution $T = 0$.

A graph of the friction force relative to the pulling force, *F/T*, as given by *Eq. (6)* has been plotted in *Fig. 4*. In *Fig. 5* we have plotted the implicit function in *Eq. (7)* and indicated the regions where the friction force is positive and negative, respectively.

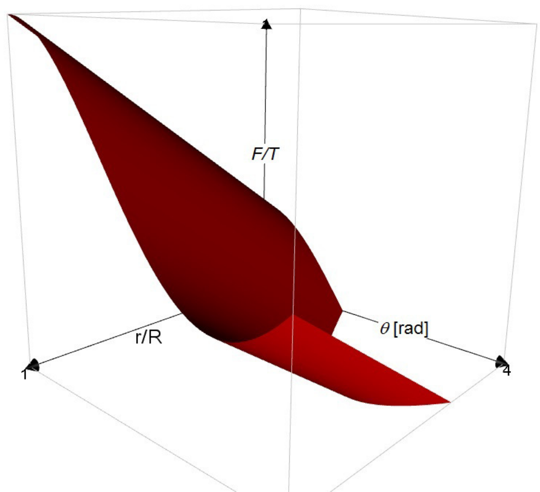

Fig. 4. Plot of $\frac{F}{T}(r/R, \theta)$.

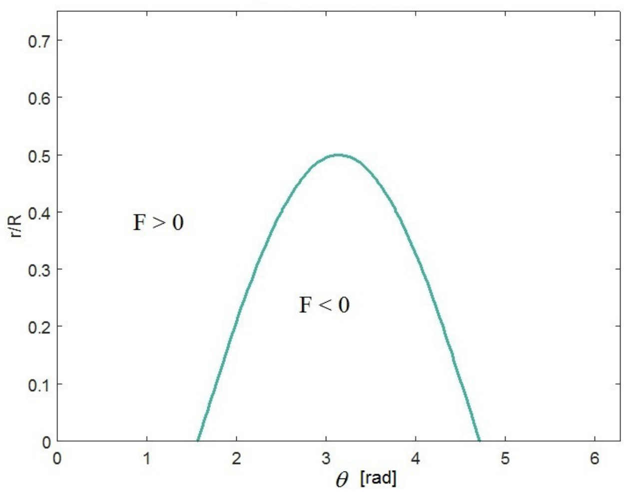

Fig. 5. Sign of the friction force depending on the pulling angle θ and the ratio *r/R*.

1.4 Critical angle

To find the angle θ_c where the cylinder is not moving despite the pull, the acceleration of the center of gravity is set to zero. With $\bar{a} = 0$ *Eq.* (1) and (3) reduce to

$$F = T \cos\theta_c \tag{8}$$

$$-T \cdot r + F \cdot R = 0 \tag{9}$$

By combining these two equations we find the criterion for the cylinder being at rest even though we are pulling:

$$\cos\theta_c = \frac{r}{R} \tag{10}$$

We note that the critical angle does not depend on the pulling force T. When the cylinder is pulled at the angle θ_c it will remain at rest until the horizontal component of T exceeds the maximum friction $\mu_s N$. By applying *Eq*. (2) this happens when

$$T > \frac{\mu_s mg}{\cos\theta_c + \mu_s \sin\theta_c} \tag{11}$$

2 EXPERIMENTAL DEMO SETUP

To illustrate the qualitative implications of the model, a fairly simple demo setup has been developed (*Fig*. 6). On top of a rectangular plate of acrylic glass some rubber material has been mounted to ensure plenty of friction from the surface. The plate rests on many small metal spheres allowing the plate to move very smoothly in the surrounding frame. At each end the plate has been connected to the frame by a couple of springs.

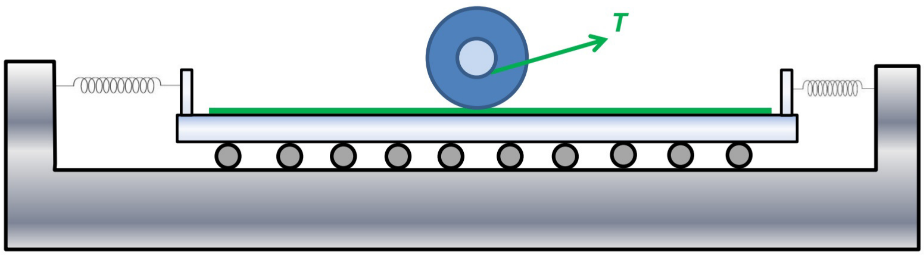

Fig. 6. Demo setup to illustrate direction of the friction force

Two wheels have been joined with a smaller cylinder between them. With a mass of the inner cylinder much smaller than the wheels, this makes up a sufficient demo model of an object with the same moment of inertia as a simple cylinder. Obviously, when pulling the wheel, the direction of the friction force can be determined by observing the recoil of the surface.

3 IN THE CLASSROOM

The example with the pulled cylinder can be used in different ways in an introductory mechanics course. What we have found most rewarding is when the students are faced with several cognitive conflicts during the lecture. This can be realized as sketched below. In addition, it is a prime example on how to model dynamics by using the equations of motion.

(a) Ask the students a (clicker) question as illustrated in *Fig*. 1. When it does not seem to be straight forward let the students discuss the question in small groups.
(b) Demonstrate (on a fixed surface) that the cylinder will move to the right. Most students will find the answer counter intuitive, and it will stimulate their interest in the setup.
(c) Let the students establish the free body diagram. Ask them to find the moment of force about the contact point to eliminate the contribution from the unknown friction force. The students will be able to conclude that the cylinder rotates

clockwise and hence move to the right, since only the pulling force is applying a moment of force about C.

(d) Use the demo setup to illustrate the direction of the friction force in this situation.

(e) Use a cylinder/spool with *r/R* > 0.5 and pull at an angle π, i.e. pulling to the left. Ask the students for the direction of the friction force. Most students think that friction always oppose the motion and will be surprised to see that the demonstration reveals the friction to be to the left as well (in agreement with *Fig.* 5).

(f) With input from students, derive *Eq.* (6) and the students will realize that friction becomes positive, thus explaining the observation. An important conclusion for the students is that friction contributes to the acceleration of the cylinder in this case.

(g) Ask the students to investigate whether the friction force might be zero (*Eq.* (7)).

(h) Show Fig. 5 to the students. With a few cylinders with different *r/R*-ratios and using different angles it is easy to demonstrate the direction of the friction force for different regions in the plot.

(i) Given for instance *r/R* = 0.3, ask the students to calculate the angles for which the friction becomes zero (with this ratio *Eq.* (7) yields $\theta = 127^{\circ}$ or $\theta = 233^{\circ}$). With some care this can be demonstrated as well.

(j) Challenge the students by asking whether it is possible to pull the cylinder without it starting to move. If necessary guide the students to derive *Eq.* (10).

(k) With a suitable value for *r/R* (not too low and not too high) it can be illustrated on the demo setup when pulling at the critical angle θ_c. It will be clear from the demo that the friction force has a direction to compensate for the horizontal component of *T*. Also, a free body diagram for the situation gives a qualitative explanation why the cylinder does not rotate when pulled at θ_c since the moment of force about the contact point is zero, see *Fig.* 7.

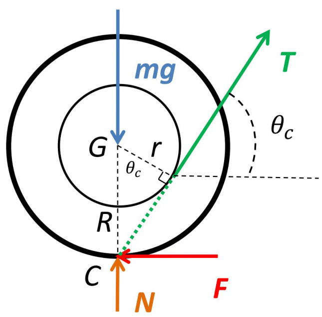

Fig. 7. Cylinder pulled at the critical angle θ_c. In the sketched situation, the pulling force *T* is fairly close to the critical value given in *Eq.* (11).

4 SUMMARY

Traditionally, students tend to simplify problems in rigid body dynamics or use their intuition instead of performing a firm analysis by use of the equations of motion. This leads frequently to misconceptions for instance concerning the direction of friction force and the representation of forces in free body diagrams. In this paper, we have discussed how it might be possible to use these misconceptions to create discrepant events and thereby stimulate the students' interest and curiosity at class. It is our hypothesis that this is a way to foster deep learning and develop the engineering skills the students need. Future work will include data collection in terms of pre- and post-tests combined with focus group interviews in order to test this hypothesis.

5 ACKNOWLEDGMENTS

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EduPark: Real-time smart parking educational system

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ABSTRACT

A real-time physical and virtual model of smart parking system is developed to teach and compare physical system implementation with its virtual simulation. Developed parking system has one entrance and exit point, six parking spots and digital display, which shows number of free parking lots. Ultrasonic sensors are used for car identification on parking lots. As a main platform Arduino is used. All events from the parking are send to the remote database for further data analysis and data visualization to end-users. This system can be used by students to understand sensor operations, various development platform operation and programming tools and methods. Training can be given on different parking operation scenarios and algorithms.

Conference Key Areas: Attractiveness of Engineering Education, Sustainability and Engineering Education, Physics and Engineering Education

Keywords: Smart parking, parking simulation, engineering education

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INTRODUCTION

Real-time systems are used in various application areas [1], like production process control, agile manufacturing, medical applications and others. Smart city concept implementation includes real-time intelligent transport systems and parking systems.

Education of different aspects of real-time systems, using physical system experience is a valuable approach, but it is usually connected with different limitations, like expensiveness of equipment, safety concerns, etc [2]–[4]. Therefore, usually computer modelling and simulations replace real physical environment during education and prototyping. There are many advantages (low costs, instant availability, no limitations, fast implementation, no afraid of making mistakes) and disadvantages (possible lost sense of reality and limited creativity in generation of realistic system's perturbations) of process virtualization.

Good alternative is to substitute real full-scale physical system with its minimized prototype, which is implemented using the same technologies, methods and equipment, including sensors. This approach has following advantages: (1) gives impression of consequences in case of control failure, (2) demonstrates process fragility and low repeatability and (3) allows separation of the controlled process and computer-driven control process [3].

Authors of this paper developed physical model of real-time smart parking educational (experimental) system, together with its computer simulation. This approach joins modelling and physical world and can be used for wide range of practical and educational aspects.

Authors choose the smart parking topic, because parking optimization is an actual problem in modern cities. With the growth of population and development of economic, the number of vehicles on the roads is increasing day by day. Parking is becoming one of the major problems for cities, and it makes significant cost position [5], [6]. Because of this, parking is limited in major cities including universities and major attractions all around the globe [7], [8].

Physical model of the real-time smart parking educational system (acronym is EduPark) is built for educational purposes to teach the students different aspects of data collection, using various sensor technologies, to program different development platforms (in authors case it is Arduino) and/or microcontrollers, to test different data transfer scenarios. Virtual system is developed to teach process visualization and simulation, to show how physical systems can be modelled in virtual environment.

1 PHYSICAL REALIZATION OF EDUPARK

Physical realization of EduPark system consists of base table surface where car-parking model is built (see Fig. 1).

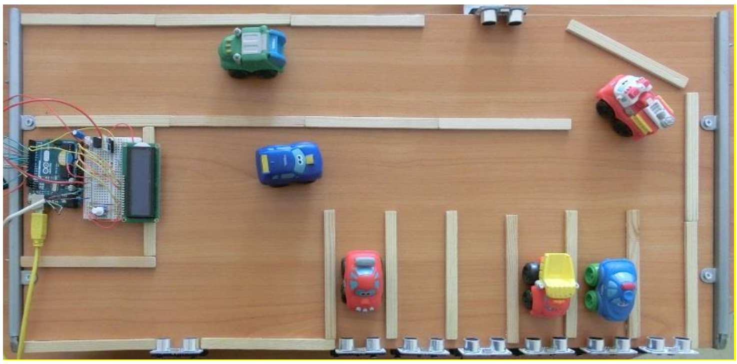

Fig.1. EduPark physical system

Parking has one entrance and one exit, six parking lots and digital display, which shows number of free parking lots. There are eight HC-SR05 ultrasonic sensors (entrance, exit and each parking lot) connected to Arduino, which are used to identify presence of car. A liquid crystal display (LCD) is used to inform about free (unoccupied) parking lots. Parking schematic view is demonstrated in Fig. 2.:

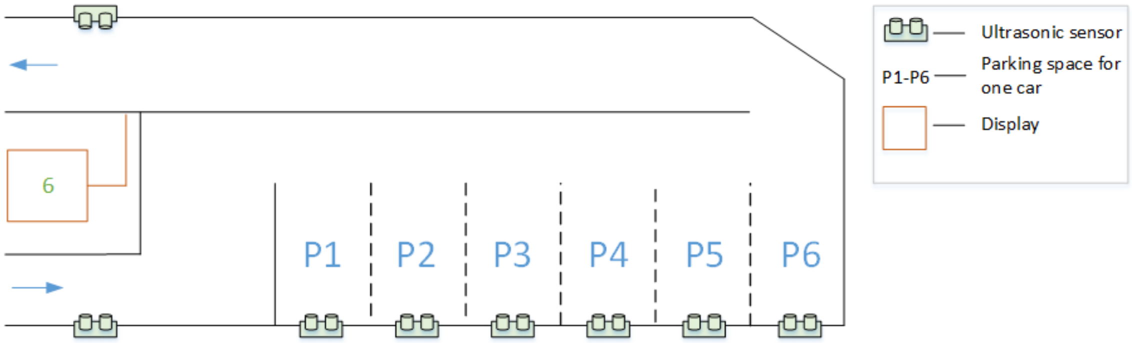

Fig. 2. Schematic view of the EduPark physical system

1.1 Arduino program

Arduino is used as a main development platform. All ultrasonic sensors are connected to the platform and their status is recorded. As well all sensor status is transmitted to the remote data collection and processing unit (DCPU, see section 3) using wireless communication module ESP8266. Schematic view of the developed Arduino system is demonstrated in Fig. 3.

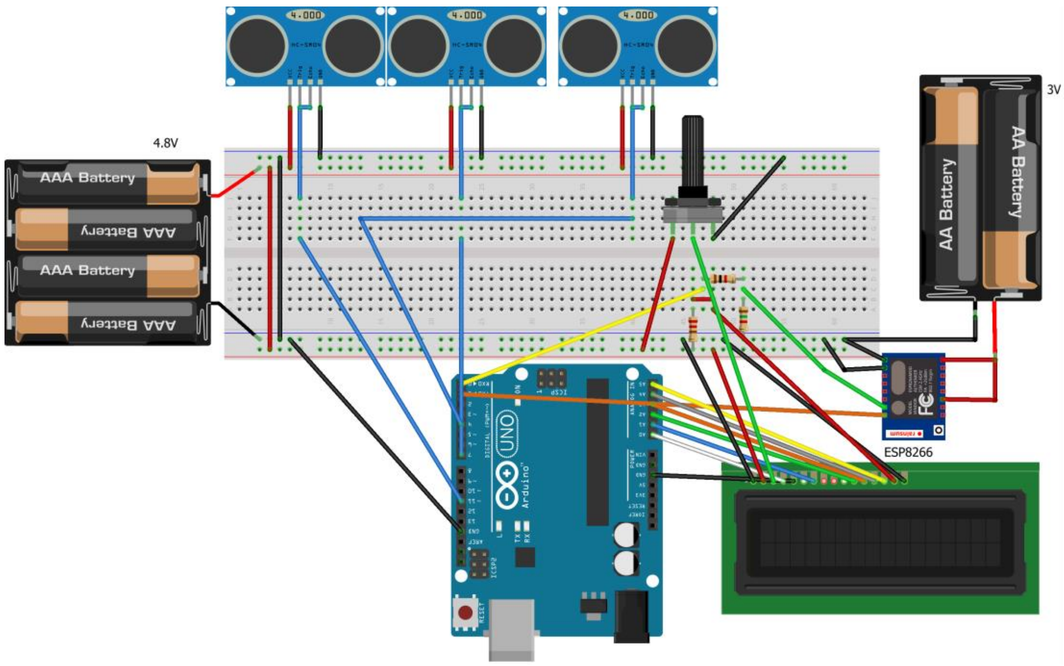

Fig. 3. Schematic view of the developed Arduino system (in Fritzing)

Detection distance of the object (car) is set to 5 cm. Arduino continuously checks for ultrasonic sensor status changes. When such changes occur – data about parking lot event (drive-in / drive-out) is sent to ESP8266 module and information on the LCD is updated. Arduino sends data to ESP8266 using serial communication (UART).

WiFi module ESP8266 creates a secure connection (SSL) with remote DCPU and sends a POST message according to defined API, containing event data received from Arduino: parking element id and event type (in / out).

Example of sent HTTP request:

```
POST /api/parkings/{parkingId}/elements/{elementId}/events HTTP/1.1
Host: parking.science.itf.llu.lv
Content-Type: application/json

{"type": "DRIVE_IN"}
```

Further data processing is handled by remote DCPU.

1.2 Simplified Arduino program

For parking event simulation and testing simplified Arduino system is developed. Sensors and their operations are substituted by push buttons. Schematic view of the developed Arduino system is demonstrated in Fig. 4:

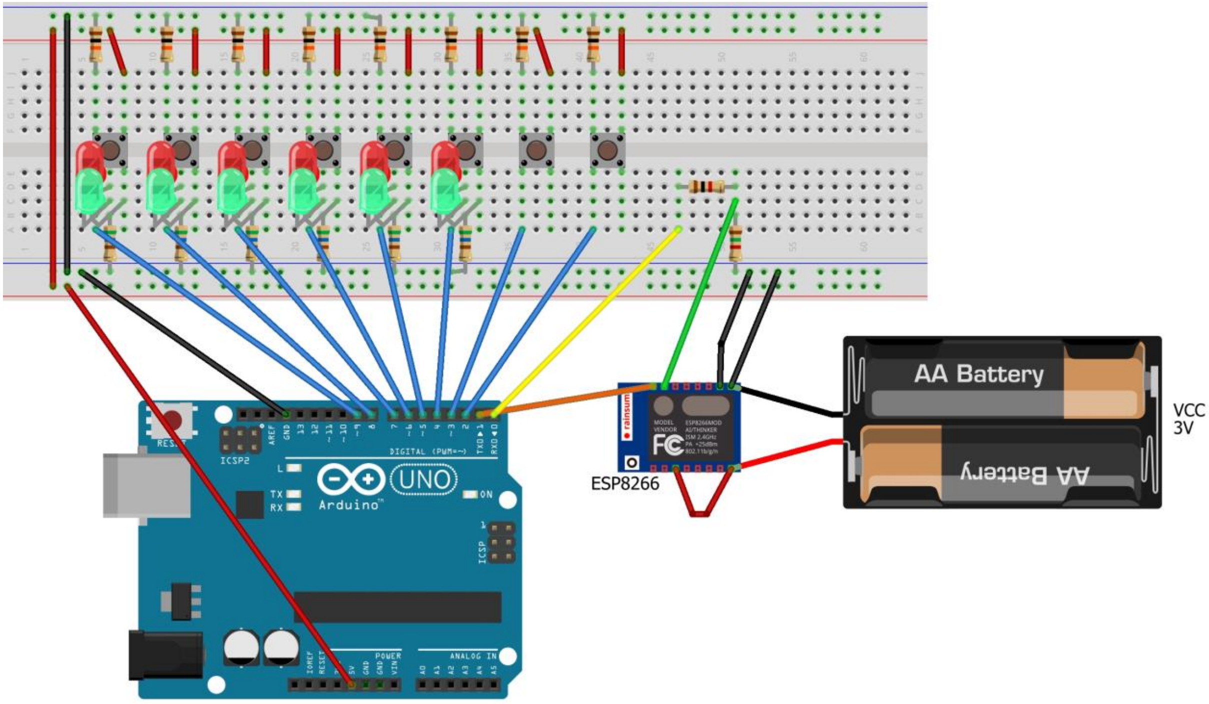

Fig. 4. Schematic view of the developed simplified Arduino system (in Fritzing)

In this case, user has to push buttons to simulate car entering and exiting parking lots. Led lights change color depending on spot occupancy. This simple system is built to demonstrate, that physical systems and sensors can be replaced by other elements without changing system's functionality and logic. Events from this system are also transferred to previously mentioned remote DCPU.

2 VIRTUAL IMPLEMENTATION OF EDUPARK SYSTEM

Together with physical parking model, also its virtual example is developed to demonstrate, that operation of physical system can be modeled and simulated in virtual environment. Fig. 5 demonstrates system's logical concept and has description of all system elements. User manually can simulate traffic flow at the parking by triggering events via available controls. All simulated events are sent to central DCPU.

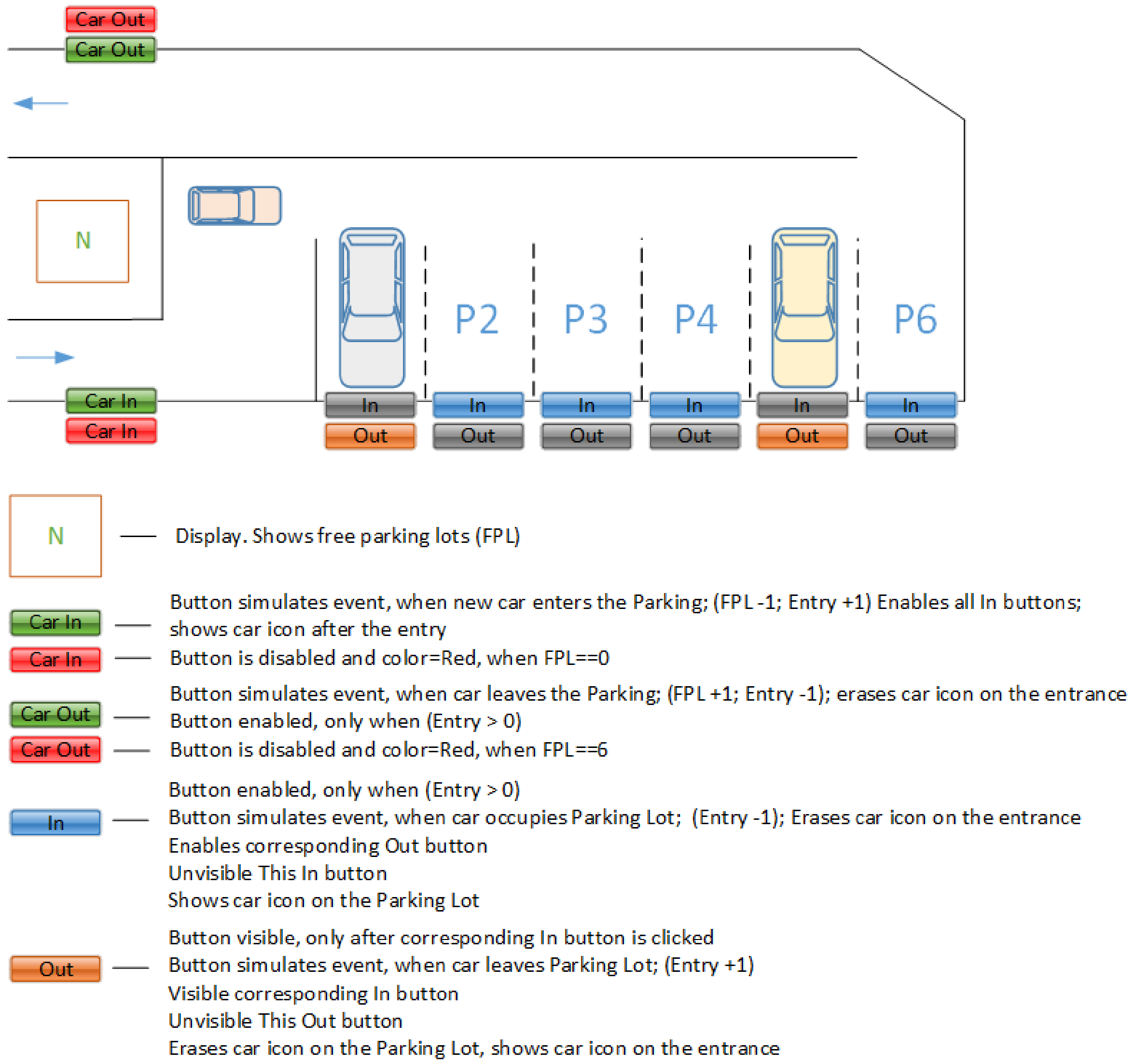

Fig. 5. Schematic view of the developed user interface for parking simulation

Virtual EduPark system is build as single page web application using Angular 2 and Bootstrap 4 frameworks. The system mimics behavior of physical parking system. It maintains state (free and occupied lots) of simulated parking, produces similar parking events and transfers them to DCPU via regular API.

In the future, it is planned to extend this virtual parking system by developing traffic flow simulation. Events will be generated automatically according to user-defined parameters: time interval for a new car arriving to the parking, duration of parking, including random deviations of these parameters. It will demonstrate, that physical model can be simulated fully automatically and synthetic data can be generated for data analysis and parking load prediction model development purposes.

3 DATA COLLECTION AND PROCESSING UNIT OF EDUPARK SYSTEM

Parking event data collection and processing unit (DCPU) is built as separate service providing general API for smart parking systems (like described in section 1 or 2).

Back-end module of DCPU provides API for registering parking system metadata, such as name, description, location, car detection technology, parking lots and other element metadata. API is used for parking event receiving from parking systems. Received data is processed according to defined parking rules, which ensure state consistency. Processing results are available for external systems (e.g. web or mobile applications) via same API.

Back-end module is built using Java technology stack: Spring Boot 1.5 framework as system backbone, MongoDB 3.4 database. Functionality is covered by unit, integration and acceptance tests build using Spock 1.1 framework.

Front-end module provides mobile-ready user interface for parking data visualization.

System shows general information about parking (e.g. description, location), time of last parking event and actual number of free parking lots. System also shows detailed information about parking elements: status of parking entry, exit and each lot (see Fig. 6).

Web system is publicly available at https://parking.science.itf.llu.lv.

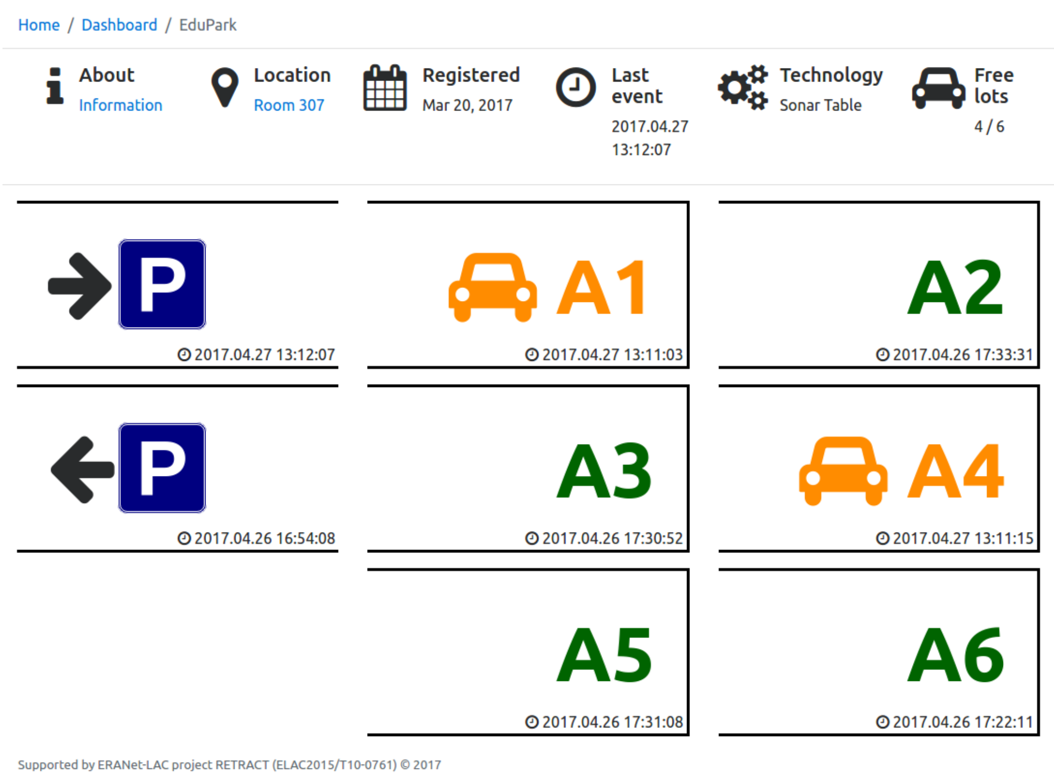

Fig. 6. Screenshot of the web system

Fron-end module is built as single page web application using Angular 2 and Bootstrap 4 frameworks. It uses regular DCPU API for receiving actual data about parking state, which is updated with 1 second interval.

In the future, it is planned to implement additional data analysis features. One of them is control of parking time and billing, which is important for local municipalities and parking service providers. Another is reservation of parking lots, which is convenient for drivers. Third planned feature is advanced parking load reporting and prediction.

4 EDUCATIONAL ASPECT OF EDUPARK

EduPark system can be used to improve engineering educational process. On its basis, complexity of parking problem can be demonstrated. Different sensors for vehicle detection can be studied. To this moment, there are ultrasonic sensors used for vehicle detection, but it is possible to use also other recognition methods, for example inductive sensors. In addition, vehicle recognition can be done by the image processing from video stream.

Students can study Arduino programming basics. In case of need, Arduino can be substituted by any other development platform (for example by Raspberry Pi). On other hand IT tools like databases, web programming, user interface development etc. can be acquired trying to develop and to improve this parking system.

The educational system EduPark is a relatively simple physical parking model, which can be upgraded and improved. In the system sensors can be substituted by buttons, to simulate presence of cars. This approach can be used to test logic of the developed system and give option to manually simulate car flow at the parking. It is possible to add more parking lots, to make more complex parking, divide it into sectors or even create multi-level parking. This will open new possibilities for improving the parking system, like creation of parking guidance system, which will navigate the car driver through the parking.

This system enables also competition of students (making better and faster algorithm, better user interface, better vehicle recognition, etc.) that makes the educational process much more attractive.

This system also can be used as a children playground for playing with toy cars and to see the parking operation. So options for improving and using the EduPark system are limited only by user and target group imagination.

5 SUMMARY

This paper presents authors developed physical mini model of smart parking system. System can be used for educational purposes demonstrating vehicle detectyion using different methods. Developed system is based on Arduino platform, together with ultrasonic sensors. In addition to physical system also virtual implementation of parking model is developed. This allows to substitute physical parking elements, but maintaining the logical functionality of the system.

Authors chosen Arduino platform can be substituted by other electronic platforms, for example Raspberry Pi. Vehicle detection can be done by other techniques, e.g. image processing.

In authors opinion such interactive way of engineering education is very attractive for students, because they can develop models of real systems without any risk. At the same time during the implementation of such systems all respective stages of real system development are maintained.

6 ACKNOWLEDGMENTS

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11.

Engineering Education Research

Curriculum Development in Engineering Education:

Evaluation and Results of the Twente Education Model (TOM)

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ABSTRACT

The University of Twente has designed and implemented a major curriculum innovation in all its bachelor programmes since 2013, the Twente Education Model (TOM). TOM consists of a pre-defined curriculum structure and specific didactic and educational starting points. After three years of implementation, evaluation data from teachers, programme directors, educational specialists and students show that the structural change was successful: all programmes have modules of 15 European Credits (ECTS), designed around a theme. All modules have a project, as was intended, but not all modules are project-led yet. With respect to the didactic starting-points, teachers use a larger variety in innovative learning, teaching and assessment methods. The numbers show that the number of students who get 60 ECTS in their first year has doubled, and the percentage of students who graduate after four years has increased from 53 to 74%. Current challenges for teachers are how to give students more control over their learning process, and how to decrease the number of summative assessments and increase the number of formative feedback moments. The university has been developing the concept of Student-driven Learning, as comprising many of the elements underlying TOM.

Conference Key Areas: Engineering Education Research, Curriculum Development, Attractiveness of Engineering Education

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Keywords: Student-driven Learning (SDL), project-led education, TOM, modules

INTRODUCTION

The University of Twente (UT) in the Netherlands is a research university hosting 19 bachelor programmes, of which 15 engineering programmes. In the programmes, engineering and technology are combined with behavioural and social sciences. Back in 2009-2010, the vice-chancellor of the UT started a process of drastic curriculum development with a small group of deans and programme directors. Guiding questions were: how could we increase the attractiveness of engineering education? What could be the added value of a campus experience, when so many open and online learning resources in engineering education are available for potential learners, which they can access at their own time, pace, and level, and oftentimes for free? This question was the starting-point for developing the Twente Education Model (in Dutch: TOM) that aims for sustainable engineering education. TOM is a rather revolutionary model for the bachelor programmes, combining both a clearly defined structure and specific didactic and educational starting points, needing a drastic (re)development of all curricula. After two years of piloting, all 19 bachelor programmes implemented TOM in their first year, in September 2013.

In this paper, the intended and implemented TOM curriculum are decribed and discussed. Curriculum development is a complex process, including many variables and actions. The authors intend to embrace the full complexity of this process rather than to focus on one singe aspect in that process.

1 THE INTENDED TOM CURRICULUM

1.1 Drivers behind TOM

There are three different types of drivers for TOM. Firstly, back in 2010, the university was working on the *renewal of her profile*. The University of Twente has always strived for an interdisciplinary approach in its teaching and research, aimed at studying contemporary societal problems and developing sustainable solutions. This characteristic has been expressed in the university's phrase *High Tech Human Touch*. It connects to the realisation that, more than gaining knowledge, students need to learn to *develop and use* knowledge at a deep, abstract level, and have to develop a wide range of skills that enable them to transpose expert knowledge to different domains, and to communicate and interact with people from other disciplines, align with general academic, problem-solving, and co-creation skills. Another characteristic of the university has been the focus in the programmes on three different roles, e.g. researcher, designer and organisor. Also, the University of Twente has a history in being entrepreneurial. The new education model should incorporate these elements.

Secondly, as reported by Vossensteyn et al, in the *Dutch education system* roughly 70% of first year students ever graduated, of which 50% within the discipline they started in [1]. For TOM, the ambitions were set that student dropout rates were to be below 30% and students should have at least 20 hours of guided activities (not *per se* classroom teaching) per week in the first year of the curriculum.

Thirdly, over the years, a lot of *educational research* has gone into the question "what makes learning effective?" Based on this research, the following didactical and organisational principles were formulated as guiding principles for TOM:

1. A steady workload is better than 'binge learning' for tests [2];
2. Frequent and adequate feedback helps students adjust learning [3];
3. A variety in teaching methods keep students engaged [4];
4. Community helps students help each other [5];
5. Ambitions must be clear and high, yet realistic [6]; and
6. Teachers work best in teams [7], with minimal regulation [8].

1.2 Clearly defined structure and specific didactic and educational starting points

TOM consists of an identical *predefined curriculum structure* for each bachelor programme, consisting of modules. A module is a full-time educational unit with a duration of 10 weeks, in which all learning goals and content are integrated. Students receive one grade and 15 ECTS upon successful completion of each module. So, there are 4 modules per year, 12 in total. *Fig. 1* shows the structure of the programmes.

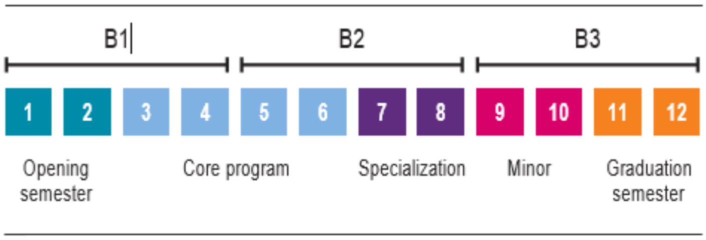


Fig. 1: 12 modules of a bachelor programme

In each module, students work in teams, addressing real-world problems, that are connected to an overarching module teme. *Project-led education* as described by Powell and Weenk [9] was chosen as overarching *didactic approach*, as a way to include the insights from educational research: project work adds a new learning mode to the already existing teaching methods; the project team serves as a community in which students help each other; projects usually keep students engaged, especially when working for external clients; it improves their motivation and helps set a steady workload; Connecting to the university vision, projects are also a vehicle to help students develop an entrepreneurial attitude and explore each of the three roles. During the project, students are being supervised by tutors, who can give them frequent feedback or invite student peers to do so. All module teachers also have to work in a team, to create a coherent module and project.

Whereas the curriculum structure with modules and projects was proposed as a top-down and strict design guideline, programme directors and teachers were given lots of freedom to design their own modules and projects, considering the educational research outcome that 'teachers work best in teams with minimal regulation'.

2 RESEARCH APPROACH

The implemented and attained curriculum of TOM have been investigated through four methods. These have been summarized in

Table 1. Note that, whereas the questions have been the same for the implemented curriculum over years, the method or the respondent group has changed. This was a result of finding an optimal fit between the goal of the evaluation and the time investment it needed from the respondents.

Table 1. Research Methods used to evaluate TOM

What	Method
Teacher perspectives on the realisation of TOM in the module designs	Semi-structured interviews (2013) and questionnaires (from 2014) using a Maturity Model, which forecasts the transformational change of the bachelor programmes in 5 aspects from the TOM vision and its operation on a module level: character; educational culture; organisation; project and integration; and assessment [10]. Each aspects is described in five subsequent 'maturation' or 'growth' stages.
Teacher experiences with design and implementation	Formal and informal meetings with module teams (2013-2014) and with programme coordinators and educational advisors working in the departments (2014-2016), on *success stories of TOM* and on *issues/challenges* they were facing.
Student experiences	Digital Student Experience Questionnaire, on organisation; perceived learning effect; integration; assessment; time investment; and overall appreciation.
Numbers of enrollment, dropp-outs, pass/fail	University systems registrate student grades on tests. They also register the amount of students enrolling and dropping out during the modules. Over the years, these numbers add up to a good overview of the output rates of the individual programmes.

3 RESULTS

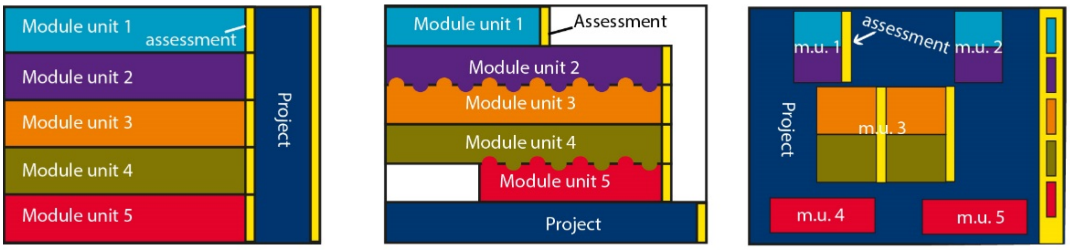
3.1 Implementation of the organisational structure

Overall, the evaluation data show that the organisational change of TOM, e.g. the module structure, was very successful. Here, the implemented curriculum meets the intended curriculum. All programmes have a fixed curriculum structure, consisting of twelve modules of 15 ECTS (see https://www.utwente.nl/en/tom/modulemap/). It can also be concluded that all modules have been designed around a theme, ánd do have a project. This is in the opinion of the authors due to the fact that the University Board proposed this as a top-down and strict design guideline, and has managed to get every programme director on board.

3.2 Implementation of Project-led Education

In many modules the project is, however, not yet the *dominant* part of the module. The freedom given to programme directors and teachers to make their own designs has consequently resulted in a variety of types of modules (see Fig. 2). All variations have pro's and con's for the teachers and the students. The first type of module mostly reflects a traditional programme, where the module units reflect separate courses, which are all being tested separately. The picture in the middle reflects a module with several subjects that are more evidently connected to and intertwined with each other. In the latter picture, the project is put central, and the module units are clustered around the project. Some of the module units are tested separately, others have no test; the learning is tested through the project deliverables. In recent sessions with 10 students from different programs, they estimated that about 50% of the modules are of type 2 or 3, but no formal data have been gathered yet.

Results of the interviews and questionnaires with teachers show that the modules are project-based, but that not all of them are project-led yet (See *Fig. 3*). Only when the module has been developed with the project as the core, full integration between module parts can be accomplished. Some coordinators perceive their module as one project, while others think the project is an extra element, that exists next to the other module parts. In some modules, students apply their knowledge in the project, but in other modules they gain new knowledge and skills as was intended.

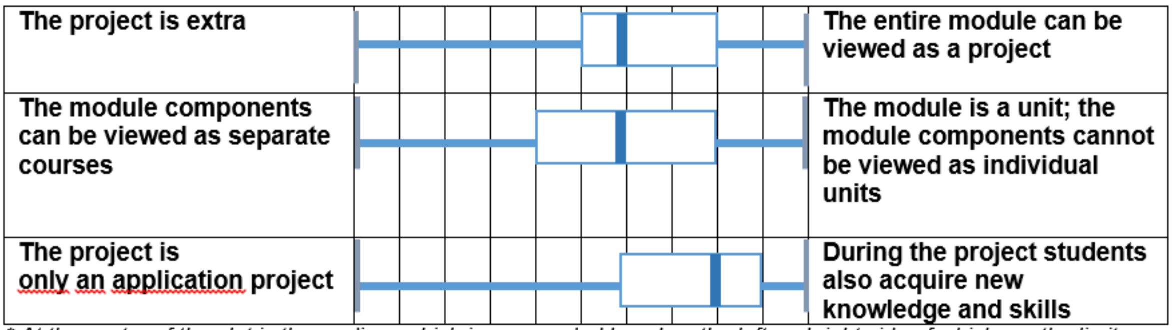


Module in which seperate theoretical module units are applied in the project and tested separately

Module in which seperate module units are applied in the project and tested separately. One or more units are connected with each other

Module in which the module is one large course in project setting and a variety of educational activities are offered. They are tested integrally

Fig. 2: Module variations



** At the centre of the plot is the median, which is surrounded by a box the left and right side of which are the limits within which the middle 50% of observations fall. Sticking out of the box are two whiskers which extend to the most and least extreme scores respectively.*

Fig. 3: Box plots of scores on the Maturity Model for projects, for all modules

3.3 Implementation of the three roles

With respect to the content of the projects, it can be concluded that all three roles (designer, researcher and organisor) are present in all programmes, but evidently not in an equal way, depending on the nature of the programmes. For example, the engineering programmes have a larger focus on the role of design, supported by research and organisation, whereas the science programmes have a larger focus on research.

3.4 Implementation of the didactic and educational starting-points

With respect to the didactic and educational starting points, there is great variation. Compared to the results of pre-TOM SEQs, TOM has made students work much harder than pre-TOM students. Whereas a considerable part of the pre-TOM students could report a *study load* of only10-20 hours per week, TOM students report a study load of over 30 hours per week, adding up to over 50 (2013: 30-40 hrs: 27%; 40-50 hrs: 38%; >50 hrs: 17%; 2014: 30-40 hrs: 41%; 40-50: 25%; >50 hrs: 6%). Also, the workload has been spread more steadily over the modules.

According to the self-assessment of the module teams in 2013-2014, assessment seemed to be the biggest educational challenge in TOM. It seems that one of the drivers behind the TOM-model “*frequent and adequate feedback* helps students adjust their learning" had stimulated teachers to implement summative tests on a very regular basis, instead of diagnostic assessments or teacher or peer feedback moments that are not graded. To verify this finding, in 2014-2015 the number of assessments were counted in modules from quartiles 3 and 4. Although differences existed among modules, the UT was unhappily surprised to see that the implementation of TOM resulted in so many tests for students: Only 5 modules had 5 tests or less; 16 modules had between 10-15 tests, and 2 modules had even more than 20 tests.

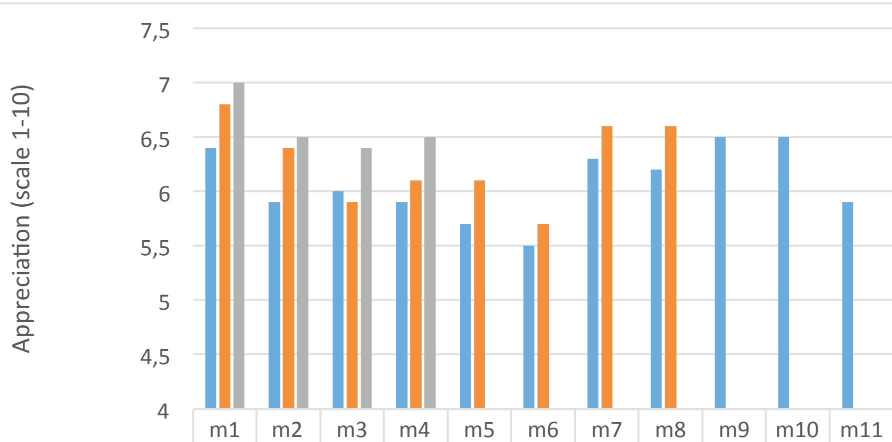
Teaching staff has increasingly realised that, although the implementation of a regular number of tests helps realise a steady study pace (see 3.4), it also likely leads to surface learning, from test to test. This insight is gradually beginning to pay off: based on analyses of the module guides and informal meeting results, the evaluators see there are less summative tests, and an increased focus on other methods to provide feedback, such as formative teacher feedback, peer feedback, use of quizzes, oral feedback in tutor groups, etc.

Accordingly, the evaluation data also show a *variety in innovative learning and teaching methods*. Teachers are, for instance, experimenting with voting tools, flipping the classroom or peer feedback; they also experiment with the amount to which they can have students influence their own learning process. With respect to *community*, students indicate to value learning and working with peers. More than 75% of the students stated to have developed specific skills through working together in projects. Several programme directors and tutors are pleasantly surprised and have indicated that first year TOM students are already better in collaboration and working in projects than students from the traditional curriculum in later years. Thus, the increase in (innovative) teacher activities, the increased amount of feedback, as well as the increased work load for students seem to be paying off.

3.5 Teacher teams

Teachers report that it is rather difficult yet very worthwhile to work in teams. They have different interpretations of educational concepts and different visions on learning, which they need to align in order to build a coherent module. High workload has been reported consistently over years, due to communication and time for alignment. The research work of Bron shows what are effective ways for module teams to meet, communicate, and learn together [11].

3.6 Overall student appreciation



	m1	m2	m3	m4	m5	m6	m7	m8	m9	m10	m11
cohort2013	6,4	5,9	6	5,9	5,7	5,5	6,3	6,2	6,5	6,5	5,9
cohort2014	6,8	6,4	5,9	6,1	6,1	5,7	6,6	6,6			
cohort2015	7	6,5	6,4	6,5							

Fig. 4: Overall Student appreciation per module

Figure 4 shows that the overall student appreciation for the modules rises over the years, usually with .3 of .4 points. The overall mean score for modules offered for the first time is around 6. Later, these scores raise up to around 6.4 to 7. Mainly because teacher teams continuously improve their modules based on the evaluations. The standard deviation varies between 1.30 and 2.00, both on university and on module level, showing that the variance among the students is high.

Further analysis of the data of module 1 in 2013-2014 shows that the items that correlate strongly (r>0.5) with student appreciation are mostly on organisational aspects:
- During the module I continuously knew what was expected of me (r=0,77)
- The module was well organized (r=0,57)
- In general, the amount of study time I had to put in was doable (r=0,67)
- The module was put together logically (r=0,62)

3.7 Study success

The proportion of students of cohort 2015 that obtained 60 ECTS in the first year has doubled compared to 2010 (53% in 2015 versus 26% in 2010; see Figure 5). Another promising finding is that the bachelor success rate from cohort 2008 onwards shows an upward trend (see fig 6). 50% Of the re-enrolled students of the first TOM cohort 2013 completed the educational programme within the nominal study period (in 2008: 17%). 74% Of the students who re-enrolled in cohort 2012 graduated at the UT within four years (in 2008: 53%).

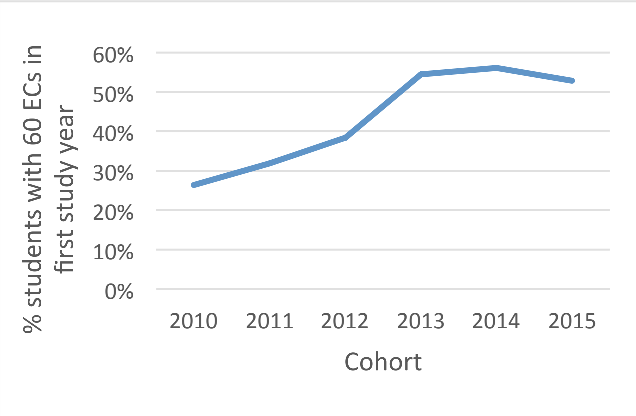


Fig. 5: Study success rate in first study year

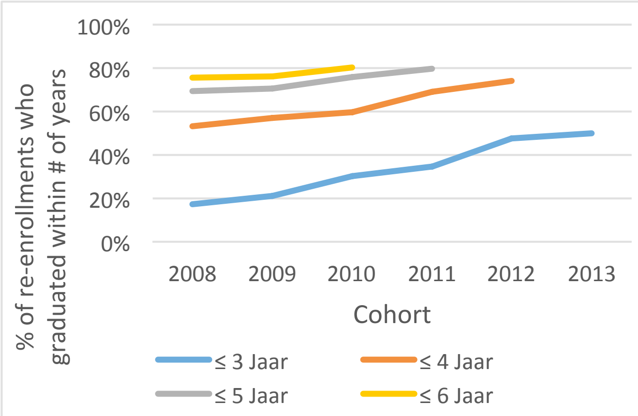


Fig. 6: Bachelor succes rate per cohort (re-enrollments)

4 DISCUSSION

In the previous sections it was shown that the overall numbers are meeting the expectations. Looking at the curriculum, the module structure has been implemented well. In sum, it can be said that on an overall level the university is well underway to reach the TOM vision. The intended steady study loads for students -compared to the much lower reported study loads by pre-TOM-students- have gone up. At the same time, students judge their study time as 'doable'. Accordingy, study success rates have gone up, which is a likely result of teachers paying more or better attention to students, and students working harder than in pre-TOM.
At the same time, there are differences between the intended and implemented curriculum. With many people involved in this complex innovation, there are multiple interpretations of educational concepts. But there is also a continuous maturing of the intentions based on the experiences with the implementation. What has become clear, is that the deliberate absence of regulation with respect to educational

guidelines has been a struggle for many teachers. Teachers tend to develop a teaching style that closely mirrors the way they were taught themselves (Biggs in Gossman (2008) [12]. Since the TOM concept reflects more innovative teachings styles, teachers need more training and support than given thus far.
Some module teams struggle with intrinsically motivating their students and offering formative instead of summative assessments, leading to students focusing on the short term assessments with possibly surface learning as a result. This corresponds to Biggs' findings that teachers who see teaching as knowledge transmission create classrooms where students score very low on the deep approach, while teachers who see teaching as facilitating student learning create classrooms where students score very low on a surface approach [13].

Since the start of TOM, it has increasingly been expressed that the UT wants to educate and encourage students to become professionals who are capable of steering their own career development, by giving them greater control over their own learning process. This notion of students managing their own learning process is embodied in the concept of '*Student-Driven Learning' (SDL)*. Although this concept is based on proven theories, including self-determined learning, SDL is a relatively new term, one which the UT is eager to adopt and implement, since it comprises many of the elements that were underlying TOM. It can be described as the curricular foundation which supports and encourages students to develop self-determination and the "willpower" to steer their own academic progress. It allows students to regulate their learning, and to adapt their behaviour to correspond with their chosen goals and values [14]. Throughout the academic programme, students will learn how to be accountable for their studies with proper guidance. This aims to activate the intrinsic motivation of the students, who are eager to learn themselves and work with peer students, and the teachers. The SDL programme thus requires students to undergo a mind shift from being a "following" student (Teacher-Centred Learning), to becoming a student -and later a professional- who, ultimately, is able to learn entirely in a self-directed manner (Self-Determined Learning) as befits the concept of lifelong learning [15]. We are fully committed to help teachers implement this concept in their curricula, through training, advices, good examples, and practices.

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Two-year colleges:
Motivational factors among older engineering students

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ABSTRACT

Two-year technological colleges provide learning opportunities for students from the socio-economic periphery or students with a relatively low level of achievement. This study quantitatively examined the factors driving older students to study electronics at a leading two-year college in Israel. Sixteen older students participated in the study. The students completed an anonymous close-ended questionnaire, based on the *SRQ–A* and the *SIMS* scales. The findings indicate that the older students are primarily driven by interest in the studies (intrinsic motivation) and by recognising their inherent value (identified regulation). However, an additional factor with a notable weight is external regulation, according to which, some of the students are studying electronics for lack of another choice.

Conference Key Areas: Engineering education research, Attractiveness of engineering education, Gender and diversity

Keywords: Electrical engineering education, Two-year colleges, Motivation, Older students

INTRODUCTION

Two-year technological colleges offer practical engineering training, allowing their graduates to directly integrate into various industrial fields, such as electronics, bio-technology, and mechanical engineering. Both in the United States and Israel, students at these colleges often belong to disadvantaged groups, or are with relatively low academic ability [1].

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In Israel, there are two educational frameworks for studying towards a practical engineering degree: the first is for younger students, who continue to post-secondary studies directly from high school, and the second is for older students, who have taken some time out from their schooling. In this paper, we focus on the latter track, supervised by the Israeli Ministry of Economy and Industry.

Nowadays, there is a severe lack of two-year college graduates in Israel, especially in the field of electronics. This lack partially originates from the decrease in the number of those expressing an interest in studying at two-year technological colleges [2]. The literature, however, is meagre [1] and mainly deals with specific pedagogical aspects relevant to engineering students at Israeli two-year colleges [3-4].

The aim of the research was to investigate the motivational factors driving older students to study electronics at a two-year college.

1 THEORETICAL BACKGROUND

Motivation refers to a person's will to invest resources in a certain activity, even when it involves difficulties. Self-determination theory [5-6], which is currently one of the leading motivation theories and has constituted the theoretical framework for many studies in engineering education (e.g., [7-10]), served as the theoretical framework for this research.

The theory argues that the factors motivating an individual's behaviour are suited on a continuum. Intrinsic motivation, originating from the interest and pleasure an individual derives from the behaviour is positioned at one end of the spectrum, while extrinsic motivation is suited at the other pole of the continuum.

Extrinsic motivation includes various types of regulation; the most important ones are described below:

- Identified regulation which results from the identification of a value (other than interest and pleasure) involved in the behaviour.
- Introjected regulation which stems from the desire to fulfil the expectations of important people to the person or from considerations of personal prestige.
- External regulation which originates from the desire to receive a reward for the behaviour, or alternatively, from the fear of punishment.

The primary motivational factors are shown in *Fig. 1*.

According to self-determination theory [5-6], the more intrinsic the sources of the motivational factors – the higher the quality of a person's motivation. The theory claims that supporting an individual's three innate needs fosters high-quality motivation. These basic needs are:

- Autonomy – feeling a person's behaviour was not imposed on him/her.
- Competence – feeling a person is able to fulfil challenging objectives.
- Relatedness – being accepted and be part of a group.

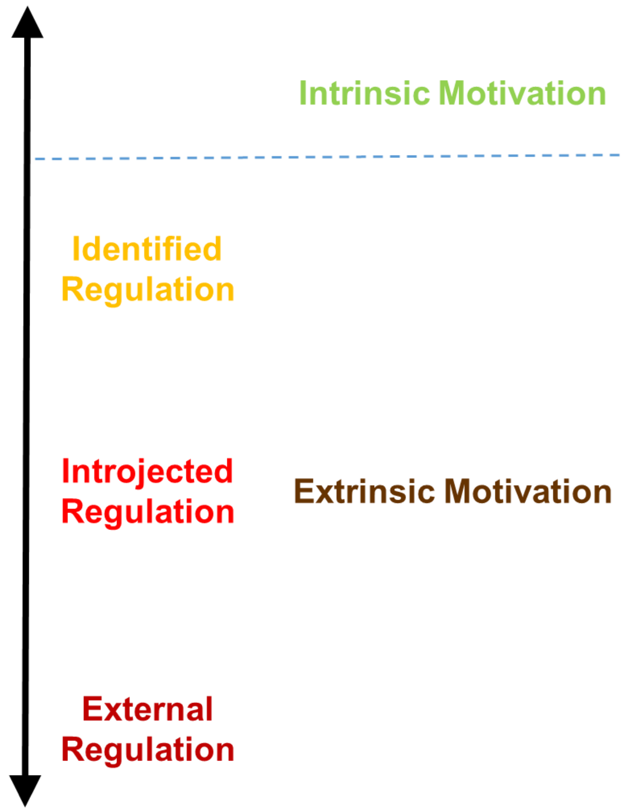

Fig. 1. Primary motivational factors

2 RESEARCH GOAL AND METHODOLOGY

The aim of the study was to examine the factors motivating older students to study electronics at a two-year college.

Sixteen second-year older students at a leading two-year technological college in Israel took part in the study. These students were studying electronics in a programme supervised by the Ministry of Economy and Industry, mentioned above.

The students completed an anonymous close-ended questionnaire. This five-point Likert-like questionnaire, ranging from “strongly disagree” to “strongly agree”, was based on the *SRQ–A* (Self-Regulation Questionnaire – Academic) [11] and the *SIMS* (Situational Motivation Scale) scales [12]. The questionnaire included twenty statements which reflected the four major motivational factors, as defined by self-determination theory. Examples are given in *Table 1*.

The statements were validated by two experts in engineering education. Cronbach’s alphas show good internal consistency, as indicated below: 0.84 (intrinsic motivation), 0.80 (identified regulation), 0.78 (introjected regulation), and 0.86 (external regulation).

Table 1. Questionnaire statements: Examples

Motivation	Regulation	Statement
Intrinsic		I am studying electronics because I think the studies are interesting
Extrinsic	Identified	I am studying electronics because I think working in electronics would be a good job for me
	Introjected	I am studying electronics because my friends are studying electronics I am studying electronics because I want people to think I am smart
	External	I am studying electronics because I do not have a choice

3 FINDINGS

The analysis reveals that students are primarily motivated by intrinsic motivation (M=76.88; SD=10.78, where the mean score M is between 20 and 100) and identified regulation (M=68.93; SD=11.89). External regulation is in the third place (M=47.08; SD=17.46) and introjected regulation is the less important factor (M=41.25; SD=12.58).

A comparison to the motivational factors among sophomore electrical engineering students from a leading university in Israel [13], shown in *Fig. 2*, indicates a significant difference (p<0.05) between the two groups in relation to external regulation. This gap, in favour of the first, is characterised by a medium-large effect size (d=0.62).

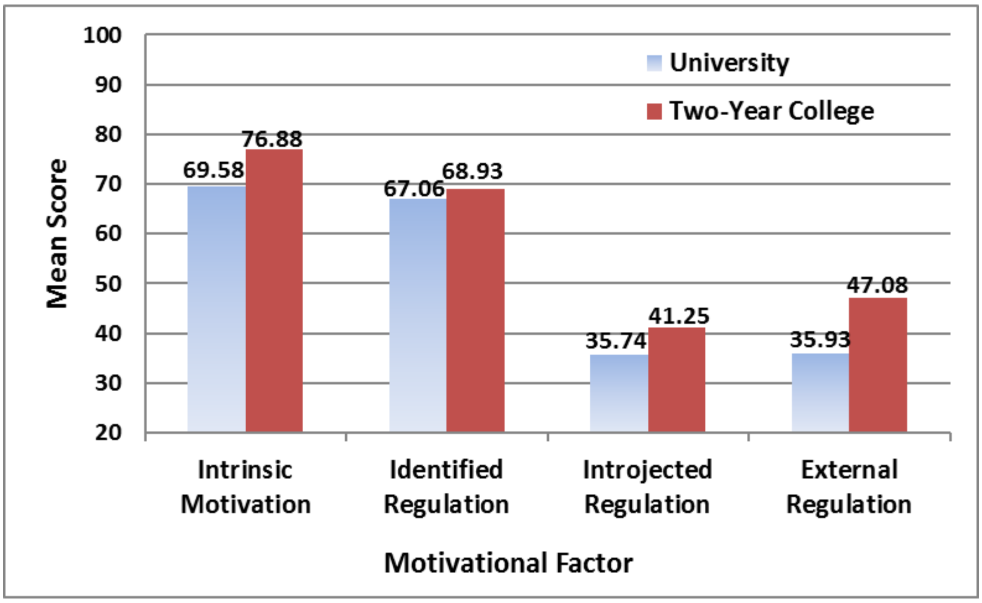

Fig. 2. Motivational factors: Mean score

4 DISCUSSION AND SUMMARY

Two-year technological colleges provide learning opportunities for students from the socio-economic periphery or students with a relatively low level of achievement. This study quantitatively examined the factors motivating older students to study electronics at a leading two-year college in Israel.

According to the findings, older electronics students at the two-year college are motivated by interest in the studies (intrinsic motivation) and by recognising their inherent value (identified regulation). An additional factor with a considerable weight is external regulation, according to which, some of the students study electronics for lack of any other option. The significant gap between the university students and the two-year college students in relation to this motivational factor may indicate that the needs for autonomy, competence, and relatedness are only partially met at the technological college.

To the best of the authors' knowledge, the study described in this article was the first to investigate the motivational factors for studying electronics in older students at two-year colleges. Beyond this theoretical contribution to the meagre body of knowledge on the subject, these results could contribute to the recognition of problems inherent to this course of study and to finding ways to increase its attractiveness both in Israel and in other countries that have a tertiary technological education system.

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Team Teaching Experiences in Engineering Education
A Project-Based Learning Approach

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ABSTRACT

As a part of the new Curriculum development, teaching and learning methods were piloted in the ICT department during the past years. The aim for this study was to find out how teaching and learning are changed with relation to traditional higher education. According to the results the team teaching will be adopted to the whole organization.

The new Curriculum is based on 30 ECTS credits semester projects due to results of piloting other options as well. Learning projects are based on an agreement with either local industry or University's R&D&I projects. Eight (8) semesters were designed by named teacher teams who will also implement the future projects. Each team was comprised of professors from various fields.

In this research team-teaching was found to give better learning results and enlarge teachers' know-how. Team-teaching and project based learning (PBL) give more opportunities to develop industrial cooperation and makes easier for students to get a professional job after graduation. As measurable values the student satisfaction factor has raised as well as the total number of credit points students have completed annually.

Conference Key Areas: Curriculum Development

Keywords: Team Teaching, Integrated Curriculum

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INTRODUCTION

The Development of the New Curriculum 2017 in Lapland University of Applied Sciences is based on the process which was started when the decision to merge two independent Universities of Applied Sciences, Rovaniemi and Kemi-Tornio, was done. The merging of these two Universities was realized on 1st January 2014. Both universities had same faculties and the overlapping in fields of studies caused a pressure to harmonize curriculas as much as possible.

The Ministry of Education in Finland is measuring the effectiveness of teaching in Universities by key figures e.g. completion percentage, the number of students who have completed at least 55 ECTS annually and statistics of the annual feedback of students. This is due to performance-based funding. To meet these key figures has been demanding especially in the ICT education. It was obvious that the new pedagogical tools were needed. Lapland UAS started the new curriculum development process and the degree program of ICT was a forerunner to pilot new learning methods.

This paper discusses the introduction of developing new curriculum based on PBL and piloting it with different student groups and organizing learning by teacher teams. The data includes quantitative as well as qualitative information that was collected from students and teachers during and after each pilot. At first paper introduces the idea of project based curriculum and how semester projects were developed using collaborative teacher teams. Second, the planning and implementation of the reformed curriculum is explained. Third, the results of pilots collected from different student teams and teacher interviews are analyzed. Finally, conclusions for further research and development are presented.

1 CURRICULUM STRUCTURE

1.1 Semester Projects

The core of each semester is a learning and/or problem solving project which is supported by the other courses of the semester. The subject matters of the courses are integrated to the project, and build upon the know-how intended for the semester along with the project.

The Project competence of students evolves along with studies on these semester long projects. These projects are large entities that combine all the subjects of the semester into an entity that provides a concrete end result as shown in *Fig*. 1. More detailed description of the structure of the seasonal projects with some examples can be found in the reference [1]. For students learning general principles of project management and team skills necessary to accomplish a common goal are the primary goals of the first year. Second year is to acquaint students with Agile methods in a project management context. The third year focuses on advanced project management skills, quality assurance and working in a customer interface. These project studies prepare the students for acting as a project manager and taking responsibility in large information systems' development projects.

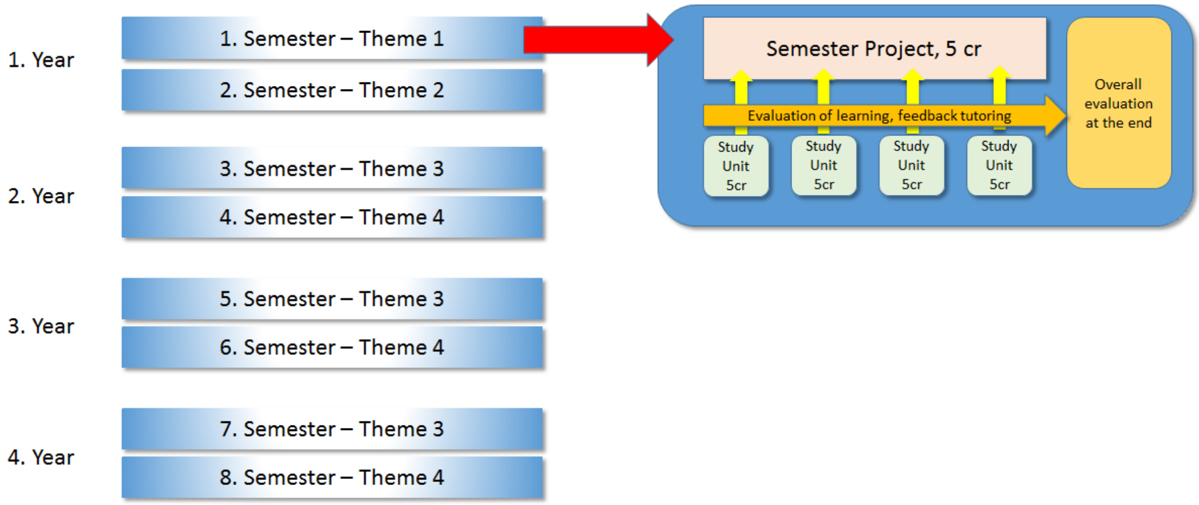

Fig 1. Fundamentals of the Semester Structure in Curriculum

2 SEMESTER PLANNING AND IMPLEMENTATION

2.1 Planning phase

The semester planning process starts by getting the customers representatives and a team of teachers around the same table. The teacher team consist of teachers who will have their courses during the semester. The number of teachers is usually 5-6. An example of annual operating plan is illustrated in *Fig*. 2.

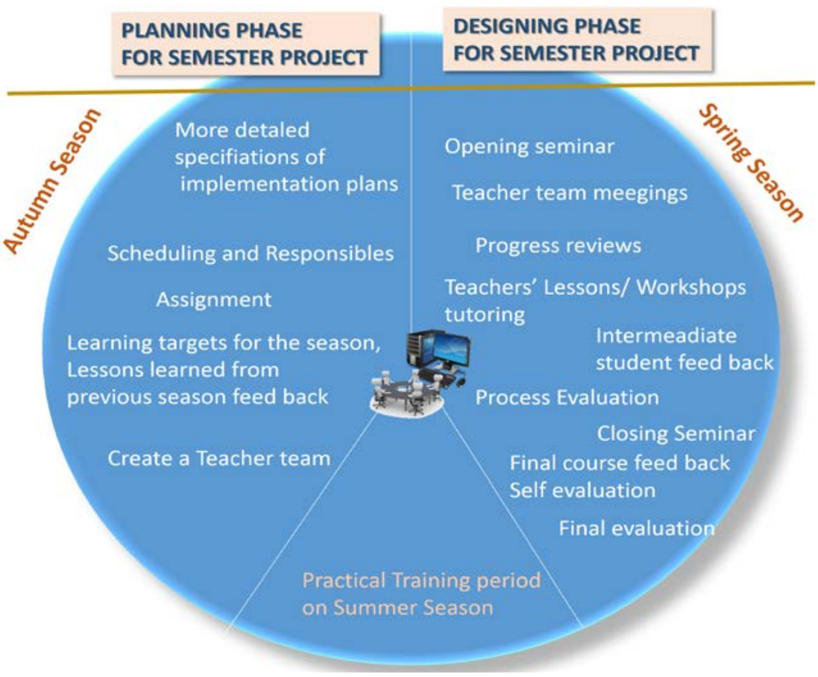

Fig. 2. The Annual Operating Plan example

The learning targets of the season and the courses are gathered and gone over by the teacher team. After that an assignment for completing the learning targets is constructed. The end result is the first draft of the assignment for students.

The assignment is deconstructed in a way that in each course the elements that support the project are defined and listed. Some decisions about the interconnected subject matters of the courses may have to be made. The end result is a list of courses and the subject matters that support the project.

The organization model is chosen for the learning project, for example a generic project management and implementation model or one of the agile methods, e.g. SCRUM. SCRUM method is widely used in the other Universities as well. For example, University of Århus, Denmark, is using it in teaching according to reference [2]. The teacher team makes decisions on, among other things, the times to start and end, the amount of mutual reviews, ways of guidance, etc. The timing for each of the courses that support the project is defined. The end result is a table shown in a *Fig. 3* that indicates the timing of the courses of the semester. The table helps to manage and understand the outline of the project as well as to calculate the weekly load of the students. The information from the Excel table is moved to SoleOPS resource management system.

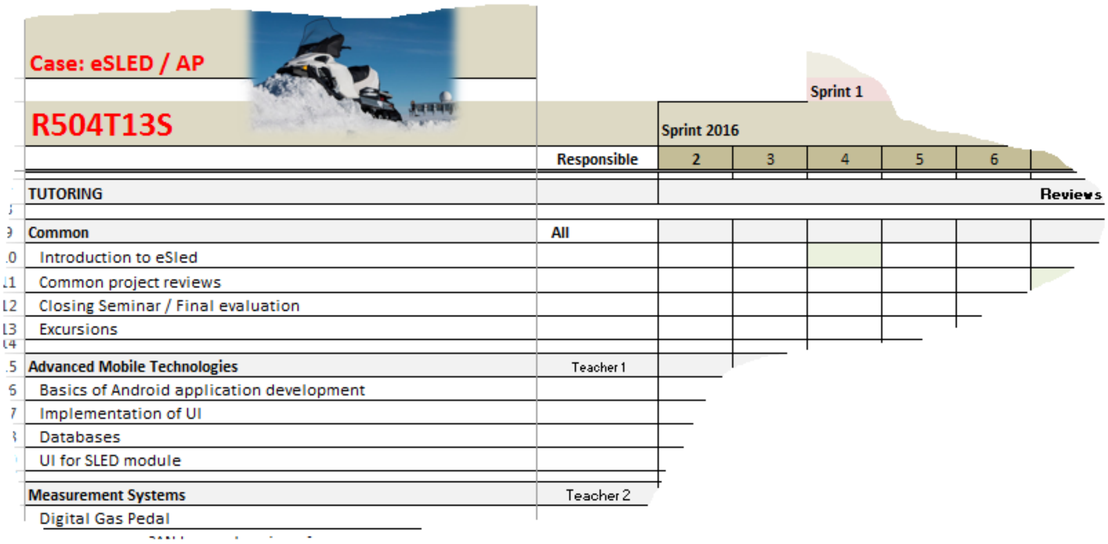

Fig. 3. An Example of the scheduling chart of one semester

2.2 Implementation phase

The teacher team have meetings on a regular basis with representatives of customers. In these meetings the progress, the status and procedures of the project groups are reviewed. The teacher team itself operates according to the methods of project management.

The progress reviews of the project groups are events that are scheduled already at the planning phase. In the review each project group pitch the team's current results. In the event the status of the project managing is evaluated as well. The teacher team gives the feedback and guides the groups in technical problems and in the project implementation process itself. At the end of the review day the teacher team continue with a meeting where subjects that have come up are discussed. Also if a more detailed help is needed the responsibilities are agreed and some team and individual assessment is done. If there have emerged any possible problem areas in the student teams, teachers can intervene early enough. Virtual learning environments, like Moodle and iLinc, are used during these learning projects for support and documentation.

During the process there are varying amount of teaching moments that support the implementation of the project in the allocated courses in forms of laboratory and workshop exercises, and lectures. The contents of these moments are decided in the planning process by the teacher team. Part of the problems in the project may be unforeseen and in these cases each teacher tries to bring their ad hoc support to the project. A workspace is provided to the students where they can act to complete the project when the opportunity rises during the working week. The teacher team aspires to be available in problem situations and tries at the very least to cheer on the students in the projects.

The season finale is a coordinated closure which is made to be as grandiose as possible. Exhibitions aimed to a large audience – at least to other students – are a great way to achieve this. The final event of semester is prepared meticulously and all exhibition goods must be made ready beforehand. The awareness of the exhibition creates a right amount of creative pressure for the whole season. According to [3] teams are able to generate lot of new ideas, but if they do not operate in the proper environment, which affords them a supportive and participative context with excellence of task performance, team creativity will not be translated to innovation implementation. The teacher team assesses the finished project in the event, where all of the results of the courses that are integrated to a one big entirety. The finale ends for the teachers in a final evaluation. The evaluation can naturally include course related subjects that are not included to the project, but the shared subjects are evaluated together.

3 RESULTS

3.1 Statistics

During the curriculum development process required quality statistics were gathered during three years. As mentioned in the Introduction the key figures e.g completion percentage, the number of students who have completed over 55 ECTS and statistics of annual feedback of students has been collected either yearly basis or at the end of each course and project to get information for further progress.

Table 1. Over 55 ECTS achieved students

Group	The amount of Students	>55 ECTS (%)
T12	15	14
T13	25	64
T14	32	47
T15	41	88

The information in the *Table 1*. shows how the percentage of achieved ECTS have varied between three student groups in the pilots. The group T12 studied with the traditional curriculum; groups T13, T14 and T15 had PBL based Curriculums. The pilot shows significant difference in the achieved ECTS. For the group T14 were made a test without a semester project and the result was immediate as seen in the *Table 1*, which was also found out in the student feedback.

The Student feedback is collected according to *Table 2*.

Table 2. Student feedback (scale 1…7).

The Feedback Subject	ICT Department (all groups)	University (total)
CONTENT AND IMPLEMENTATION OF STUDIES	5,18	4,80
STUDYING AND STUDENT SUPPORT SERVICES	5,40	5,12
GUIDANCE IN STUDYING AND LEARNING	5,17	4,69
COLLABORATION WITH WORKING LIFE	4,37	4,59
DEVELOPMENT OF COMPETENCE	5,18	5,21
SATISFACTION WITH LAPLAND UAS	5,42	5,05

Behind the average figures in the *Table* 2. there are more detailed yearly based numbers that shows also the effect of the new PBL based curriculum.

Compared to the older statistics the continuous improvement have been achieved, but there is still work to do. Even though most of the results are above the university average there is for example the “Collaboration with working life” that has arisen some questions. One answer to this question was found from the written feedback and discussions with students: Although learning projects were industry based and there were real customers, all students didn’t realize this as a collaboration with working life.

Students’ free written feedback gives also good information in further development. Student feedback experiences has been similar in [4], especially they found out significant improvement in the student progression.

3.2 Experiences

The new project based Curriculum has shown it's effectiveness during the pilots with different student groups. Projects are real life projects either from local companies or R&D-projects with other stakeholders. The suitable courses are integrated to the project and learning is done according to the same rules as in working life in real companies and projects.

Teachers are not working alone and more effort and time have to be used for the semester project planning. This brings also the company representatives closer to the university while they are also invited to the planning phase and to visit or give the information to students' "companies" that are working with the project. Teacher experiences are shown in *Table* 3.

Table 3. Teacher feedback.

To be noticed	Was worth to
Everything to the master time table	Working together is nice and fun
Meaning of the preplanning phase is significant	Very instructive
First time very challenging, repetition makes it easier	Not bored
Evaluation is worth to complete together in the teacher team if possible	Problem solving together makes it easier
Planning phase should be started as early as possible	The joint assessment will support your own decisions
Reviews takes some time from the "ancient" one-way lectures in resource planning	The project team of students carry each other
Suitable and accessible space is required for self-oriented project workshops	Better completion percentage
Physical location of the teacher team as close to workshops as possible	Continuous learning
Teacher team located very close to each other to ensure the open communication	
The beginning is always difficult	
New culture requires change in attitude, others are slower than the others	
Project management and teamwork skills are required	

The results are satisfactory and very similar to described in reference [5]. The change is required not just as a form of new curriculas but in attitudes and management support (leadership). The final completion percentage can't be measured yet, it'll be possible earliest at year 2018.

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Tipping your toe in the 'Emerging Technologies' pond from an educational point of view

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ABSTRACT

This paper is about an explorative research into the use of emerging technologies in higher engineering education. New technologies are poised to better prepare students for the labour market and therefore help to endow vital innovative and creative skills. It is not yet fully clear what these skills are, but technological innovations are a good indicator of what to expect. Emerging technologies are technologies not yet widely adopted like there are 3D printing, Virtual Reality and Internet of Things. The diversity and the complexity of these technologies require a better understanding to decide about the value of such technologies for education. The research aims at the development of an approach that will help teachers to investigate, test, and assess the usability of such a technology in their micro-environment of teaching and learning.
This explorative research comprises an examination of the current use and experiences in education and the industry, an indebt analysis of some of the technologies and some small-scale experiments concerning the use of such technologies in daily educational practice. The paper summarizes the research results

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so far. Notably education is challenged to acquire an active role in assessing the usability and maximizing the opportunities of these technologies.

Conference Key Areas: Open and Online Engineering Education, Engineering Education Research, Continuing Education and Lifelong Learning

Keywords: Emerging technologies, Education, Virtual reality, Internet of Things

INTRODUCTION

This paper deals with an explorative research into the use of emerging technologies to better understand the possibilities and limitations of these technologies for teaching and learning. Technology has changed society, but not yet fundamentally transformed education. It is expected that the next generation of technologies will affect education more profoundly, also because of the massive integration of these technologies in our society at large [1]. In line with this development is the changing demand on the labor market for skills that are significantly different from what it used to be. Engineering education has been rather reluctant in using new technologies to improve their performance. The one argument has been that we do not know yet what the skills of the future will be. With the latest findings education cannot continue to say that this is a world we do not know yet [1], [2], [3]. A proactive approach is needed to figure out if and how these emerging technologies can be applied to modernize curricula and, thus, to better prepare education for their tasks and students for the labor market [4].
Emerging technologies are recent developments not yet widely adopted, but expected to influence educational practices. They tend to be in a dynamic state of change and will most likely be further developed and refined, [2], [5]. Because of the complexity, it is crucial to have a certain level of understanding to judge if a technology might help or not. This judgement is very much related to the micro-environment of the teacher who should be able to investigate, test, and assess the usability of a technology.
The first part of the paper zooms in on current knowledge and experiences derived by desk research and interviews. The following part is about a more indebt analysis of two emerging technologies: Virtual Reality (VR) and the Internet of Things (IoT), which are expected to have a profound impact on education in the years to come.

1 RESEARCH CONTEXT

1.1 Problem statement

Engineering education needs to explore the potential relevance of emerging technologies and emerging practices for teaching and learning, because these have an important role in making education more innovative and productive [2]. Therefor a better understanding is needed of what these technologies can do for education. This is a rather difficult question, because the decision on the usability of a technology or tool is being hampered by the increasing number of different emerging technologies, the speed of development, the multitude of educational settings and the time it takes to research all this, [6]. This is why teachers, educators and institutions have a hard time to develop a strategy to select and apply technologies [2].

1.2 Research focus

The purpose of this explorative research is to take a closer look at this problem, capture experiences in higher education and the industry, identify the added value for the learning process and identify what strategy might be of use. This exploration very much

looks at the micro-environment in which students and teachers are confronted with the question about the usability of these technologies. This is an ongoing research with findings from desk research and interviews and some small-scale hands-on experiments, which are half way through at the time of writing.
With emerging technologies, teachers are confronted with an unpredictable lifecycle of an application, implications for course redesign and the need to acquire new skills. This may eventually trigger a further reframing of the role of the teacher when these technologies proof to be of value [3].

2 LITERATURE REVIEW

2.1 Emerging technologies and education

Emerging technologies are technologies not yet widely adopted, but expected to influence educational practices in the years to come. These technologies like 3D printing, the Internet of Things, Virtual Reality, Makerspace, Learning Analytics, etc., are in a dynamic state of change, continuously refined and developed, but also can become obsolete with regard to new developments. In short, their state is rather unpredictable which makes it difficult to grasp the value for education [3], [5]. In addition, the diversity of educational contexts and settings and the different methodologies make it difficult to identify clear and specific implications for educational practices. Reference [5] claims that we do not have the tools yet to understand the implications of these technologies on educational practices, teaching, learning, and institutions, because it has not been researched yet.
Technology use in daily practice and in education show a multitude of technologies and applications with the overly linked patterns of usage making it difficult to decide about the specific contribution for education. The literacies needed to understand the rationale and limitations, makes appropriate and timely usage and research in this area rather complicated. In addition, the concepts and instruments used in most current educational research are not necessarily the appropriate instruments to assess the value of new technologies in new and different teaching and learning practices, [8]. Research obviously is struggling with this new complexity.
In the next two sections, we zoom in on the findings of two promising emerging technologies being virtual reality (VR) and the internet of Things (IoT). The goal is to bring the discussion closer to the interest of the main stakeholders, being the triangle student - teacher – organization and discover what these technologies have to offer.

2.2 Virtual Reality

Virtual reality (VR) simulates reality using a PC or smartphone in order to immerse the user in a sensory experience. With a VR headset on, one plunges into a 3D environment where you can look around, you can walk around and even use controllers to interact with objects and influence the virtual world you are in. In other words, users can experience and influence this world in various ways. The promises for education are that the learner is in control of the immersive environment, can move around, try things out, take tests multiple times, and explores different solutions. The one thing VR evokes is physical motion in a simulated real world and feels emotions. Obviously, VR engages and stimulates, but what do educational scientists say about the benefits?
Affordances of a 3-D Virtual Learning Environment (VLE) corresponds with spatial knowledge representation, experiential learning, engagement, contextual learning and collaborative learning [8]. More research is needed though to relate these affordances to learning benefits. One of the issues is that most studies retain the existing pedagogy

while using new technology, which makes it hard to capture what can be beneficial for very different VR supported teaching and learning practices [7], [8].
VR is seen as very helpful in subjects as engineering and architecture to design and manipulate virtual structures. VR has also shown to be effective in medical training, the military, air and space, warehouse training, coaching, onboarding, and we see more positive results, [5]. So evidence is building up which is a good basis for the verification of the perceived value and helps to guide research in the right direction. Also the technology is improving and with the investments the promise is that access and the use base will improve significantly in the years to come.
Can students learn as well with VR as in a traditional setting and what are the design features for the virtual environment to make it work [5]? The need to find out is urgent since these technologies will be dominantly present in our daily lives, in private, at work and at school. In Table 1, a summary of findings categorized in line with the educational triangle. This certainly is not complete, but is an indication of what VR is capable of and for what purpose.

Table 1. Virtual Reality: summary findings

1. Relevance for teaching and learning	· Virtual reality can mimic our sensory experience of the world. · It helps to construct an authentic learning environment · Learning with strong spatial, physical and interactive focus · An asset for inquiry-based learning · Potential for the training of practical skills · Contextual settings that mirror real world situations
2. Students	· The VR world can be experienced with others · Provide a contextual learning experience · Enables students to construct broader understandings based on interactions and virtual objects · Deeper levels of cognition and new perspectives · Exposure to real world companies and technologies
3. Teachers	· Positive impacts on the classroom, including enhanced group dynamics and peer-to-peer learning · Placing the course in a rich contextual setting · Mirror the real world in which new knowledge can be applied. · Avoid tricky laboratory settings and offer 24/7 opportunities to test, analyse and report
4. Organisation	· Incorporating VR learning environments into education programs · Serve the geographically diverse students with on-campus experiences · Facilitate group projects, discussions, networking · Renewal of staff development aiming to equip teachers with the skills and means to select, test and decide about technology use.

2.3 Internet of Things

The second technology we want to look at is the Internet of Things (IoT). The IoT is a network of smart physical objects, which are interlinked into a functional aggregation in which the whole is more than the parts. It is known as machine-to-machine communication (M2M) and some rather talk about the internet of everything (IoE) that comprises all objects, people and data smartly interacting together. IoT is inter-networking physical devices like vehicles, smart devices, buildings and other items, embedded with electronics, software, sensors, actuators, and network connectivity that enable these objects to collect and exchange data. IoT is used by the Media for Environmental monitoring, Infrastructure management, Manufacturing, Energy management, Medical and healthcare, and others.

IoT envisions a situation in which the objects of everyday life will be equipped with microcontrollers, transceivers for digital communication, and suitable protocols that will make them able to communicate with one another and with the users, becoming an integral part of the Internet [9], [10], [11]. The IoT concept, by enabling easy access and interaction with a wide variety of devices such as, home appliances, surveillance cameras, monitoring sensors, actuators, displays, vehicles, will foster the development of a number of applications that make use of the potentially enormous amount and variety of data generated by such objects to provide new services to citizens, companies, and public administrations. This concept finds application in many different domains, such as industrial automation, medical aids, mobile healthcare, elderly assistance, intelligent energy management and smart grids, automotive, traffic management and others.
A general architecture for the IoT is a very complex task, mainly because of the extremely large variety of devices, link layer technologies, and services that may be involved in such a system, [12]. In Table 2 an overview of findings concerning the relevance of IoT use in education.

Table 2. Internet of Things: summary findings

1. Relevance for teaching and learning	· Skills shortage recommends that institutions increase diversity in STEM · Have the potential to enhance aspects of campus life · Has a great potential when it comes to learning analytics · Nice instruments for data collection · Stimulate learning experiences in a physical space
2. Students	· Students gain access to emerging technologies to transform ideas into realities · Aggregation of data will help students to understand their learning trajectories · Expected improved learning, feedback and support new experiences. · Will consolidate the involvement and knowledge of classical theory and modern technology.
3. Teachers	· Teachers need support to use IoT in strengthening pedagogical capabilities · The need of rubrics to understand the educational impacts · The self-made dashboard as a tool for coaching students at the point of time and need.
4. Organisation	· Modernization of curricula · Investment in new equipment for academic and research laboratories · Institutions partnering with industry to equip students with the latest skills · Connecting devices generate data on learning and campus activity. · Implications for privacy and security of data.

3 METHODS

The exploration started with an inventory of emerging technologies and tools that potentially give way to innovation and are used or about to be used in technical universities. The inventory was based on both a literature review and a review of reports and web resources like blogs and others and included a series of interviews with stakeholders in engineering education and at representative industries.

The exploration was extended with small-scale experiments on VR and IoT to better grasp the possibilities and limitations in the day-today learning environment. The outcome of the research so far is based on the exploration and the experiments, although not all are finished yet at the time of writing.

4 RESULTS AND OUTCOME

4.1. Emerging technologies and education

The technologies discussed are in a dynamic state of change and are continuously developed and refined, or becoming obsolete. The assumption was that these technologies can help to improve education, but we are still in a phase that we do not have the tools yet to fully understand the implications of these technologies on educational practices [5]. Research evidence over the last 40 years consistently identifies positive benefits, but also clarifies that the results very much depend on how well the technologies are being used [6]. Evidently, the skills to handle these technologies are in high demand and therefore education is urged to act. The industry worries about the willingness and capability of education to bridge the skills' gap.

Most experiences with these technologies, and in particular with VR and IoT, are in the industry. Consequently, education should use their relationships to extend their view on how these technologies work in business practice. The role of the teacher in this is crucial, but in their micro-environment they are not yet equipped to select, test and ultimately decide about these technologies.

4.2. Case study Virtual Reality

Two VR experiments are being executed which are half way through at the time of writing, so this is a state of affairs. One experiment is at the Centre for Language and Academic Skills of the Delft University of Technology (DUT) that offers a mandatory course on Presentations Skills for minors (VR-1). The second experiment is at the Department of Water Treatment at DUT, about a virtual tour in Waste Water a Plant (VR-2).

VR-1 dealt with the lack of opportunities to practice presentation skills in an authentic environment. The goal of the course is to improve presentation skills. The current program consisted of lectures, reading materials, check lists and opportunities to prepare and present short pitches and five to ten minutes presentations in groups or individually. Since the groups were large, like 60–150 students, the teachers and students felt that there was not enough time and opportunity for real time practice.

The experiment started with testing several apps for presentation skills. With the preference to self-develop an app a first design was made to clarify the demands and the requirements. Administrative issues comprised financial policy, privacy concerning the student use of an app for learning purposes and institutional ICT policies. These time consuming elements led to the decision to use an existing app with a restricted set of options. Clearly improving the possibilities to practice presentation skills requires an indebt understanding of the new technology to be able to reframe the course in the existing context. The VR-1 research focus is on the experiences of an A and B group of students and the teachers' experiences. For the analysis user data are collected, with survey outcomes and interviews to summarize the first experiences.

VR-2 is about developing a virtual tour in a waste water treatment plant. The teacher considered this tour essential for the understanding of the students, but was troubled by the fact that such tours were time consuming, difficult to plan and review and an increasing number of online students never had the opportunity to visit such a plant. Virtual tours are known tools in the tourist industry, factories, museums, the gaming

industry, etc. So nothing new, but developing a sound educational product requires a sustainable design showing installations and processes in an integrated manner.
The main question was how to develop such a tour that would fit the course design? It was decided to involve student assistants and students directly in developing the tour. They prepared a script framed by the initial course design and their experiences. They attended two introductory workshops to become familiar with VR systems and were trained to produce the VR-product under the guidance of a VR expert. VR-2 is being produced and receives lots of attention and requests from other faculties, which are faced with similar problems. Apparently, this effort evokes interest, as it is clear for what purpose the technology is being used.

4.3 Case study Internet of Things

This case study is about the design and implementation of educational experiments in an electric drives laboratory with Internet of Things (IoT) technology. The objectives were to upgrade and reengineer the existing laboratory equipment and to provide students with practical experience on up-to-date control of electric drives, and improve their understanding of the theory learned.

Along with other *smart* automation systems, electric machines have entered the realm of IoT. The induction motor control system when connected with IoT is able to circumvent a wire-bound sensor solution for drive over the web and enter the Internet-connected world. A host of embedded sensors is required in order to generate big data for cloud-based monitoring of induction motors drives and controllers.

The reengineering of existing educational laboratory includes:

- Device connectivity directly or indirectly via a gateway: electric motors, power electronics, microcontrollers, sensors, measurement instrumentation, internet.
- Data analysis, processing, decision, control, visualization and presentation, storage.
- Devices to facilitate bidirectional communication with the backend system to provide device registration and discovery, data collection and analysis, logic design and visualizations. The concept includes visualizing output data in real-time, sending data to the monitoring system and data security.

The students operate the system in both modes: with local control and with IoT control. Upgrading the educational laboratory equipment with IoT connected sensors, devices, and intelligent operations enables new educational opportunities for students, professors and curricula. It increases the benefits of the applied experience in the real physical on-site laboratory. From the professors' point of view, as human capital, there is an important investment in research and development of new innovative educational modules, with real practical application of new technological systems, involving design, test, pilot study and validation.For the educational laboratory, is expected that the IoT will result to a modernization of curriculum, plus improved operational efficiency and reliability. Our initiative improved students' experience and benefits organizations, which hired them. Although the apparent task of IoT is to connect the unconnected systems, its benefits and added-value results after data analysis and engineering and managerial decisions. The path from sensors to control and decisions involves microcomputer hardware and software, data acquisition, analysis and process, data quality and privacy and data management and builds an excellent knowledge of all involved fields of teaching, learning and apprenticeship.
So far the results in using this adapted laboratory show that there are multiple added values: new educational modules for existent curricula; well informed instructors in new

technologies; better prepared and trained graduates; industries opening new jobs for better trained candidates in modern technologies.

5. CONCLUSION

Emerging technologies will continue to influence our society and are expected to affect education more profoundly than before. To decide about the value for education we must develop an understanding of these technologies, which will allow students, teachers and institutions to judge if and how such technologies can help to improve teaching and learning. Due to the complexity, the diversity, the speed of development and the decay, education is challenged to develop an approach that can make these technologies work. For education to fully profit from the opportunities it is eminent to develop a pro-active strategy to develop a sustainable approach. The contribution of this exploration so far is that is helps to better frame the question.

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Otherness and Belonging

Integration of Practitioner-Academics into an Engineering School at a Research Intensive Institution

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ABSTRACT

Engineering schools in the UK are increasingly adopting learner-centred, authentic learning approaches such as problem and project based learning to address the perceived lack of employability skills in engineering graduates. These methods are labour- and capital-intensive, and these demands for work-ready graduates are taking place in a period of real cuts in per-unit student funding from government. To address these funding gaps, universities are increasingly focussing on securing research funding, leading to a preference for research active academics at the expense of academics with industrial experience. To plug these skills gaps, engineering schools are increasingly reliant on practitioners to teach on industry-focussed talks. However, the integration of practitioners into academic environments has not been smooth. In this paper I adopt a theoretical framework inspired by Bourdieu and Archer to identify the constraints faced by practitioners when they move into academic roles.

Conference Key Areas: Please select three Conference Key Areas

Keywords: practitioner-academics; research excellence framework; research intensive university

INTRODUCTION

The introduction of the Research Assessment Exercise (RAE) in 1986, and its subsequent replacement by the Research Excellence Framework (REF) in 2014, has led to an increased preference by UK higher education institutions for research-active academics who meet RAE/REF targets (Harley 2002). Meeting RAE/REF targets is beneficial as it gives institutions increased access to government research funding, and improves their reputational capital, as measured by current academic league tables.

However, the pursuit of RAE/REF targets has led to a fall in the number of engineering academics with the relevant industrial experience necessary for the effective delivery of engineering courses (Alpay and Jones 2012; Graham 2015; Tennant et al. 2015). Engineering schools have attempted to address this shortage of practical engineering skills in their teaching by hiring experienced engineers on teaching-only contracts.

However, the integration of practitioner-academics into engineering schools has not been smooth (Craig et al. 2016).

To overcome shortages of relevant industrial experience, engineering schools are increasingly recruiting industrial practitioners on teaching-only contracts. However, the integration of practitioner-academics into engineering schools is proving to be difficult, primarily because of lack of parity between research and teaching activities within UK universities(Craig et al. 2016).

In this study I adopt Elder-Vass' (2010: pp 113) synthesis of Archer's (2000) and Bourdieu's positions to theorise that the higher education social environment determines the locus of opportunities and possibilities for individuals working within it, and that individuals respond differently to social environment dynamics based partly on their personal dispositions, abilities and capacity to act. Such a position has enabled me to explore the following research question:

> What is the role of structure and agency in practitioner-academics' decisions to pursue academic careers, and their subsequent decisions to either stay on in these roles or to quit?

1 METHOD

1.1 Overview

My study focussed on a group of teaching-only academics who had previously worked in industry and were now working in the faculty of engineering of a research intensive institution in the South of England. The institution is a member of the Russel Group of universities, an elite grouping of the UK's research intensive universities. To preserve the anonymity of the research participants, I shall use the pseudonym "the Elite Southern University" to designate the research intensive institution.

1.2 Research participants

The teaching-only academics whom I studied were all at the rank of principal teaching fellow. At the time of the study, the rank of principal teaching fellow was the highest rank that teaching only academics could attain at the institution. I specifically targeted this rank for my research because, compared to the more junior ranks of the teaching-only academic role, individuals at the rank of principal teaching fellow were more established in their academic roles, and because of their seniority, they had more personal experiences of what it takes to progress in a teaching-only academic role at the institution. All of the five research participants were programme directors on one or more undergraduate courses, with primary responsibility for the content and structure of their degree programmes, and for all the teaching on the programme.

To ensure the confidentiality and anonymity of participant data, I closely followed the guidelines from the UK Data Archive. All personal information belonging to participants was stored in a separate location to the interview data and all the data files were password-protected. To keep track of the participants, I used a simple alphanumeric identity code to number the participant as well as to encode their academic career grades. I did this by encoding the principal teaching fellows as PTF1, PTF2, up to PTF5 respectively. At the time of the interviews, the youngest participant, PTF1, was a 33-year-old male, and the oldest participant, PTF4, was a 68-ear -old male. The remaining three were all females, with two, PTF2 and PTF3, in the age group 55 to 60, and the last one, PTF5, being in her mid-30s.

1.3 Life history study

In this study I used a life history approach to gain insight into the career histories of the participants. Chase (2007) defines life history as “an extensive autobiographical narrative, in either oral or written form, that covers all or most of a life.”

To gather data from the participants, I used the conversational one-to-one interview style. I adopted this style because it allows interviewees to freely use narrative in their responses (Goodson and Sikes 2001: pp 27). For this method to be effective, I had to allow the participant to narrate their stories as freely as possible, with as few interjections as possible.

2 RESULTS AND ANALYSIS

2.1 Section outline

In this analysis I focus primarily on the self-identities of the research participants and the attitudes that arise out of embracing such identities. I also highlight the impact of the prevailing institutional culture on the two primary activities associated with a university, namely teaching and research. I then draw out the potential outcomes arising out of the clash between the identities held by the research participants and the university institutional culture.

2.2 Practitioner Identity in a Higher Education setting

All the five principal teaching fellows who were interviewed for this study have maintained their identity as professional practitioners. For instance, PTF4, who has carried on working in industry in addition to teaching in the university describes himself as follows:

> So if you would like, I have not had an academic career, I have always been somebody from industry that has taught.

PTF1, who is in his early thirties, and who has previously worked in industry as a structural engineer, describes himself as follows:

> I am a structural engineer, I am a practising structural engineer, and I am a chartered engineer, and I think when I was at university I had the idea in my head that I could lecture, I would be good at lecturing

Similarly, PTF5, who worked as an archaeologist before joining the Elite Southern University sees herself as an archaeologist.

All the research participants view teaching as an important contribution in developing the next generation of professional practitioners. For instance, PTF5 views her teaching as a means of improving training in surveying, which is an integral part of archaeology:

> I suppose what brought me to the Elite Southern University was that in my gut I always wanted to teach surveying, I wanted to teach surveying to archaeologists, I wanted to present it in a kind of logical clear, informative way, because I think, there was, there is still a little bit of a gap there I think in education.

Similarly, PTF4 sees his role at the Elite Southern University as contributing to undergraduate teaching in his area of expertise by “making a combination of academic and practical” teaching to ensure that by the end of the undergraduate programme, students are adequately prepared for careers in his field of practice.

In general, all these teaching-only academics still value engagement with their professional practice. For instance, even though PTF5 is fully employed by the Elite Southern University, she still maintains her engagement with her professional practice:

> I have always liked that kind of project work, and I love going to work in different countries … I think that helps in this line of work as well. so and I think I am very lucky here in that, I still, I keep all my contacts, my links, so I still go and work on projects in Egypt, and I do the GIS and I do surveying, I kind of keep my hand in there as well.

In line with all the other research participants, PTF5 believes that this engagement with her professional practice is of benefit to her teaching:

> I think the students quite like knowing that the person teaching them goes out into the field and does stuff. … . And then with undergraduates, a lot of them will go to work in engineering firms over the summer, and they will be given surveying jobs to do, and they come back in September, and they go, that stuff you that you taught us, we actually had to do it.

Similarly, PTF1 believes that going back and forth between industry and university is good for his teaching:

> I need to go back and forth, whether that is a couple days of a week here, a couple of days a week there, whatever it is, I will certainly need to move back, because I don't think I will be as good at what I do, which is teach engineering, unless I am practising it.

It is therefore apparent that all the research participants hold teaching in high regard. Basically, they view it as their duty to train the next generation of professional practitioners, and, from the transcripts, it is clear that some of them willingly took salary cuts to leave industry and work in academia.

2.3 It's all about Research

Given their interest in teaching, all the five research participants report that they experienced what amounted to a cultural shock when they entered the Elite Southern University. They had not anticipated the extent to which research is dominant in the university, and they had not anticipated the extent of marginalisation of the teaching function when compared to research. PTF4, who still works in the construction industry, in addition to teaching three days a week in the institution had this to say:

> The external view of the university is that it does teaching. It would expect 90% of its effort to be teaching, and just a bit on research. I think most external people in construction would have no comprehension about the focus on research as opposed to teaching. In fact, they would probably be quite horrified.

Amongst the five participants, the general consensus is that the Elite Southern University is structured primarily to enhance its research capacity. For instance, some participants feel that the primary role for the teaching-only role is to support departmental research, with teaching being only a secondary requirement. For instance, PTF5, who worked in the IT industry before joining the Elite University upon retirement, had this to say:

> … the business model is built around top class researchers being attracted in who can produce the highest level of research output and publications, and you put the structure of teaching fellows in place to

help support that happening, you want the highest, high quality teaching, but essentially you want it to sit in its box and deliver so that research can get on with being research. so it's just viewing the, if you like, the state of teaching fellows as a resource that helps you achieve other objectives, and so it's not in itself a, there has been little or no attention until relatively recently to the career development of those individuals because if one left you could get another one.

There are perceptions amongst the research participants that research active academic staff have more opportunities for career progression than non-research active academic staff. For instance, PTF3 suggests that when the teaching-only route was established, it was difficult to get promoted through it:

> … so they came up with this teaching fellow - senior teaching fellow-principal teaching fellow route, and it was a struggle to get through it. I was made senior fellow probably on grounds of my longevity of service. I was made principal teaching fellow through the promotions exercise and that was absolutely fine and it was the first time. I had been here for about 18-19 years it was the first time that anybody had recognised the key contributions that teaching was making to this place. And alongside all of that I have done everything that a teaching fellow should do, I have been a keynote speaker at international conferences, I have travelled all over the world, couldn't see you last week because I was in Singapore external examining, and I have produced over 50 books, I have produced loads of conference papers, and loads of teaching initiatives as well.

There is also a perception amongst the teaching-only academics that the current promotion criteria for teaching-only academics are weighted more towards research than to teaching. PTF4 made this observation:

> Again somebody else has gone from promotion from a senior teaching fellow to a principal, and part of the requirement is to demonstrate your research record, which seems completely bizarre. The fact they are teaching fellows is they don't bloody do any research, so why when you are looking at promotion in somebody who is teaching only do you have to have a research profile. It's because the Elite Southern University can't divorce the two, and can't value the teaching as highly as the research.

The teaching-only academics also express the feeling that the current promotion criteria are opaque, to the extent that some of those who have successfully applied for promotion are not sure of the reasons for their success. According to PTF2:

> … the trouble is promotions are done behind closed doors so the bit that really impresses them you just don't know because you don't get feedback. It's either you get it or you haven't, I think. If you get it they don't tell you why you got it, they just said you got it

This opacity is leading some teaching-only academics to seek promotion through appointment to another teaching-only academic role within the institution, rather than applying for promotion in their own roles. This is what PTF3 had to do:

> … that was one of the reason I pushed hard when I got offered this job to go for principal teaching fellow. I felt quite frankly that's the easier option. I think in promotions it's easier to apply for a job and get. I think

> I met most of the promotion criteria. I have not come across enough people who have gone through that step to know exactly what's required.

2.4 We are survivors

All the five research participants feel that they are survivors who have worked hard to be where they are, and who still need to continue striving to break down the barriers that the institution, and society at large, has placed against them and others coming from similar backgrounds as them. For instance, regarding her role as a teaching-only academic at the Elite Southern University, and the challenges she is faced with in this role, PTF5 had this to say:

> I suppose I don't tend to kind of, I look at what I have done in all my career, I have never kind of sat still and just been like ok, we just carry on. I am always trying to do something else, expanding, sort of challenging the stuff, and then or I do stuff, I take on something new that takes me out of my comfort zone, and then within about 4 weeks I am crying at home saying why did I take myself out of my comfort zone.

In order to gain promotion to principal teaching fellow, PTF1 and PTF5 had to collaborate together to persuade their departmental management, to facilitate their promotion. Explaining how they managed to succeed in a department that was generally hostile to the idea of promotion for teaching-only academics, PTF1 said "… we didn't get where we are by working hard in a corner, and being very quiet about it." Both PTF1 and PTF5 believe that their own efforts to gain career advancement were ultimately beneficial to the entire teaching-only community at the Elite Southern University because, as PTF1 observed:

> … the good thing in the Elite Southern University is that once the precedent is broken it's easier to point to it, and so teaching fellows should use it to get that as a way to get where they want, they should point to other examples in other departments and use them.

PTF3 also had to work hard to convince management to facilitate their promotion as well as to secure working conditions for teaching-only academics that were comparable to those of research and teaching academics in their department. Regarding her own promotion, PTF3 stated:

> I also approached my head of department about the possibility of making an application for senior promotion based on my teaching and based on my work on the development of teaching and learning, and he laughed and told me that I was basically delusional, and that as an individual with no publications basically what planet are you on?

However, this did not deter PTF3 from seeking promotion. Instead, she sought the support of both the Dean and Vice Dean for Education of the School of Engineering, who in turn persuaded the head of her department to support her application. Commenting on this episode of her career, PTF3 said that she had relied on her previous experience as a marketing and communications expert in the field of IT to come up with a successful strategy for gaining promotion.

PTF3 took up the teaching-only role within the university following retirement from an earlier career. She believes that she is not financially dependent on the university, since she has a paid-up mortgage, and receives a pension from her previous career. She feels that her personal and financial circumstances place her in a strong position to speak out on behalf of other teaching-only academics who are in less fortunate positions than hers:

> I think the majority are not in a position [to speak out]; I suspect the majority are being held because they need the money, they have families, they have mortgages, most of us have to earn a living, we got bills to pay, and we got expenses to pay.

Hence, in a way, this group of senior teaching-only academics see themselves as the pioneers of a new academic role who, collectively, and individually, have to fight with the institution to ensure that conditions of employment improve, both for themselves and other teaching-only academics.

3 CONCLUDING REMARKS

This study reveals that professional practitioners who leave industry to take up academic roles within higher education generally have a high enthusiasm for teaching. Such academics primarily view themselves as professional practitioners who are doing their profession a service by engaging in teaching the next generation of professionals. They are intrinsically motivated to teach. Because they identify themselves as professional practitioners, and because they are in academic role within universities, I have coined the term practitioner-academics to describe them.

However, as the practitioner academics enter the university system, they come up against a formidable adversary. This is none other than the entrenched research culture within higher education. As this study shows, research is the dominant narrative within universities, and it is the prism through which every activity and individual within the university system, particularly research intensive universities, is judged and evaluated.

Even though some practitioner-academics are particularly resilient, as indicated by this sample of practitioner-academics in this study, still there is an experience a binary division between those engaged in research and those who are primarily in the university to teach.

Özbilgin and Woodward (2004) have coined the dual term othering-and-belonging to explain a binary fissure that is experienced by outsiders when they engage with a well-established social system. In this study, practitioner-academics are the outsiders, and their ability to stay on in the university system and make a positive impact on university teaching depends largely on the extent to which the university system is prepared to mitigate the negative impact of its entrenched research culture. This does not mean that research is bad. Rather, this study suggests that universities need to become more inclusive if they are to excel in both research and teaching to the benefit of society.

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Vygotsky's Zone of Proximal Development in Connection with Technology-Enhanced Learning Environments

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ABSTRACT

Technology-enhanced learning environments (TELEs) that support social interaction between teachers and learners are common in engineering higher education institutes. TELEs are often equipped with professional hardware and software, which not only enable learners to gain access to variety of learning instruments, but also allow learners to practice with authentic equipment and design tools. Furthermore, teachers can use TELEs and scaffolding principles to organize teaching in several ways that are beyond traditional classrooms. This paper discusses the potential of TELEs to shape the zone of proximal development (ZPD) of learners such that they could do harder learning activities than would otherwise be possible in less conducive environments. In addition, an example of a conducive TELE is presented that might have enlarged ZPD of learners, and, as such, may partly explain good learning outcomes obtained. The illustrations in this paper may help teachers to gain better understanding of the benefits of environment creation as well as to organize learning episodes that are suitable for ZPD-based thinking.

Conference Key Areas: Engineering Education Research, Sustainability and Engineering Education, Continuing Engineering Education and Lifelong Learning

Keywords: Zone of Proximal Development, Scaffolding, Technology-Enhanced Learning Environments, Engineering Education

INTRODUCTION

The concept of zone of proximal development (ZPD) belongs to Vygotsky's sociocultural theory of learning that enable teachers to understand learning processes through conscious intellectual activity in social settings. The paradigm of ZPD is that learners are more capable with the help of a more competent peer or teacher than they could be alone. In principle, teachers should challenge learners with tasks they cannot completely do on their own; rather teachers should provide just enough assistance such that learners are finally able to complete the tasks independently. Such an assistance process is known as *scaffolding* [1]. In general, scaffolding can be built in various ways; for example, by contact teaching, personal advice, peer interactions or feedback, which all share social dimension. In contrast, learning materials and activities not involving human interactions such as video clips, virtual laboratories, games and other software can also be understood as scaffolds that help learners to complete specific steps of some complex task. Please refer e.g., to [2–4] for more information on software-based scaffolds. Nonetheless, teachers should design and assign learning activities within ZPD of learners, set up environments that are conducive for those activities, and use scaffolding in order to enable high learning gains.

Currently, universities invest in technology-enhanced learning environments (TELEs), which are equipped with ancillaries such as modern web-technologies, audiovisual hardware, and professional software. Furthermore, construction and furniture layout of these environments are usually organized such that group-work and social interaction between teachers and learners are readily enabled. Therefore, TELEs are believed to provide better support for various teaching methods, enhance flexibility of learning, and favor authentic learning activities to be conducted compared with traditional classrooms. Furthermore, TELEs also enable natural support for social scaffolding processes and even for tailoring specific scaffolds for specific learning activities. Hence, it is justifiable to link the concept of ZPD of learners with TELEs, and to investigate TELEs' potential to enlarge the notional size of ZPD of learners. As such, this paper applies diagrammatic reasoning like in [5], in order to illustrate Vygotsky's ZPD in connection with TELEs.

The main contributions of this paper are: 1) to illustrate that TELEs have potential to shape ZPD of learners, and 2) to present an example of a TELE with selected scaffolds that have been set up for particular educational objectives intended to bachelor's level engineering students. The illustrations and examples in this paper may help teachers to harness TELEs and scaffolding principles for the benefit of learning. They may also help teachers to design and organize learning episodes that are suitable for ZPD-based way of thinking. At best, pedagogical scripting and scaffolding connected with TELEs may actually enlarge ZPD of learners, which is an important standpoint for any educational activity, as it would generally allow higher level tasks to be completed by learners. The scientific contribution of this paper is perhaps not limited to engineering higher education only. The discussion is presumably general enough so that other educational disciplines may benefit as well.

1 ZONE OF PROXIMAL DEVELOPMENT AND PRINCIPLE OF SCAFFOLDING

The ZPD describes set of learning activities that individual learners cannot do only by themselves, but which they can complete with scaffolding. According to Vygotsky [6], the set of such learning activities can be defined as "the distance between the actual development level, as determined by independent problem solving, and the level of potential development, as determined through problem solving under adult guidance or in collaboration with more capable peers". The ZPD and scaffolding along with an appropriately assigned learning activity are illustrated in *Fig. 1*.

Initially in *Fig. 1*, the learning activity is beyond learner's independent abilities, that is, before scaffolding has taken place. After successful scaffolding, learner is ready to complete the learning activity using his own abilities without help from scaffolds. The fictitious boundary of ZPD therefore defines new limits for the zone of current development (ZCD), which defines the set of learning activities that learner is able to do unaided. Updated ZCD maps individual development process and it makes learner more receptive for higher-level activities.

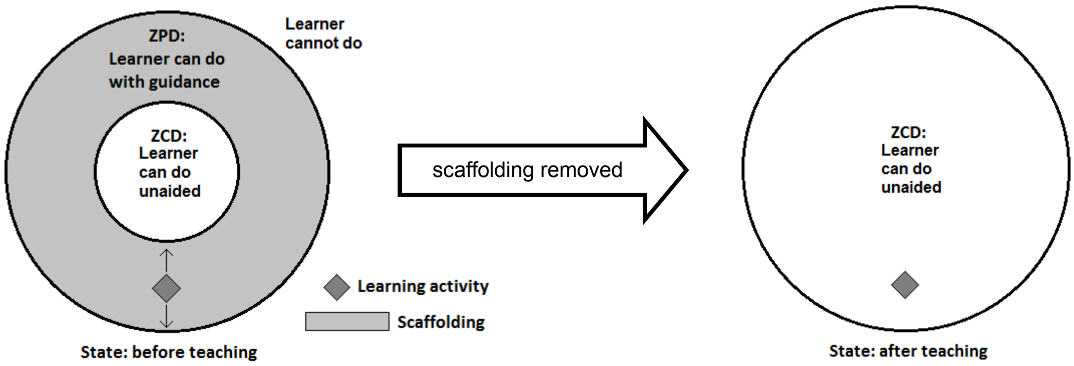

Fig. 1. A learning activity (diamond) is initially beyond learner's independent abilities. After teaching, scaffolding is removed and learner is ready to complete the activity using his own abilities. The boundary of ZPD defines the limits for the updated ZCD.

In this sense, *Fig. 1* clarifies the necessity of teaching: teaching attempts to make learners to do more, and it helps learners to surpass their current abilities. *Fig. 1* also emphasizes the nature of activities that should be assigned to learners: Teachers should assign activities that learners are unable to accomplish themselves, but which they can do with guidance [5]. Furthermore, the learning activity gets harder when it is placed near the outer boundary of ZPD, and easier, if it is moved towards ZCD.

In [5], Wass & Golding have recommended that harder tasks will lead to improved learning. Hence, attributes such as knowledge base, mastery of substance, pedagogical scripting skills, and even courage of teachers do play an important role when learning activities are placed near the outer limits of ZPD of learners. It is also crucial that sufficient prerequisites of students are ensured. Nonetheless, it should be noted that each learner do hold different abilities, and hence, individual ZPDs and ZCDs differs between learners. Furthermore, individual learners generally require unequal timely investment for completion of learning activities. Taking this viewpoint, the quality of students, their current knowledge level, abilities, and regulation skills limit the level of learning activities that can be assigned without e.g., cognitive overload and making things too difficult for students to handle under a sensible timespan.

2 LEARNING ENVIRONMENT AND LEVEL OF POTENTIAL DEVELOPMENT

In [5], Wass & Golding have proposed that changes in teaching environment change ZPD of learners. Specifically, they believe that learning environments that are targeted for particular learning activities can enlarge ZPD of learners, and, as a result, would allow learners to complete harder tasks compared with less conducive environments. Such a claim is relatively strong, but it is also very significant, because learning gains could be improved by focusing on environment creation. The extended ZPD of learners, i.e. the increased level of potential development enabled by a conducive learning environment is depicted in *Fig. 2*.

However, Wass & Golding mostly focus on the role of social environment, where active engagement and sustained discussion between students and teachers occur, and where prompt feedback is given to students. They also put emphasis on the learning activities occurring within the environments e.g., critical evaluation tasks versus rote learning and factual recall. Undoubtedly, their claims and examples are convincing and trustworthy.

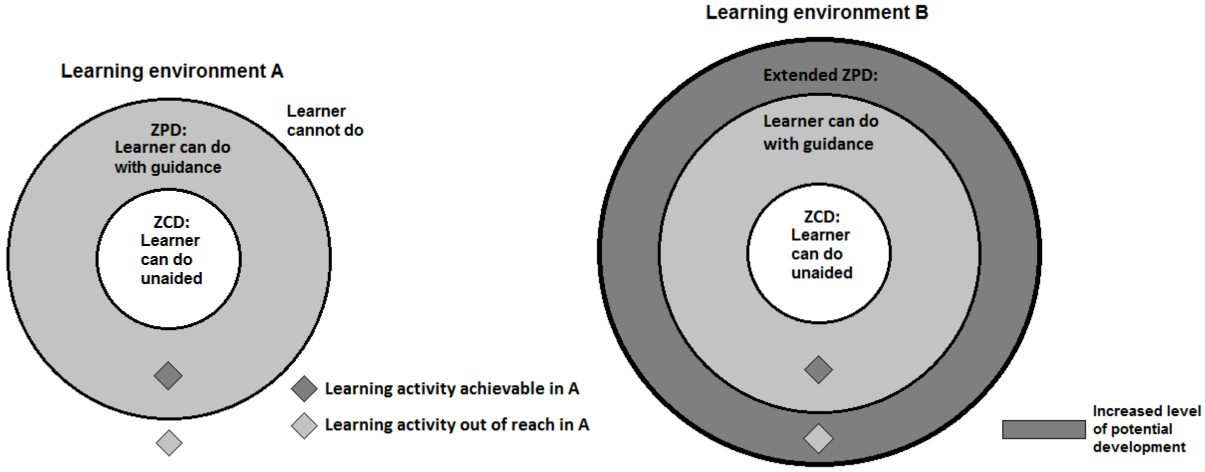

Fig. 2. Learning environment B is more conducive for particular learning activities compared with environment A. Harder tasks can be completed in B than in A. Environment B therefore increases the level of potential development of learners.

Yet, neither theoretical studies nor empirical research has been focused on the potential of physical or virtual environments to shape ZPD of learners. Shaping ZPD of learners essentially means that learners' abilities to complete learning activities through *scaffolding* are changed, and that change, in this case, must be linked to the scaffolding process itself. In addition to teacher's direct actions and social interaction, technology-mediated ancillaries offered by the TELEs can further strengthen scaffolding processes. Hence, it is justifiable to link scaffold-supporting features of these ancillaries to the notional size of ZPD of learners. The activity viewpoint as described in *Fig. 1* and *Fig. 2* is especially useful for such a purpose.

It is important to note that TELEs are commonly found in educational institutes throughout the world; especially in engineering higher education institutes. An example of a modern TELE is depicted in *Fig. 3*, which potentially resembles environment B in *Fig. 2*.

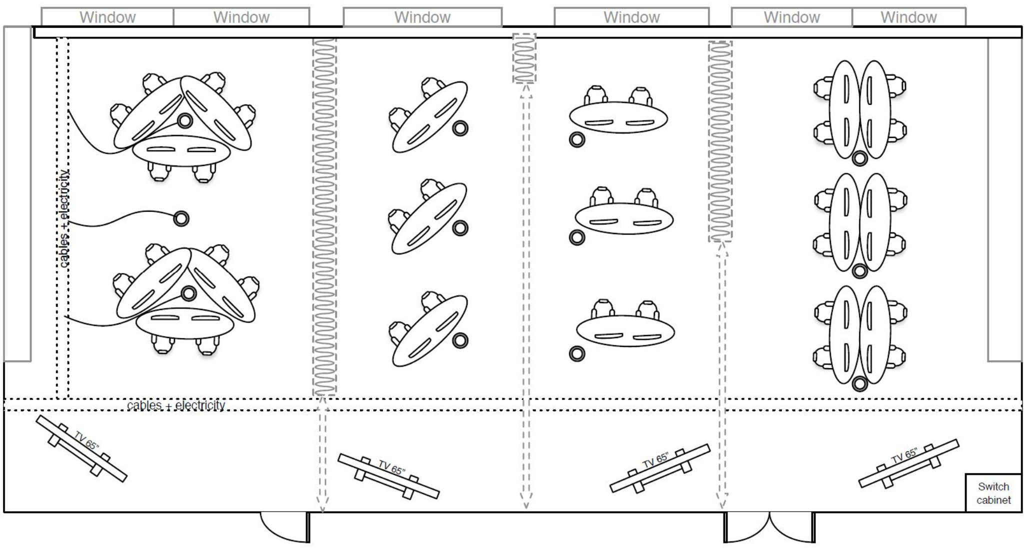

Fig. 3. A cell-oriented configurable TELE that supports varying group sizes. Each desk is movable and consists of two workstations and individual PCs. Desks can be attached together to form larger consoles. The whole TELE can be divided up to 4 separate cells, and each cell have an own large movable display, which is accessible from any PC. All PCs are equipped with professional engineering software, and have quick access to online library and other learning resources. [7]

In what follows, an example of a conducive TELE that have been set up for particular learning activities is presented; namely, a miniature process environment for flexible learning and open-ended engineering design. Better learning outcomes have been obtained since the fabrication of the pilot environment compared with earlier approaches by monitoring the performance of a batch of 50 engineering students.

Nonetheless, students have generally performed better: They have been able to solve more advanced and more difficult problems than before. They have shown critical thinking, even as regards to their own work. They have compared and contrasted their work with their peers. They have invented new strategies for solving engineering design tasks, and to some extent, have been more satisfied and happier than before.

However, scientific reasoning for such improvements is still somewhat unclear, and hence, the diagrammatic framework of ZPD and scaffolding as in *Fig. 1* and *Fig. 2* is selected to provide new insights to the relation between scaffolding and learning. Partially, the improvements have come at a price e.g., by necessity for goal orientation and sustained engagement, which require regulation skills and increased timely investment for completion of learning activities. Some students have been uncomfortable with such features and slight avoidance has been observed. It also seems that well-performing students perform even better, while others underachieve. Social cognitive theory and self-efficacy may partly explain the avoidance behavior.

3 EXAMPLE: MINIATURE PROCESS ENVIRONMENT FOR FLEXIBLE LEARNING AND OPEN-ENDED ENGINEERING DESIGN

Miniature demo processes that are small-scale versions of industry-scale processes are trending in engineering education. Some of them have fixed structure; some have additional freedom of configuration. Miniature processes benefit both teachers and learners. For example, teachers can easily bring them inside classrooms, and use them to illustrate physical phenomena, and to show real-time technical demos to students. Teachers can also set up environments in which several different miniature processes are simultaneously installed. Depending on room design and regulations, students can be allowed to have relatively free access there, practice open-ended engineering, and make use of science for the benefit of their own learning. Better access enhances flexibility of learning, while open-endedness provide alternate ways to understand lecture notes and other course material. Open-endedness also enables students to discover new things in science with their own volition.

An example of a certain workstation from such an environment is depicted in *Fig. 4*. The miniature process in the right-hand side of *Fig. 4* is a rotating DC-motor that can be supplemented by two different attachments; namely, by a rotating disc attachment and by an inverted pendulum. The disc can be used to understand rotary motion as well as to investigate position and velocity control, which both are widespread in different areas of technology. The inverted pendulum on the other hand can be used to learn balance control, which is relative common e.g., in mobile robots. Furthermore, software-based virtual laboratory environments, or simulators, can relatively easily be created to supplement device level equipment. An example of such an environment is MathWorks Matlab/Simulink software, where students can do e.g., model-based design before working with the physical device. These virtual environments can be constructed using block diagrams that show causal connections between each physical instrument. They are also able to quickly produce comparable results as the real equipment does. Interested readers may refer e.g., to [8] for more examples on pedagogical use of virtual laboratory environments.

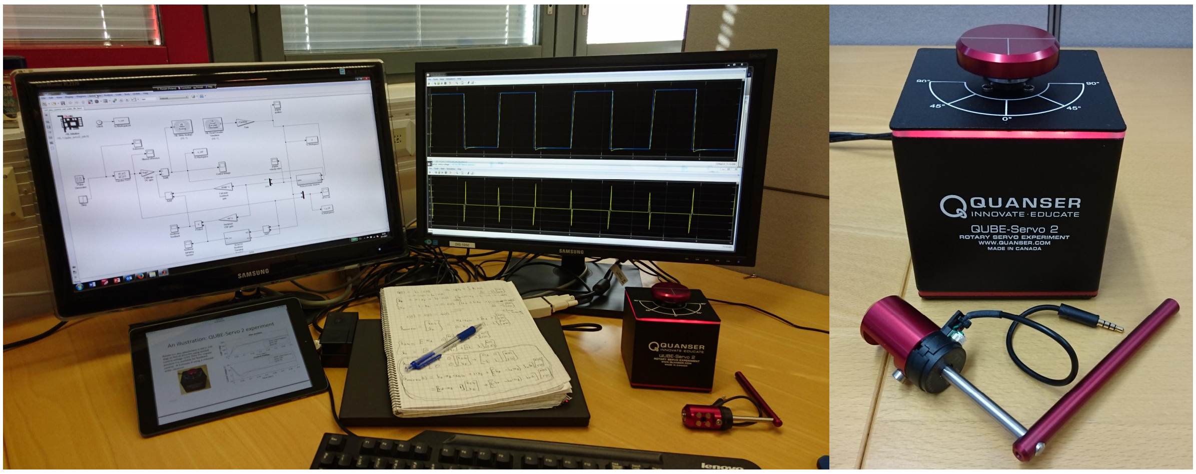

Fig. 4. Workstation of process environment (left) and miniature DC-motor (right).

In what follows, an example of a thoughtfully scripted learning episode that is executed in the miniature process environment is briefly discussed. The rotating DC-motor of *Fig. 4* is adopted as an example device. The episode is broken into three separate phases that have specific ZPD-based educational purposes.

Phase 1: Student groups are first given a teacher-made but only partly completed simulator that is based on the mathematical model of the physical DC-motor. The parameters of the model are available in the manufacturer's datasheets, and students are required to browse through the datasheets and complete the model. After completion of the model, students need to do several preselected simulation tasks that help them to understand the dynamic characteristics of the system.

Phase 2: Student groups need to pick a topic from several different alternatives available e.g., position control of a rotary disc attachment. Students are also given a set of standard design constraints and requirements that must be fulfilled using the simulator before working with the physical device. For the most active students, the simulator allows them to freely carry out open-ended engineering design e.g., by trying different theoretical methods and learn from the experience. In addition, there are number of different approaches available in each topic that can potentially yield good results. It is left for students to find a reasonable approach, and justify their choices. Finally, an experimental result from the manufacturer is provided to students for benchmarking purposes.

Phase 3: When students have satisfied all design constraints and requirements, they are ready for the actual experiments. The tests are carried out such that three groups are present at the same time. The purpose of such a choice is that students see different design approaches of different topics and their rationale. Hence, they can learn from other groups as well, which allow them to weigh their own design with others. More importantly, teacher provides short and personalized microteaching during the testing phase, which strengthens students' understanding. Microteaching in this case provides specific support for specific tasks, and it allows prompt feedback to be delivered to each student groups, and even to individual students.

The simulator in Phase 1 makes students familiar with the operation principles of the given physical system. Furthermore, datasheet browsing helps students to understand how essential information is commonly shared through them. The preselected simulation tasks predict dynamic behaviour of the real equipment, and enable students to virtually observe several quantities that cannot be displayed by the physical instruments. The simulations not only demonstrate the benefits of software-based design in terms of general engineering work: access, time-scale, prediction, data-analysis, etc., but they also illustrate limitations of virtuality e.g., model uncertainties and other sources of error. Therefore, the virtual simulation environment works as a software-based scaffold that aims to enlarge ZPD of learners by surpassing the limitations of physical environment, and by offering much faster information retrieval compared with physical devices.

The requirements in Phase 2 problematize students' work and draw their attention to issues that might otherwise be overlooked. More importantly, the requirements make students to do sustainable, reliable and safe engineering design, which serve them in the long run. That is, the list of requirements is one of the key scaffolds that enable students to do successful work.

Phase 2 is also the point when students face engineering challenge: they must seek relevant literature and find potential solution candidates for their own topic. Often, students must do some trial-and-error experiments as well, which actually strengthens their knowledge level, because they learn characteristics of the chosen candidate. Students must also weigh the pros and cons of the candidates, and hence, they understand why some candidates work better than others do. Through this process, students learn important features of engineering science, research and practice, as well as the phases of work and design, and the iterative nature of project working, which all prepares them to face engineering challenges in the future. In addition, the benchmark result gives a challenging reference for students to see what kind of performance is roughly expected. For most of the students, the benchmark result seems to be a driving force towards better engineering. Furthermore, many student seem to understand that good results are not easily achieved, and hence, effort, timely investment, teamwork and help seeking are required in order to reach meaningful learning objectives.

Finally, Phase 3 allows students to see their own design in action. Because there are several groups simultaneously present, students can share their knowledge to their peers, discuss about them, and possibly use help from the teacher ('the more capable peer') to support their findings, or to provide additional information. That is, Phase 3 focus entirely on improving the social dimension of learning compared with strictly teacher-led instruction, and thereby, aims to enlarge ZPD of learners through social scaffolding process in a supporting environment.

Students have been surprisingly satisfied with the social scaffolding process delivered by the teacher at the end of Phase 3, and with the technological ancillaries within the TELE. According to student feedback, many felt that these kind of learning episodes with task diversification, technological learning instruments as well as with active social interaction between students and teachers have substantially helped their personal learning and development processes, and, as a result, they have expressed willingness to learn more by co-creation of authentic problem solving. It also seems that students get fascinated when they see the outcome of their own design in real-time, which tend to increase motivation towards completion of learning activities.

In summary, it is justifiable to believe that the created TELE enable learners to work with hard authentic learning activities that are placed as in the right-hand side of *Fig. 2*, and hence, scaffolds students to reach high-level educational objectives otherwise out of reach. Therefore, the fabricated miniature process environment might resemble that of environment B in *Fig. 2*, but more experiences need to be gained to make implications that are more representative.

4 SUMMARY AND ACKNOWLEDGMENTS

The possibility of technology-enhanced learning environments (TELEs) to increase the level of potential development of learners was discussed in this paper. The level of potential development was identified with Vygotsky's zone of proximal development (ZPD) and with the notion of scaffolding. Diagrammatic reasoning was used to illustrate that TELEs may enlarge ZPD of learners, and, as a result, would allow high-level academic activities to be completed by learners. The key argument in this case is that TELEs and their ancillaries may strengthen scaffolding processes, which translate to better learning outcomes. Furthermore, an example of a conducive TELE along with specifically designed scaffolds were shortly presented that support ZPD-based teaching practice and claims in this paper. The scientific contribution of this paper may help teachers to gain new insights for the scaffolding potential of TELEs, and to use environment creation for the benefit of learning.

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The ‘Kick-off project’

- an engaging entry to a transdisciplinary master education

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ABSTRACT

For students starting at a master program where transdisciplinary processes are an integrated part of the curriculum, it can be a difficult adaption when they have to mix methods and theories across boundaries. The overall questions dealt with in this paper are how to introduce students to understand and use the transdisciplinary approach through a problem based design project, and how to give the students a meaningful and engaging introduction to their future study. The theory behind the pedagogical approach Problem Based Learning (PBL) is reflected in a “Kick-off Project” from a new transdisciplinary master programme in Lighting Design. During the project the transdisciplinary elements of creating meaning and value through lighting design, the important elements of PBL and the process of applying this through a playful process model developing and realizing a 1:1 lighting design project in a specific context will be introduced. The results show that it is possible for students to make a meaningful design project showing insight in and understanding of a transdisciplinary education, combining PBL approach and a design model.

Conference Key Areas: Sustainability and Engineering Education, Curriculum Development, Engineering Education Research

Keywords: Problem based design, problem based learning, transdisciplinary education, lighting design

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INTRODUCTION

Several educational institutions have started interdisciplinary or transdisciplinary master educations. (We are using the term transdisciplinary according to Meeth [1]). For students starting at a master program where transdisciplinary processes are an integrated part of the curriculum, it can be a difficult adaption when they have to mix methods and theories across boundaries. A new transdisciplinary science and engineering master program in Lighting Design was launched in 2014 at Aalborg University integrating lighting technology, architecture and media design. The students have different educational backgrounds representing these fields as well as different nationalities. One of the main concerns was how to introduce the problem based learning (PBL) and transdisciplinary design aspects of the program to give the students a common understanding of and the ability to combine technical and humanistic knowledge in an integrated creative design process. These challenges are met through the pedagogical approach of the Lighting Design program, which is based on PBL [2] [3]. All Aalborg University programs are using the Aalborg PBL model and first year bachelor students get an introduction to the model [4]. The questions dealt with in this paper are: How to introduce students to understand and use the transdisciplinary approach to Lighting Design through a PBL design project, and how to give the students a meaningful introduction to their future study.

1 BACKGROUND

1.1 Lighting Design

Lighting has undergone a revolution in recent years. New sensor technologies and computation intelligent control of light, energy-saving potentials and new LED technology can be applied to a sensitive and cultural architectural lighting design approach. The process of designing with light have to move away from a split focus between a rational engineering and an intuitive architectural approach to a complex transdisciplinary design process integrating media technology as knowledge area, methods, tools and equipment [5]. The Lighting Design Master has duration of 2 years. After the first semester in 2014 a small survey was made. Here it became evident that for many students it was their first project using PBL and a transdisciplinary learning approach was not easy. The problems were related to project work, cooperation and communication as well as difficulties of transferring the traditional theoretical 3 half - days PBL introduction into their 15 ECTS semester project. On that background, it was decided to change the introduction to integrate PBL and Lighting Design in a student project, and the concept of a 5 ECTS “kick off project” as an entry to the PBL methodology, the transdisciplinary approach and creative potentials in designing with light was defined.

1.2 Pedagogical approach - PBL and The Lighting Design Experiment

The pedagogical background for the Lighting Design master program is a process model, The Lighting Design Experiment (LDE) [5] and Problem Based Learning and project organized group work (PBL) [6]. This LDE model supports students to structure complex problems in such a way so they are able to integrate and apply knowledge from different disciplines [7]. Students define their projects within a semester theme, and most of the problems addressed by students in the different semesters are interdisciplinary by nature, since students start from a given theme, finding a problem to solve, analyse and use several disciplines to address it and

solve it – always facilitated by a teacher [8]. The process is the anchor of the project and is based on an iterative process of idea generation, problem area analysis leading to a final problem statement, design, implementation, test and conclusion [4].
The ‘Kick-off project’ is based on a design-based learning approach, the Lighting Design Experiment, where students in their project should be creating narratives by transferring, translating and transforming knowledge on light from different fields [10]. Design based approach has shown successful results for students developing skills and understanding, when they needed to undertake solutions of complex and sometime ill-structured problems [10] [11]. According to theories of PBL and situated learning, designing creates contextualized and authentic learning, because design tasks force students to understand and work in an environment that demands skills and domain knowledge close to real work environment [12]. We find that design-based learning in general and Lighting Design in particular is well connected with PBL project work which will be the pedagogical approach for a ‘Kick-off project at the Lighting Design master program first semester. This approach has potentials for using the ‘Kick-off project’ as motivational and engaging factors, while knowledge about different aspects of lighting design are mediated through student’s projects. At the same time knowledge about Problem Based Learning are applied during students learning process.

2. METHODS

2.1 The experiment as a tool, how do we analyse the kick-off project

The ‘Kick-off project’ is an experiment to introduce new master students to Lighting Design, PBL and to get knowledge about their new transdisciplinary learning environment. The kick-off project has been running in 2015 and 2016. 56 student’s projects have been developed in 13 groups, which consist of a design task scale 1:1, a written report and a presentation of the design solution in context.
We have used an exploratory case-study approach [13] in combination with the descriptive, mixed- method case study [14] [15] [16] to investigate the process and results of the ‘Kick-off project.
This examination explored the process of learning by design within the context of an intro project. Furthermore, we are evaluating the PBL competences acquired during the project work: analysing all students in particular this study addressed the following research questions:
1) How did the students show understanding and ability to define a narrative and the narrative they have chosen into the overall project theme: “designing with light”?
2) How did different aspects of the project process reflect the PBL competences.
3) Did the students integrate different disciplines in their project?
4) How did the ‘Kick-off project’ function as a good introduction?

We have analysed the 13 reports from two years using the four parameters:

1. The PBL structure, understanding of the process

2. Ability to analyse the context and formulate chosen narrative leading to the problem statement and the design they wanted to work with where light is one element in a transdisciplinary design.

3. Ability to create a narrative through light integrating the amount of disciplines and methods needed for the design solution

4 The general quality of the student’s productions (the narrative using light, the report and the reflection.

3 KICK-OFF PROJECT – SEEING THE LIGHT

Fig. 1, The Cast Collection*, Fig.2* Lighting faces. *Fig. 3* Projecting POP art

The 5 ECTS kick-off project, 'Seeing the Light – Creating new Narratives' [9], takes its departure in a real-world scenario, where a playful approach to lighting design will create new ways of seeing how light can create new narratives in the unique, historical and cultural context of The Royal Cast Collection by the harbour front in Copenhagen. The aims are to give the new students an experience and understanding of the complexity of seeing and understanding light and lighted objects in spatial contexts by collecting knowledge from different fields and synthesize this knowledge into a problem statement, and to explore new potentials through the development of a lighting concept, reflecting the concept of PBL. Referring to the LDE the design process will develop and test solutions in using different methods and theories related to the areas; lighting, architecture and media technology.
The Royal Cast Collection consists of more than 2000 plaster casts of sculptures of the human form from across Europe, and which can reveal narratives of everything from pagan gods to Christian traditions. The sculptures are created for specific sites and for daylight conditions. The students were asked: *How can light create new narratives in The Royal Cast Collection?*
During the first week, the students were given an introduction to methods and tools related to the three academic fields and three courses of the semester. A lecture on Architecture introduced how to see, analyse, understand and document objects in different context, the narrative, visual fantasy. The students were introduced to the lighting equipment and lighting technology. The curator of the collection gave an introduction to the history behind the sculptures and the old warehouse. Finally, the concept behind Problem Based Learning and methods related to how to work and design in groups was introduced through two sessions during the first week. The students were divided in groups of 4 -5 representing different fields and nationalities and allocated a supervisor. The process was structured in three steps referring the process of PBL and the model of the LDE [10].

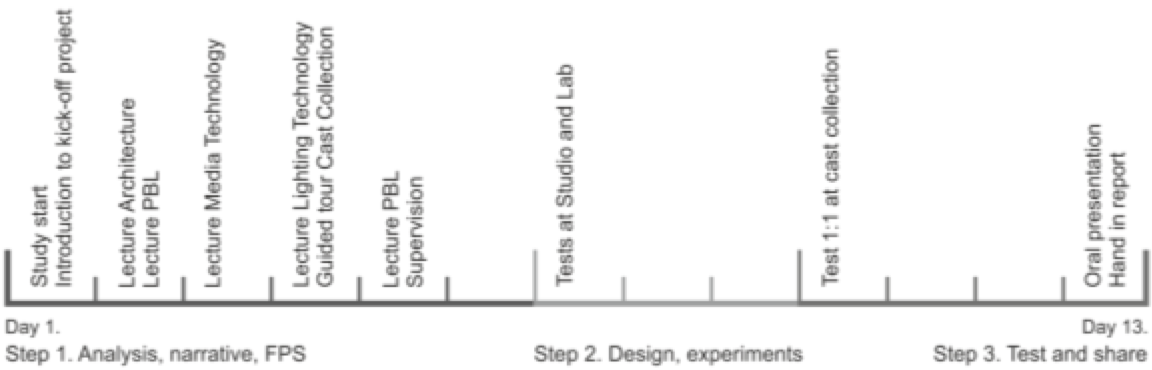

Fig. 4. Timetable for the kick-off project, knowledge input, 3 steps and tasks

4 RESULTS

As part of the results from the 13 projects, one characteristic project is selected to roughly illustrate the structure and steps in the process.: The project title is: 'Popping up in the Royal Cast Collection. Experiencing pop-art and ancient culture in a new light'. Focus is on the process of working with the narrative of the Greek God Apollo investigating how light can express the contradicting sexuality of the sculpture [17].
Step 1: Analysis of the context and choice of narrative. The focus area was defined on basis of observations of the sculptures, the architecture and the light. Knowledge about the art history and the user group was given by the curator of the museum. Knowledge on the fact that gender and sexuality is a very discussed topic and relevant to chosen statue was studied and included in the narrative: "Provoking and highlighting Apollos contradicting sexuality. The statue is not as masculine as other male statues". On that basis, the final problem statement was defined: *"How can the contradicting personality of Apollo be highlighted through light".* The final problem statement is based on analysis of four different knowledge areas in the context, art history, architecture and effects of lighting as well as topics related to society in general.
Step 2: In order to answer the FPS several design experiments were conducted. The positioning of the sculpture in relation to other sculptures, the walls and window was defined. The lighting fixtures were tested. Coloured light (pink and blue) was introduced to add an extra layer to the experience and perception of contradicting sexuality. The students then started experimenting with the effect of the shadows through digital renderings using 3Ds Max, V-ray and Photogrammetry and by tests in the studio and the light lab at the university as well as tests at the Cast Collection.

Fig. 5. Design Experiment in light lab and at Cast Collection exploring male and female characters.

Step 3: Test and charring knowledge. The students tested the findings from Step 2, at the collection, adjusted it and it is communicated in their project in report, Furthermore their narrative is presented through a 1:1 lighting set-up at the cast collection and through simulations.

In the following we are showing an overview of the Kick-off projects from 2015 and 16 we have made a table showing 4 elements in the process of making a project. It is of course an abbreviated illustration of a very rich picture of 13 projects. The 4 elements are: The Narrative, the Final Problem Statement, the Transdisciplinary elements defined by the number of different knowledge areas and methods combined in the process and finally the PBL structure.

The narrative	Final Problem Statement (FSP)	PBL	Disciplines
A woman is punching a man. Two characters in a pop-art theme.	How can a humoristic lighting installation make people more interested in the museum?	max	4 4
Mortality and loss: a woman is going through the third of the five stages of loss – the stage of bargaining as she prays a night in a church for her dying son.	Is it possible to use lighting to bring out the emotional stage of loss? Analyzing the history be-hind 5 medieval tomb sculptures.	max	4 methods 3 fields
Depict 8 bust casts in a manner that would embrace the superior socio-economic status of their character around the idea of Nouveau Riche reflected in reflective, shimmering golden effect.	How do you create a narrative without words and by only using lights?	max	6 methods 3 fields
Bringing life to the busts and the space in or-der to support the ware-house atmosphere in a more compel-ling way.	With what kind of light settings can you alter the existing facial expressions of busts in a dramatic way?	max	3 methods 3 fields
Present the story about slavery that has been in Denmark. The statue is used as a canvas and tattoos are used to pay attention to this situation.	How can we tell a story though projected tattoos on one of the statues in the Royal Cast Collection at the West Indian Warehouse?	max	4 methods 2 fields
Provoking and highlighting Apollos contradicting sexuality. The statue is not as masculine as other male statues.	How can the contradicting personality of Apollo be highlighted through light?	max	6 methods 3 fields
Bring out the story within each individual exhibit in a group consisting of statues in a row on one side and a relief on the opposite side to create interaction and an overarching narrative,	Bring out the story within individual exhibits. Combining those stories to create interaction and an overarching narrative. Creating interactive space to involve the visitor.	middle	5 methods 3 fields
The story of Lacoon and his sons – the way the father faces death – weather stoically or by creaming and revolting against the damnation.	How can we, through the use of light, make the audience aware that the father in the sculpture might be screaming?	max	4 methods 4 fields
The Hammurabi code: bringing forward the original story to show the great importance this statue where a Sun God is telling the king what to write in the law.	Imagine if we bring the feeling of the history behind the sculpture alive by adding light.	max	4 methods 4 fields
A showdown on the Venus sculpture with the western world's definition of beauty and creating a message about the human body a beautiful no matter size or skin color. Nobody should feel ashamed of their body	How can we visualize other definitions of beauty to the sculpture?	max	6 methods 3 fields
Not clearly stated but revealed during the project: A sculpture's expressions in its specific historical context. Middle Age to Renaissance.	How can we create a specific narrative with the interplay of lights and shadows around the plaster cast copy of the Madonna Della Cintola?	middle	5 methods 4 fields
Story of physical slavery turned into a nowadays form of mental slavery. Addiction to smartphone and social media usage and problems of false norms and standard created by the addiction.	To design an installation which will let you think about how addicted we are to our mobile phones.	max	4 methods 3 fields
The story of the natural progression of a girl becoming a woman, then a mother, and then setting her child free in the world.		middle	4 methods 3 fields

Table 1. Analysis of the 13 kick-off projects and the four elements

All students did reach the overall learning goal for the ‘Kick-off’ project. They made a meaningful project based on their narrative inspired by statues in the Royal Cast Collection. The motivation and engagement was very high during the 13 days of project work, otherwise the students would not have managed to work so hard as they did to accomplish their rather complex and ambitious goals of their projects (see table 1) Integrating the theory of PBL in a ‘real’ transdisciplinary project seems to be a good solution for students to get the knowledge transformed in a concrete project as a method and structure. Furthermore, the complex challenge raised in each student project motivated them to use and integrate several knowledge areas to formulate a narrative, define a Final Problem Statement, establish design experiments and make a design solution, test and evaluate. In 11 projects knowledge from more than 3 or 4 areas has been used as well as 11 projects have used more than 4 different methods, and they are well integrated in the different steps of the project. The PBL model are in general well used in all project, which also is reflected in the relatively short time students have had for their project work (table 1). 11 Projects have used all steps in the PBL structure and have managed to use in their process as a tool for structuring their project as well as using the ‘freedom’ it gives to integrate their new knowledge in a transdisciplinary, creative process. Furthermore, the students now are familiar with each other and know their different backgrounds.

5 CONCLUSION AND PERSPECTIVE

It can be concluded that through a ‘Kick-off’ project based on Problem Based Learning and design the students get knowledge, competence and skills for making a complex project. Furthermore, it was demonstrated that it is a very good basis for understanding the transdisciplinary nature of a complex design field as Lighting Design. All groups have integrated several knowledge areas in their project indicating that they have started to develop technical as well as PBL competences and skills needed for working with a transdisciplinary lighting design approach.
As a follow up on this ‘Kick-off’ project we would like to follow a semester during all 4 semesters at Lighting Design, analyzing how the students develop their knowledge, skills and competences both within PBL and transdisciplinary design.

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Engineering grand challenges and the attributes of the global engineer: a literature review

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ABSTRACT

Technology has been changing world in ways never imagined. The ever-evolving society and rapid development posed different demands and challenges to the engineering profession. Addressing these challenges means to re-vision and reform the ways we educate future engineers and the attributes need to be enhanced. This paper reports a literature review with aim to (1) understand the different stakeholders' perspectives, namely students, educators, and employers, (2) understand the profile of the global engineer (i.e. knowledge, competences and skills), and (3) outline and discuss learning strategies. As a result, the paper presents the main gaps in the existing knowledge, formulates research hypothesis, and proposes a research design for a follow up empirical study to investigate further the engineering grand challenges, the attributes needed to solve them, and the learning environments required.

Conference Key Areas: Engineering Education Research

Keywords: Engineering education, grand challenges, attributes, learning strategies

INTRODUCTION

In the past decades, international reports and research have outlined the central role technology plays in the contemporary society and the global challenges being faced. Engineering education always evolves and adapts to social challenges. In the past, engineering education reacted to social challenges by adding disciplines to the curriculum. In the present, engineering education must take a proactive response to the current fast societal change [1], [2]. For example, the UNESCO report on "Engineering: Issues, Challenges and Opportunities for development" [2, p. 6] looks into the global context in which engineers operate and the need to *"*effectively innovate and apply engineering and technology to global issues and challenges such as poverty reduction, sustainable development, and climate change – and urgently develop greener engineering and lower carbon technology*".* The National Academy of Engineering [1], [3] also examines the roles engineers will play and the professional contexts of the future, pointing to aspirations and desired attributes. Professional contexts include systems perspectives, customerization, public policy debates, and understanding of engineering, calling for attributes related to systems thinking, teamwork, communication, interdisciplinary knowledge, creativity, and innovation. The Global Engineering Deans Council [4], in cooperation with the International Federation of Engineering Education Societies (IFEES), launched a survey to validate the performance and proficiency of the competencies defined in the last years by international engineering organisations and which are considered essential for the preparation, performance, and employability of future engineers. From this study, five broad categories emerged: technical, professional, personal, interpersonal, and cross-cultural competences [4] which define the "Attributes of a Global Engineer". These reports do not only point towards engineering education challenges and the requirements to address them, they also refer to the critical gap between what needs to be taught and what is taught in engineering schools. However, it is up to the institution, academic staff, and students to construct and develop a curriculum and learning environment that enhances the "global engineer" attributes.

This paper reports a literature review with aim to (1) understand the different stakeholders' perspectives, namely students, educators, and employers, (2) understand the profile of the global engineer (i.e. knowledge, competences, and skills), and (3) outline and discuss learning strategies. As a result, the paper presents the main gaps in the existing knowledge, formulates research hypothesis, and proposes a research design for a follow up empirical study to investigate further the engineering grand challenges, the attributes needed to solve them, and the learning environments required.

Using thematic keywords such as "engineering education challenges", "engineering education students' perspectives", "engineering education industry perspectives", etc. relevant literature was searched. Different bibliographic databases and engineering education journals were used. In this paper, we focus mainly on research articles and books. The following three sections address the different themes referred to in the above aims.

1 STUDENTS' AND INDUSTRY PERSPECTIVES ON ENGINEERING EDUCATION

Studies, concept position papers, and reviews involving engineering education stakeholders, namely students, academic staff and industry, are not new in the literature (see for example [5]–[9]). These publications explore different themes and provide valuable knowledge to develop and innovate engineering education further. Curriculum reforms, preparedness for professional life, type of attributes are examples of the themes explored (see for example [10], [11]).

Several empirical studies focus on investigating curriculum reforms and use students' grades and ratings to validate the changes implemented. They show efforts, mainly at course and programme levels, in changing engineering education and are built on the need to develop the right skills for the professional practice (see for example [12]–[14]). Some studies explore students' perspectives about their qualification and preparedness for professional life using surveys and interviews as methods (see for example [5]–[7]). This paper focuses on the latter literature in order to investigate industry and students' perspective on engineering education and preparation for the profession. The publications addressing specifically industry perspectives involve mainly literature reviews and position papers [5], [8], [15]. They do not focus so much on what kind of learning pedagogies but give hints of features learning environments should recreate. On the other hand, it seems that there is a lack of studies taking the academic staff perspectives on these themes. Independently of the type of stakeholder, all publications point to how engineers should be educated, their professional roles and contexts, as well as the attributes needed to thrive. They also provide insights to the discourses and interpretations the different groups of stakeholders have about skills needed and their enhancement.

McMasters [8], [15] refers to the engineering profession as an "*ever-evolving*", "*ever-volatile*" and "*ever-changing*" enterprise, which is a response to society's demands. Consequently, there is a need for close collaboration between governments, industry and academe in order to: (1) define and discuss the needed steps to supply well-prepared graduates with (2) the right skills and motivation to thrive in an engineering career. These include a reflection on how to attract and retain engineering students and how they are being educated. Focusing on the latter, the author uses the evolution of aerospace engineering, the professional environment and demands (namely market, environment and social demands) to present the 21st century engineer and the type and scope of the attributes needed.

Presently, one of the major developments in engineering professions is the invention of *integrated product teams* (IPT) and *integrated product development* (IPD)[2], where processes of design, manufacturing and marketing are integrated by bringing together interdisciplinary groups (including customers) [5], [8], [16]–[18]. This leads, for example, to a re-conceptualization of teamwork and systems thinking as attributes, namely in what kind of teams students form, what kind of problems and contexts they learn from and the subsequent skills enhanced (e.g. creative and critical thinking, problem solving, self-directed learning, etc.) [5], [6], [8]. Other attributes are creativity and innovation that are primary requirements for rapid technological breakthroughs [8].

Almi *et al.* [6] refers to rapid advancement of software engineering and the gap between engineering education and industry requirements. The latter consider that young engineers are not ready to face “real life” due to a highly demanding environment where it is required for graduates to work under pressure, have good communication skills, and be able to follow processes, have a solid work ethic, and project management skills.

In sum, there are few studies investigating the industry and employers perspectives about attributes.

The emphasis is not only on the set of attributes needed, but also on how they intertwine and the formats assumed in connection to professional practice (i.e. breadth and depth). From the industry perspective, two type of attributes are emphasised: teamwork and (design) system thinking.

Martin *et al.* [5] investigates engineering graduates perspectives of how well they were prepared for work in industry. The results show that students perceived their strengths in technical background, problem solving, formal communication and life-long learning attributes. The study also identifies weaknesses areas, which are: work in multi-disciplinary teams, leadership, practical preparation and management skills. Similarly, to the industry perspective, teamwork appears as an important attribute and it is presented along with good interpersonal skills (e.g. listening skills, sharing information, cooperation with office colleagues, and cope with office dynamics) and leadership. Furthermore, teamwork is discussed from two perspectives: horizontal (e.g. teams formed by different engineering experts) and vertical (e.g. collaboration with different levels within company).

Another attribute pointed to is lifelong learning which is defined as the ability to *adapt to changing work environments, learn new skills, and assess one’s own abilities* [5, p. 169]. Once more, this attribute is very much aligned with the industry perspective and the current vision of the engineering profession, i.e. ever-volatile enterprise.

Hasse *et al.* [7] defined four types of engineer groups based on students perceived relevance of technical skills (e.g. science and mathematics) and non-technical skills (e.g. interpersonal and professional skills). The four groups vary from (i) high focus on technical skills, (ii) high focus on both technical and non-technical skills, (iii) high focus on non-technical skills. The groups profile depended on different factors, namely gender, confidence, and motivation for the engineering profession. Furthermore, this study shows the heterogeneity among engineering students and the propensity of the

[2] See for example the Principles of Integrated Product Development at http://www.npd-solutions.com/

at risk group to drop out. Therefore, it is important to consider the curriculum and learning experiences provided to engineering students in order to attract, retain, and motivate them. In the professional setting, engineers assume different and complex roles and work in multidisciplinary teams; consequently, the way students are educated should not only mimic these conditions but also provide possibilities for students to create their “portfolio of attributes”. Streiner *et al.* [19] refers to relevance of multicultural and international learning experiences as a means to prepare students to a globalized profession.

In summary, the literature refers to reasons it is needed to qualify engineers with attributes beyond the technical ones. From the perspectives considered, literature shows an overlap on the types of attributes needed (i.e. breadth) and their different landscapes of practice (i.e. depth). Consequently, educating engineers for the 21st century is not only about equipping students with adequate attributes but also takes into consideration the heterogeneity of motivations and exposing them to a diversity of learning experiences which enhance the needed attributes and mimic the professional practice. To achieve this, it is important how academia collaborates with industry and the surrounding communities. Another interesting point worth referring to is that most references and studies cited refer to Australia, US and European contexts. There is a lacking perspective from Asian and African contexts and engineering challenges.

2 PROFILE OF THE GLOBAL ENGINEER

The profile of a global engineer consists of the attributes necessary for the engineer to successfully interweave the technical, business, human, cultural, and environmental aspects of society’s problems to bring forth solutions for grand challenges. This literature review seeks to identify and validate those attributes. A comprehensive work was completed by the Global Engineers Deans Council (GEDC) [4] to create a list of attributes. Following is a description of the list and perspectives brought from a variety of recent works to both confirm the list and identify any aspects of the list that might need further expansion.

The *Attributes of a Global Engineer Project* is the work of the International Engineering Education special interest group, a sub-group of the American Society of Engineering Education’s (ASEE) corporate membership council. This group, in coordination with the GEDC, the International Federation of Engineering Education Societies (IFEES), and supported by the Boeing Company, developed and validated a list of the “desired competencies and characteristics needed by engineers to effectively live, work, and perform in a global context [20].” We use these attributes as the point of departure for this study. The attributes, now commonly associated with the GEDC are paraphrased in table 1. Validation starts with comparing the attributes to the expectations of engineering outcomes. Two such expectations are the graduate attributes of the Washington Accord [21] and the ABET student learning outcomes [22]. All of these attributes and outcomes are accounted for in the GEDC attributes of the global engineer.

Table 1. Attributes of Global Engineer

• Technical	Think individually and cooperatively
Fundamental principle understanding	Positive self image and confidence
Technical literacy	Initiative and willingness to learn
Product life-cycle	• Interpersonal

Project management	Functions on team
• Professional	Mentors others
Communicate in variety of ways	• Cross-cultural
Communicate to tech and non-tech audiences	Political, social, economic perspectives
High professional competence	Applies business and ethical norms in context
Continuous improvement	Global perspective
Effective decision making	Language fluency
• Personal	Interdisciplinary perspective
Think creatively and critically	

In 2004, the National Academy of Engineering (NAE) [1] published the attributes of engineers in 2020 as a forward-looking vision on needs of the practicing engineer. Now, as 2020 is approaching, the vision provides grounding to the new work of the GEDC. The paraphrased list from the Engineer 2020 includes: strong analytical skills, practical ingenuity, creativity, communication, business and management, leadership, high ethical standards, professionalism, dynamism, agility, resilience, flexibility, and lifelong learning [1]. Of this list, most items are explicitly presented in the attributes of the global engineer, however, leadership, practical ingenuity and dynamism, agility, resilience, and flexibility are not explicit.

While not stated in the GEDC attributes list, the comprehensive list would align with the skills commonly associated with effective leadership such as communication, professional competence, effective decision making, positive self-image, etc. With regards to practical ingenuity, the NAE describes ingenuity as “skill in planning, combining, and adapting… to solve problems” [1]. This concept could be derived from the GEDC attributes, but perhaps is important enough to be explicitly stated when considering the grand challenges.

Thomas Friedman in *Thank you for Being Late* [23], identifies how, for the first time in history, the advances in technology (due to rapid growth in computer speeds, data storage, software, and sensing capabilities) are outpacing the abilities of humans to adapt to change. This phenomenon highlights the need for engineers to possess the attributes of dynamism, agility, resilience, and flexibility in order to quickly adapt to problems and find solutions in new contexts.

We believe that the concepts of practical ingenuity and dynamism, agility, resiliency, and flexibility should be made explicit when addressing the grand challenges as opposed to being implicit as combinations of the GEDC global attributes.

In *Educating Engineers* in 2009 [24], Sheri Sheppard *et al.* describe the need to majorly transform engineering education to better align with the needs of engineering practice. Sheppard *et al.* contend that the new-century engineer must have the attributes presented by the NAE in Engineer 2020 and also be focused on the professional values as described in the many codes of conduct published by professional society. In particular, these values are being competent in one’s own work, not misrepresenting one’s own competences, and continuing to build one’s own competence [24]. The competences themselves are quite well presented by the GEDC global attributes; however, Sheppard's *et al.* work brings to light the need for the engineer to explicitly "own" these competences through a self-analysis of strengths, weaknesses, and continuous improvement. This explicit identity of one's self as an engineer would fall into the "personal category" of the GEDC attributes and is one that we see as essential for an engineer to be able to develop.

Al-Atabi, a member of the GEDC, wrote a handbook for Conceive, Design, Implement, and Operate (CDIO[3]) implementation, *Think Like an Engineer* [25]. Beyond the CDIO explanations, Al-Atabi includes a chapter on emotional intelligence. Self-awareness, social awareness, empathy, and relationship management are addressed in this chapter. These attributes lead the engineer to be able to understand equity and empower inclusivity. The 2014 comprehensive *Cambridge Handbook of Engineering Education Research* [26] dedicates a complete section to diversity and inclusiveness. In many parts of the world, the engineering profession suffers from a lack of diversity. Inclusivity emerges as a necessary attribute for the global engineers to both navigate relationships within the profession and to understand the contexts for problem solutions.

In the *Making of an Expert Engineer* [27], James Trevelyan interviewed and observed practicing engineers to distinguish the patterns associated with engineers who were well regarded to be "exceptional performers". Synthesized results identify attributes associated with successful practice. The foundations he identified are: engineering and business science, tacit ingenuity, and accurate perception skills. Further pointed out is the "extent to which engineering practice relies on human performances, particularly collaborative performances" [27]. Through a comprehensive analysis and description, Trevelyan both validates the majority of attributes put forth in the GEDC global list and brings further light to the issues of self-awareness and environmental sustainability. As was brought to light by Engineer 2020, the concept of ingenuity as an explicit attribute is further verified as well.

Looking to the future of engineering education, Goldberg and Somerville published *A Whole New Engineer: The Coming Revolution in Engineering Education* [28]. The authors categorize the aspects of an engineer in a way substantially different than the lists of attributes put forth by the other sources in the literature. They identify the engineer has having six minds. They are: 1) analytical mind, 2) design mind, 3) linguistic mind, 4) people mind, 5) body mind, and 6) mindful mind. The global attributes from GEDC could be associated with each of these minds. However, some of these "minds" receive little attention in the global attributes. In particular, the people mind and the mindful mind address the need to understand one's self and others and how these human connections evolve into the improvements engineers make for society. Additionally, the mindful mind expands the global attribute of "willingness to learn" to include the ability to reflect and direct one's own learning [28]. This expands the idea of lifelong learning to a more comprehensive model of self-directed learning [29].

The perspectives of the GEDC came from the perspectives of corporate members and academic leaders. They received inspiration from the NAE Engineer 2020 [1], but in retrospect we reached back to that publication to identify the importance of ideas not

[3] CDIO is a framework intended to educate the upcoming generations of engineers. The CDIO syllabus uses four areas to identify the development of engineers: 1) disciplinary knowledge and reasoning, 2) personal and professional skills and attributes, 3) interpersonal skills: teamwork and communication, 4) conceiving, designing, implementing, and operating systems in the enterprise, societal and environmental context [37].

explicitly stated in the GEDC list. Sheppard addressed the perspective of designing engineering education and highlighted the attributes needed to meet the professional societies' codes. Trevelyan took the perspective of expertise in practice. Goldberg and Somerville were looking at a coming revolution in engineering education and how the whole new engineer will be developed. From the wide variety of perspectives in this literature, we are able to find complete validation of the global engineer attributes list. Further we found evidence that there are parts of the list that need expansion in order for the global engineer to face the grand challenges. The modified list is included below with additions underlined.

Technical: Engineering-related knowledge, skills, and abilities needed for success

- Demonstrates an understanding of engineering, science, and mathematics fundamentals
- Demonstrates an understanding of information technology, digital competency, information literacy, and systems thinking
- Demonstrates an understanding of stages/phases of product lifecycle (design, prototyping, testing, production, distribution channels, supplier management, etc.)
- Demonstrates an understanding of project planning, management, and the impacts of projects on various stakeholder groups (project team members, project sponsor, project client, end users, etc.)
- Applies practical ingenuity to the solution of complex problems

Professional: Workplace related competencies for global performance

- Communicates effectively in a variety of different ways, methods, and media (written, verbal/oral, graphic, listening, electronically, etc.)
- Communicates effectively to both technical and non-technical audiences
- Maintains a high-level of professional competence
- Embraces a commitment to quality principles/standards and continuous improvement
- Applies personal and professional judgment in effectively making decisions and managing risks

Personal: Individual characteristics needed for global flexibility

- Possesses the ability to think both critically and creatively
- Possesses the ability to think both individually and cooperatively
- Maintains a positive self-image and possesses positive self-confidence
- Possesses a self-awareness and capability to identify one's own strengths and weaknesses in order to manage continuous personal development
- Shows initiative and demonstrates a willingness, and capability to learn self-directedly
- Demonstrates perseverance, urgency, resourcefulness, and flexibility

Interpersonal: Skills and perspectives to work on interdependent global teams

- Functions effectively on a team (understands team goals, contributes effectively to team work, supports team decisions, respects team members, etc.)
- Mentors or helps others accomplish goals/tasks
- Acts inclusively and equitably

Cross-cultural: Society and cultural understanding to embrace diverse viewpoints

- Demonstrates an understanding of political, social, economic, and environmental/sustainability perspectives

- Demonstrates an understanding of the ethical and business norms and applies norms effectively in a given context (organization, industry, country, etc.)
- Possesses an international/global perspective
- Possesses fluency in at least two languages
- Embraces an interdisciplinary/multidisciplinary perspective

Figure 1. Profile of the global engineer – modified from GEDC global engineer project

3 LEARNING STRATEGIES AND GOOD PRACTICE EXAMPLES

Clearly, twenty first engineering graduates must be skilled in competencies beyond the traditional technical competencies of the engineering profession [20]. Engineering education must be comprised of three key axes: technical, professional, and global skills [30]. This section will look at what are the learning principles to develop the needed attributes, what are good curricular examples, and how are they organized.

The engineering education system of the future will need to be broad-based to provide the needed flexibility and adaptability for the every changing technology and environment. At the same time, the current gap needs to be addressed between what needs to be taught and what is taught in engineering schools.

Goldberg & Sommerville, in *A Whole New Engineer: The Coming Revolution in Engineering Education* [28], provide three important historical transformation lessons: 1) changes cannot be small, minor tweaks to curriculum do not work; 2) students are sensitive how genuine the education system is to the work world; and 3) approaches and strategies of change from the past have failed to bring about desired change. This has resulted in engineering education being severely misaligned with the times.

While there may be a developing broad agreement within the engineering community that a need exists to better prepare engineers for global practice [31], there is less agreement as to what educational experiences will be best develop the desired attributes in graduates and even more so in terms of the means and metrics to judge it.

The GEDC identified the following curricular considerations or learning principles for developing the competencies for twenty first century graduates:

- Experience in an increasingly distributed team context, which crosses country and cultural boundaries.
- Promote awareness of the broader impacts of engineering
- Broader perspective than is available in many current curricula
- institutions need to assess their curriculum in its ability to meet needs
- Need for industry involvement
- Recent trend in engineering education involving project-based courses, especially with projects overseas

They also recognize that “it is up to the institution, academic staff, and students to construct and develop a curriculum and learning environment that enhances the ‘global engineer” attributes’” [20].

A review of engineering literature readily support for each of the curricular considerations. Trevelyan [27] in *The Making of an Expert Engineer* identifies one of the issues with current engineering curriculum is that few, if any, engineering education have extensive engineering practice (beyond laboratory research). More need to consider professional practice experiences such as the project-based consideration identified by GEDC. Trevelyan also identifies issues with rewarding individual achievements versus rewarding results through working with others, reinforcing the need for more curricular time focused on working in a team context that closely reflect the professional work environment.

Al-Atabi [25] identifies with the second and third considerations by calling for a focus on system level thinking and application to education along through a team learning experience utilizing real projects and holistic learning. Grasso and Martinelli [32] also identify the need for engineers to practice more holistic thinking and avoid the prevalent and needless limitation of solution spaces to only those that contain technological answers while sorely lacking consideration for the many other contextual factors involved with actual engineering professional practice.

Sheppard, *et al.* [24], in *Educating Engineers: Designing for the Future of the Field,* emphasis the need to engage practitioners to bring professional practice to the center of the student engineering education expertise. They state that "curriculum changes focused on introducing educational experiences to develop attitudes and skills in concert with disciplinary-oriented scientific and technical knowledge are difficult to effect". Faculty must work in an interactive fashion, just like practicing engineers, to create academic programing that is better aligned with professional practice across the entire student curriculum and within individual courses, "by reflecting, assessing, debating, designing, and prototyping a truly networked undergraduate engineering program, one that engages both the teacher and student in learning in the context of professional design".

Educating the Engineer of 2020 [3] provides a similar guiding strategy for curriculum improvement and proposes that effective improvements for engineering education must focus on the whole educational system and move beyond the current ineffective approach of incremental improvements to single aspects of complex curriculums. The publication also promotes a systems level educational change.

What are some good education examples based on these learning processes? How is the curriculum organized? The 2012 Graham report [33] and the 2010 and 2013 UNESCO reports [2], [34] identify problem/project-based learning (PBL) as an integral part of successful curricular changes and as one of the key steps in the "design and implementation of an effective engineering curriculum," respectfully. Graham's study revealed that a majority of the highly regarded examples of change involved the use of PBL within an "authentic, professional engineering context." Project-based learning is a core theme throughout the 2013 UNESCO report to achieve the Washington Accord graduate attributes and to provide the "personal learning experiences" needed for the transformation of engineering education. It identifies that,

> "Project Based Learning (PBL) is a widely reported approach to address the need to change engineering education, from the formal presentation of technical material to a student experience model. It provides activities, which simulate the role and responsibilities of practicing engineers, and develops the general graduate attributes that have been identified as essential. […] This relates more closely to a realistic engineering environment, provides an opportunity for students to learn from each other, and assists the development of the essential graduate attributes of team- work and leadership."

The Cambridge Handbook of Engineering Education Research [26] also positions PBL as an educational practice worth consideration. The second section of the handbook, "Engineering Learning Mechanisms and Approaches," focuses on approaches for transitioning from traditional to a variety of active student learning approaches in engineering education. This section begins with an explanation of problem-based and project-based learning models by Kolmos and de Graaff as an example of the curricular approaches engineering education should be considering [35].

Some good examples of PBL were part of a 2014-2015 a series, entitled PBL History and Diversity, broadcasted from the UNESCO Center for PBL at Aalborg University. The series has been captured in a soon to be published book, *PBL in Engineering Education: International Perspectives on Curricular Change* [11]. The book begins with defining PBL and providing a historic perspective of PBL. It is based on the 40+ years of PBL at Aalborg University and then continues with six additional models and practices of PBL implementation at higher education institutions across the world.

Connecting these PBL models back to the learning principles identified by the GEDC, they all:

- Have an integrative approach that utilize a team-based approach
- Through the real-life context of the work, promote awareness of the broader impacts of engineering and also develops the broader perspective for students
- Due to the professional practice nature of the experiences, industry or real-life customers/projects are needed. Student performance on these project provides some assessment on the curriculum's ability to meet desired educational needs
- Certainly incorporates the use of project-based courses

Not only do these examples represent the potential for PBL to develop the attributes of a global engineer, the global application represented addresses a critique for the tendency towards only North American or European perspectives for the global approaches and impacts of engineering [36]; clearly from these examples, PBL represents the cultural perspectives from around the globe. If attributes desired are those of a global engineer, any approaches to improvement of engineering education must fit into all the cultures of the world.

4 MAIN CONCLUSIONS

This paper presents a literature review regarding the attributes needed to address engineering global challenges. It starts by looking into students and industry perspectives where the evolution of professional practice aligned with society change and technological development emphasise the attributes needed such as multi- and interdisciplinary teamwork and systems thinking. The literature review not only define and validate, in detail, the breadth and depth of these attributes but also refers to the type of learning environment and experiences needed. The learning environment and experiences emphasise students' active role and participation in the learning process and curriculum constructions like problem based, project organised learning (PBL) advocate. Even though curricular transformations and research about the ways 21st century engineers are educated have been addressed in the engineering education community, there are some remaining questions namely: (1) Are the curriculum changes sufficient to address the societal challenges and produce engineers with right qualifications? (2) How are the attributes defined as learning outcomes and enhanced (in both breadth and depth) in curricular changes? (3) How do the different stakeholders define and prioritize the attributes listed? (4) How well do students feel prepared to perform in global contexts? These are examples of emergent questions to investigate further, taking both qualitative and quantitative methods and in diverse parts of world and learning environments. By doing so, engineering education research has the knowledge and tools to become proactive towards societal changes rather than reactive.

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The European Journal of Engineering Education as a venue for engineering education research publication: a meta view

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ABSTRACT

Responding to growing international interest in the growth and evolution of engineering education research (EER), this paper reviews six studies of the European Journal of Engineering Education (EJEE) published from 2004 to the present and synthesizes their findings. It observes a steady movement towards more research-based content over the 40 years of the journals existence, one that has involved an expanding and increasingly connected community of scholars. It notes that its authors are not restricted to European scholars but are drawn from a global EER community. The paper points to the most influential topics for EJEE authors both in the 1990s and in more recent years. It also indicates some specific areas for authors to improve the reporting of research submitted to the journal.

Conference Key Areas: Engineering Education Research

Keywords: engineering education research; citation analysis; bibliometric analysis,globalization.

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INTRODUCTION

Over the last decade there has been increasing interest in mapping the overall evolution of EER as a field of inquiry. Lohman and Froyd[1] looked at the process from a predominantly U.S. perspective, van Hattum-Janssen et al. [2] studied EER evolution in Portugal while Edstrom et al. [3] have characterised it in the Nordic context. In parallel with this tendency, there have been a number of more specific studies of research published in the main EER journals. This paper examines 6 published studies that considered aspects of the European Journal of Engineering Education (EJEE) and synthesises their main findings and draws out conclusions about the journal as a publication venue for engineering education research.

1 RESEARCH QUESTION

What can be concluded about the European Journal of Engineering Education as a venue for EER publication from a review of empirical studies of the journal's content?

2 METHODOLOGY

A systematic review approach [4] was adopted to identify relevant publications, these were then analysed, and their findings synthesized.

3 PROCEDURE

Three databases ERIC, Google Scholar and B-on (a Portuguese database accessing 26 academic and scientific data collections) were searched with the strings indicated in Appendix 1. 44 papers were identified that provided some analysis of EJEE articles and when these were read by the authors, 14 were selected on the basis that they included empirical bibliometric data on the journal's articles. As the authors wished to focus on studies presenting original research that was based on empirical bibliometric data, 8 of these 14 were eliminated on the basis of the following criteria:

- editorials (2);
- were previous conference papers by authors where more complete data was published in a later journal article (4);
- analyzed less than 30 EJEE papers (2).

The remaining 6 studies were selected for analysis in this study (see Table 1).

In the next section, we will briefly describe each of the studies (here listed alphabetically based on first-author name) and summarize their main findings.

Table 1. Details of the 6 studies analysed

Title of study	Authors	Year published	Years analysed	# of EJEE articles analysed
1. Women Studies in Engineering Education: Content Analysis in Three Refereed Journals [5]	Chou	2013	2000 to 2009	450 (approx.)
2. Detecting phase transitions in community structures using big data analysis of the engineering education research landscape: a European perspective [6]	Madhavan& Williams	2016	1993 to 2014	1028
3. How authors did it–a methodological analysis of recent engineering education research papers in the European Journal of Engineering Education [7].	Malmi et al.	2016	2009, 2010, 2013	155
4. Engineering education in Europe and the USA: An analysis of two journals [8].	Osorio & Osorio	2004	1998 to 2000	150 (approx.)
5. Engineering education research in European Journal of Engineering Education and Journal of Engineering Education: citation and reference discipline analysis [9]	Wankat, Williams & Neto	2014	1975, 1983, 1993, 2003, 2013	187
6. Not so global: a bibliometric look at engineering education research [10]	Williams, Wankat& Neto	2016	2010 to 2014	251

4 FINDINGS

1. Women Studies in Engineering Education: Content Analysis in Three Refereed Journals

The author applied content analysis to articles in EJEE and two other journals: the Journal of Engineering Education (JEE) and the International Journal of Engineering Education (IJEE) with the aim of investigating the research characteristics found in women’s studies publications.

He observed that “unless the editorial teams for engineering journals create a special issue for research on the topic, the number of annual publications for women studies is limited”. In the decade under study the author noted that the number of such studies published was similar across the 3 journals (18, 17 and 16 for EJEE, JEE and IJEE). He concluded that "analysing female engineering students' learning experiences is a mainstream research trend. Recruitment and career development for female college engineering students are less discussed research topics.” It was also noted that in the articles analysed, JEE published predominantly US authors whereas the other two tended to publish authors from Europe, the US and from South Asia.

2. **Detecting phase transitions in community structures using big data analysis of the engineering education research landscape: a European perspective.**

The authors applied a big data analysis and network visualization techniques to examine the evolution of EER via a study of articles published in EJEE and IJEE assuming that as the two journals are published in Europe that they broadly reflect trends in European research.

The authors note that “the engineering education community publishing in these two journals has grown significantly. Starting with just 912 authors in 1997 with 4.066 connections, the community has grown to 15,577 authors with a staggering 114,398 connections.” Nevertheless, they comment that “there is still a significant amount of community building that needs to take place to connect various parts of the European and international EER community (…) there is currently a significant potential to connect and grow within this network. Given the growth of the network over the years of our analyses, the effect or ability of the individual within the larger context of the community remains particularly low. This may be a significant bottleneck to achieving major advances within the international community.” They conclude by suggesting that “the topical maps show that the European community is broad and diverse – but may lack a particular focus or may need to focus on some key big ideas to promote propagation.”

3. **How authors did it – a methodological analysis of recent engineering education research papers in the European Journal of Engineering Education.**

This study investigated research processes applied in recent publications in EJEE to explore how papers link to theoretical work and how research processes have been designed and reported. The paper’s authors concluded that EJEE papers build moderately on a wide selection of theoretical work and that while a great majority of papers have a clear research strategy, data analysis methods have tended to be mostly simple descriptive statistics or simple/undocumented qualitative research methods. They further noted that in a significant number of papers there were “shortcomings in reporting research questions, methodology and limitations of studies”.

4. **Engineering education in Europe and the USA: An analysis of two journals.**

The paper presents a comparison between EJEE and JEE in the late 90s based around a content-analysis approach. It found that there was a strong similarity in the top topics covered by both journals: “courses,” “programs,” “assessment,” and “society” account for 52.8% in JEE, and 59.7% in EJEE. On the other hand, “The topic “women and minorities” in engineering education appears several times in JEE. This reflects the interest of this topic in American education. By contrast, in EJEE there are no articles covering these subjects.” It is interesting to note from the Chou study that in the subsequent decade EJEE went on to be comparable with JEE in coverage of this sub-field.

The international nature of EJEE was indicated by the diverse number of countries represented amongst its authors while 90% of JEE authors came from the United States and excluding Canada (3.8%), other countries of the world were represented in JEE in only 6.2% of the papers. The European publication had a high count of papers about the topic “countries” (papers about a specific country) (…) the subject term “countries” appears only once in the American publication. This is another indication of the international orientation of EJEE.

5. Engineering education research in European Journal of Engineering Education and Journal of Engineering Education: citation and reference discipline analysis

The study employed citation and reference discipline analysis to trace the evolution of the research published by EJEE and JEE over a 40-year period. It did so by sampling papers published in issues of each journal at 10-year intervals from the 1970s to the present day. It focused on changes over time of the type of scholarship found in the articles samples. It also investigated the disciplinary background of the references cited by article authors as underpinning their research (reference disciplines).

Its authors concluded that “both journals followed similar trends. They progressed from opinion essays, reports, and descriptive articles to research articles. JEE and EJEE both became more frequently cited. There was a qualitative evolution in breath of scholarship with increasingly interdisciplinary research articles with more collaboration and more references. This is more accentuated in JEE.”

They also noted that “the citation data and reference discipline data show that there has been a notable tendency in both journals, but most particularly in the case of JEE, to cite and build upon research in other disciplines” They went on to caution that “while some will see this as a welcome indication of growing interdisciplinarity and developing maturity of EER as a field of research, others may perceive it as a sign that the published articles may be losing their engineering and scientific character and becoming less accessible to the broad mass of engineering educators”.

With regard to the affiliations of the authors published in the two journals, the findings were similar to those of the earlier Osorio & Osorio study in that “EJEE currently publishes authors from all over the world. EJEE authors in the issues sampled have come from the following 44 countries: Algeria, Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, Colombia, Cyprus, Czechoslovakia (before the split into the Czech Republic and Slovakia), Denmark, Finland, France, Germany, Ghana, Greece, Hong Kong, Hungary, India, Iraq, Ireland, Israel, Italy, Japan, Jordan, Kazakhstan, Korea, Lithuania, Malaysia, Malta, Norway, Poland, Portugal, Saudi Arabia, Slovenia, South Africa, Spain, Sweden, Switzerland, the Netherlands, Trinidad, UK, and USA.

The geographical spread of the authors of JEE is significantly less broad than that of EJEE. If the data is representative of all years, 97.7% of the authors are from the USA and Canada and the remaining eight countries (Denmark, Greece, Hong Kong, India, Nigeria, Singapore, Thailand, and UK) share the remaining 2.3%”.

6. Not so global: a bibliometric look at engineering education research

Given that EJEE and JEE are published by the European Society for Engineering Education (SEFI) and the American Society for Engineering Education (ASEE) respectively, it is perhaps not surprising that 4 of the 6 studies that were sampled for this analysis include some comparison between the two journals. The final study analysed here focused on the global character of publications in the two journals along with those published in the annual conference proceedings of the two societies (4321 papers in all).

The authors present lists of the most cited authors in each of the four publication venues. Considering the fields of scholarship of the most cited scholars, they conclude that while work on active and collaborative learning is highly influential on both sides of the Atlantic, PBL (project and problem based learning) is a major reference for European scholars.

The principal finding of this comparative study was that “citations in ASEE conferences are dominated by sources with US affiliations, whereas the SEFI data show that while US sources are frequently cited, European and other authors are also well represented. With regard to the journals JEE and EJEE, a similar pattern is observed. These results suggest that, in citation terms, European EER is relatively global but US EER is not”. The authors conclude by suggesting that if the EER community is to aspire to quality scholarship, there needs to be debate around how such issues can be tackled. An initial sign of such a debate getting underway could be seen in the fact that JEE later invited two of the authors of that study to write a guest editorial for its October 2016 issue discussing how such a silo effect could have come about [11].

5 CONCLUSION

The journal has been published by SEFI for over 40 years and while in the earlier decades it served mainly as a house organ to publish information for members and opinion articles, the past fifteen years have seena steady movement towards more research-based content and this has come from a rapidly expanding and increasingly connected community of scholars. Over the last five years’ citation analysis suggests that the research around the topics of active and collaborative learning and of PBL have been the most influential to the authors published in the journal. Gender and diversity issues have been receiving growing attention since the turn of the century.

Authors published in the journal are not restricted to European scholars but are drawn from a global EER community and this is also the case with those who are cited in its research articles. Empirical data presented in the studies do indicate that EJEE has been progressively strengthening as a venue for EER publication. Nevertheless, authors could improve the reporting of research submitted to the journal by giving more attention to the presentation of research questions, methodology and the limitations of studies.

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APPENDIX 1

Table A1. Strings used for searching the databases consulted

Search strings	Total hits			Hits with analysis of EJEE articles		
	ERIC	B-on	Google Scholar	ERIC	B-on	Google Scholar
"citation analysis"; "European Journal of Engineering Education"	1	11	52	0	8	26
"bibliometric analysis"; "European Journal of Engineering Education"	1	6	24	0	5	18

Experiences on taking electronic exams at Tampere University of Technology

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ABSTRACT

In this case study, we have gathered teacher and student experiences on electronic examining system EXAM at a technical university. We will introduce the electronic examination system EXAM, the process of completing an exam and data of user experiences. Computer-based exams are often considered hard or even impossible to use in engineering subject exams but in this research it is shown that both engineering teachers and students find electronic exams easy to use and adaptable. In the spring of 2017 EXAM consortium implemented a national student feedback survey on EXAM. Feedback was collected from almost 750 students and 40 teachers of Tampere University of Technology and the data gathered is analysed and shown in this study. The results indicate that teachers as well as students are generally very satisfied with the electronic exam system and often prefer the electronic version over the traditional paper version.

Conference Key Areas: Engineering Education Research, Curriculum Development

Keywords: Electronic Examination, assessment, electronic assessment

INTRODUCTION

Different forms of electronic exams in assessment have been used in small-scale for several years at Tampere University of Technology. Because of the nature of engineering studies, lecture hall exams done with a pen and a paper have been the mainstream method of executing final exams not only at Tampere University of Technology but also at other universities in Finland. A need to offer cost-effective examination service suitable for hundreds of students at the same time and lack of cost-effective, computer-aided examination environment was the main promoter to create new forms of electronic assessment environment.

In 2013 a group of universities started a common project to investigate and create a suitable concept for electronic examining. The project eventually created a new electronic exam system EXAM. EXAM concept consists of the exam software (EXAM), customized workstations and network environment, camera-controlled exam rooms and the process to supervise the students. Compared with other online exams e.g. home based exams, these exams done in special premises can be controlled and users are easily identified. Because students can freely choose their examination time and date and are not taking the exam at the same time, the capacity issues are not a problem.

Another big promoter of the electronic examination was the need to assess directly things that literally have been studied during the course, for example coding skills. Naturally, it is nearly impossible to test the use of software with a paper and pen. In an electronic exam, it is possible to take an exam using a specific software and demonstrate the knowledge in that.

It is known that the grading should consist of all the things that are happening in the classroom [4]. In case of courses where there are more than 100 participants, this is not possible but with an electronic exam and continuous assessment, this obstacle can be overcome.

1 BACKGROUND

1.1 EXAM Electronic exam concept

The EXAM electronic exam system is a software system and a concept, which has been developed in cooperation with universities, universities of applied sciences and government funded IT centre for science in Finland. At this moment, there are 24 higher education institutes taking part in the EXAM consortium. This means potential usage of over 200000 students nationally. The project started in 2013 and first deployment was made December 2014 at Tampere University of Technology.

EXAM concept consists of the exam software (EXAM), customized workstation and network environment, camera-controlled exam rooms and the process to supervise the students. EXAM consortium has mainly took part in specifying the EXAM system requirements and the examining process. Exam room implementations are done by each university themselves. EXAM software can be used as a cloud service and end-users access it via web browser so the workstation resources vary between universities depending on their needs. The actual exam comes available at specific time booked and at the specific workstation based on the IP address it has.

Real-time and recording sound and camera surveillance is used for the supervision of electronic exams. Depending on the organisation, also access control and random check-ups are used. Upon request, the students must authenticate their identity with a recognisable photo identification. Access information at Tampere University of Technology can be combined in order to verify the identity of the person taking the exam and to work out any misuse during exams. Potential cases of disturbance or cheating may be monitored in real time and the camera footage may also be viewed as needed. In Table 1, the EXAM system is presented as functions that are available to students, teachers and administrators.

Administrator	Teacher	Student
• course data interface • administration of exam rooms • user identification • study register interface for attainments	• creating exams (personal, general, maturity exams) • questions (essay, fill-in, multiple choice) and question bank • assessing and grading exams, also automatic grading • giving personal feedback	• booking an exam time • taking the exam • receiving personal feedback

Table 1. The functions of the EXAM system

1.2 EXAM process shortly

Examination process starts when a teacher creates an exam and e.g. specifies the exam period when students are allowed to take the exam and the length of the exam. The exam period can vary from one day to years depending on exam, assessment type and also on the capacity issues like amount of available computers.

Exam period also means that students are not taking the exam at the same time but can choose suitable time. Therefore, students can show their skills when they are personally well prepared for it. For teachers, it means that they have to create a question bank from where the questions can be randomized for the students. Also grading differs from traditional paper exams, which are all taken at the same time, as the questions vary and students take them during the whole period set for the exam.

When the student's exam booking is current, the student enters a camera-controlled exam room. Students are able to enter the examination rooms with their student cards. The exam comes available when the student logs in to the EXAM system.

After the student has submitted his/her exam, it comes available for the teacher’s evaluation. The evaluation includes assessing the answers, grading the exam and giving personal feedback.

An example of the EXAM examination classroom in Tampere University of Technology is presented in Figure 1.

Figure 1. Electronic examination system EXAM class room

1.3 Benefits of the EXAM system

EXAM system has been welcomed very warmly by students as well as by teachers and positive results in the questionnaire were expected from all the interest groups. Students are positive because they can write their answers electronically, they can choose the time of the exam to fit their own calendar and study rhythm and take the exam when they feel prepared. It is shown that students need very little support in the examination process but teachers often require support and encouragement in using electronic examination [1].

Teachers have praised that EXAM system helps them to actually test what is taught at a course. For example, programming students have to show their coding skills during the exam or a mathematics student takes an exam where questions are solved by using Matlab. Rytkönen et al. already showed that students are more willing to take an electronic exam and that it takes a shorter time to finish an electronic exam than a paper based one [3].

At Tampere University of Technology EXAM has shown to fit in such courses where teachers want automatically evaluated exams including multiple-choice questions, personal exams and exams where special software may be used. At the moment, the workstations are equipped with touch screens, Matlab, Mathcad, Pycharm development environment, Excel, Word, Paint and calculator so teachers are able to create exam questions utilizing all this software. This enables the use of various kinds of exams. Also continuous assessment is easily carried out by using weekly exams and midterm exams.

Due to the nature of engineering studies, the electronic exam is not always user-friendly way of assessing students' knowledge. In cases where the assessment requires calculations or drawing and electronic aids are not a standard and are not used in the classroom, the EXAM system is not yet at its best. Therefore, it is acknowledged that paper-based exams still have their place. But as users have been very happy with the system, all teachers at Tampere University of Technology are encouraged to trial electronic examination and efforts are made to increase the number of exams in the EXAM system.

2 DATA COLLECTION

2.1 Data collection and background information

EXAM consortium implemented a student feedback survey on exams taken in electronic exam room. The electronic exam feedback was collected during February and March 2017. At the Tampere University of Technology the questionnaire was sent to all students who had participated in at least one electronic exam during 2014-2017. Almost 750 students and 40 teachers answered the survey. Also the time stamps of exams taken were collected from the system and evaluated to give find out when students are taking exams.

As seen in the Figure 2. majority of the students who responded had taken 3-5 exams in the EXAM system and as seen in Figure 3, most of them prefer the electronic examination. There seemed to be no big difference on the preference of examination type regardless how many exams students have taken.

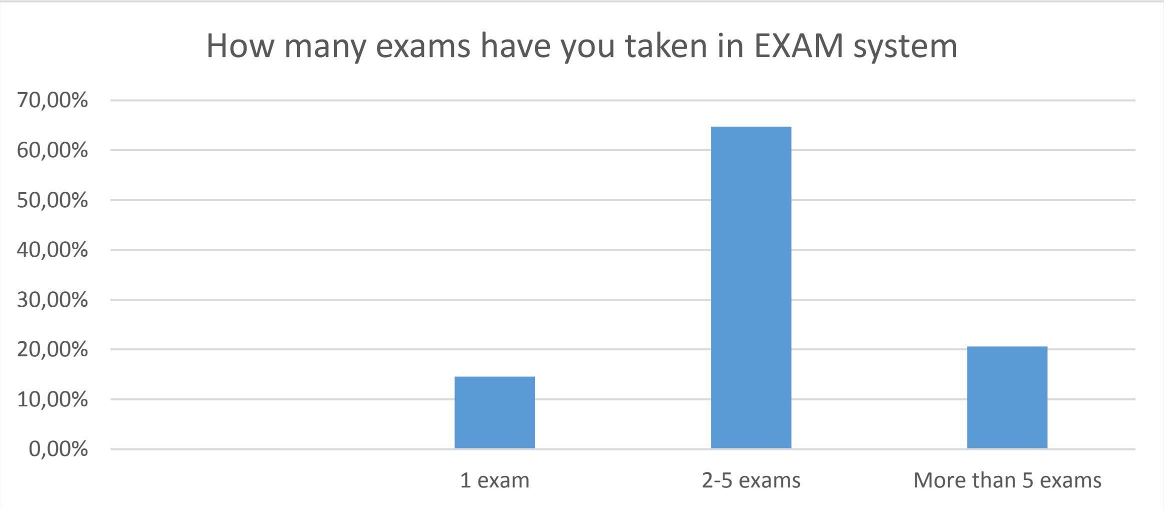

Figure 2. How many exams the students have taken in the EXAM system

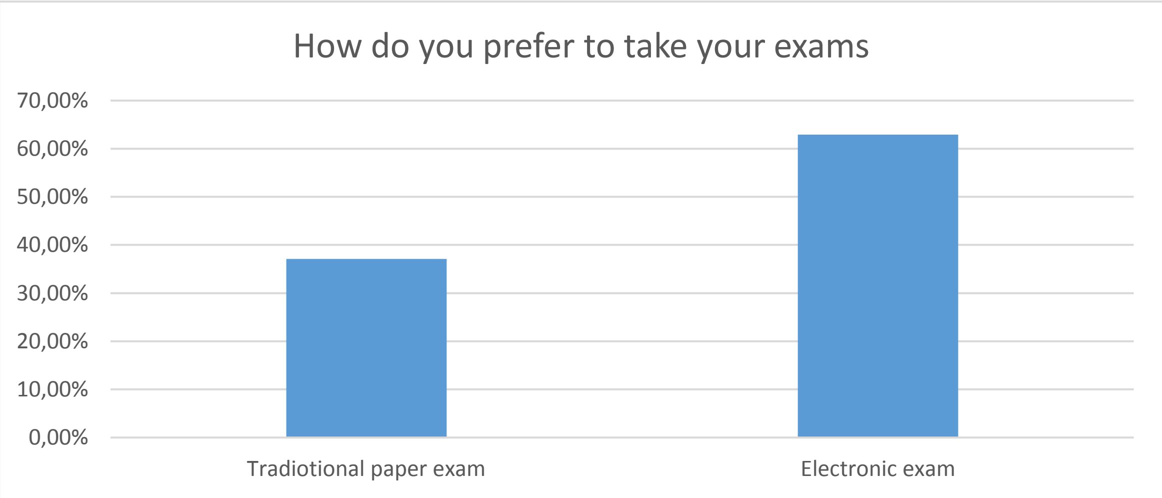

Figure 3. How students prefer to take their exams

Majority of the teachers that responded to the survey had also examined more than two exams in the system as seen in Figure 4. Thus we can expect them to have a solid experience in the system.

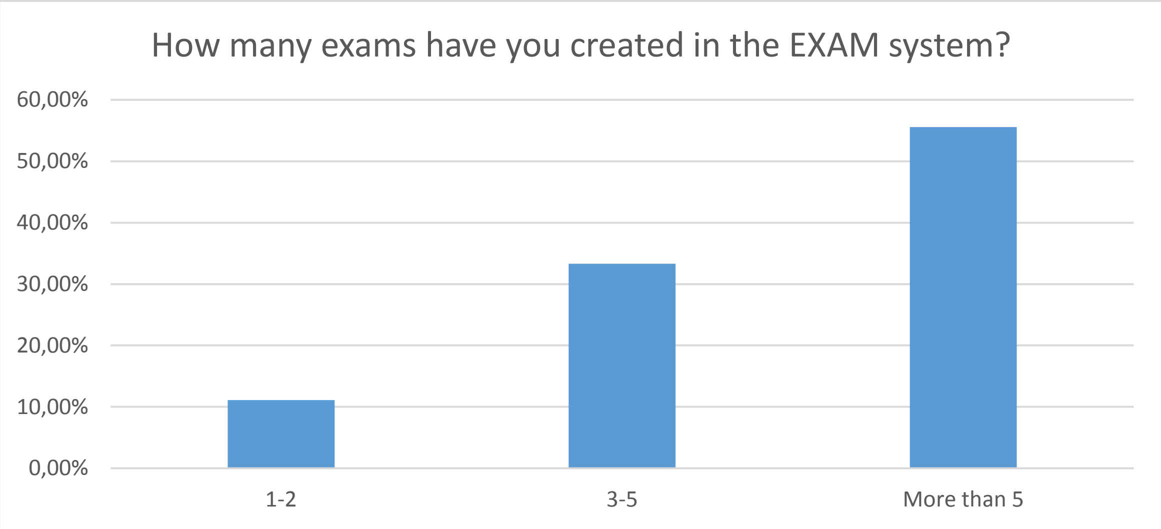

Figure 4. How many exams has a teacher examined in the EXAM system

3 FINDINGS

3.1 Students' views on EXAM system

As expected based on the previous research, most of the students were very content with the electronic examination system. They reported that signing up for an exam is easy, the exam was easy to take in the system and the examination class rooms are well functioning, as seen in Figure 5. We can conclude that taking an electronic exam in EXAM system is very easy to students as they evaluated the easiness on scale from very difficult (1) to very easy (4) and all averages were above 3,5.

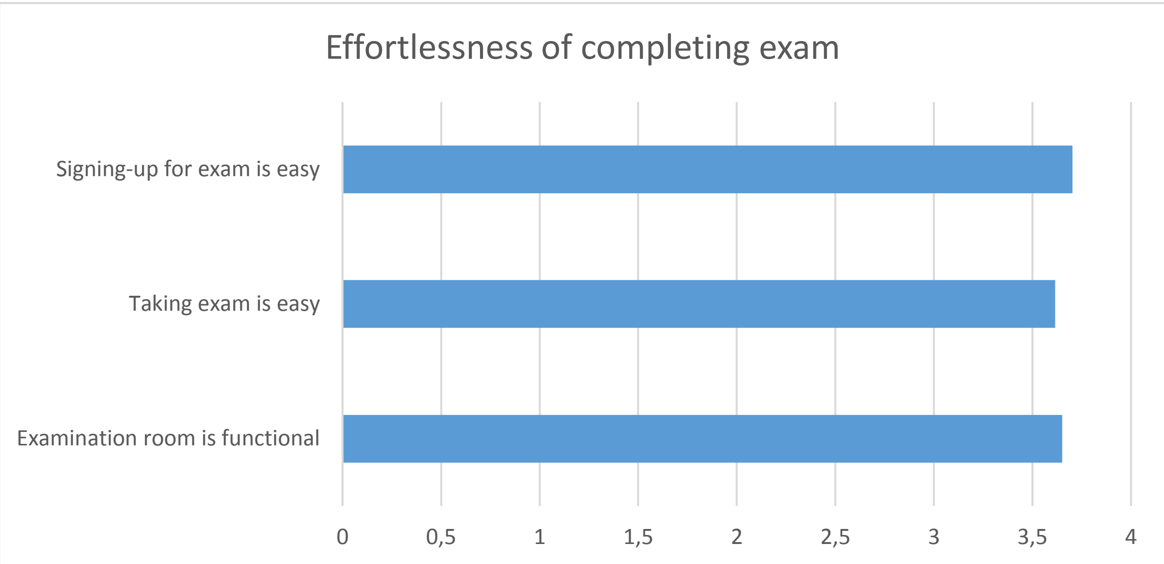

Figure 5. Easiness of completing an exam in EXAM system on a scale very difficult (1) to very easy (4).

In the first years when the electronic exam was implemented it was seen that students were insecure how to use the system when taking the exam for the first time. Thus, a test exam was created. Students can enroll, take the test exam in exam premises and explore how the EXAM system works so that in their actual exam they can only concentrate on the subject.

3.2 Teachers' views on EXAM system

The teachers were more positive about the EXAM system than was expected. They also thought that both creating and evaluating the exam is fairly easy. Only creating the questions was seen more challenging as seen in Figure 6. As indicated in literature, teachers were in general more doubtful about the system than the students [1].

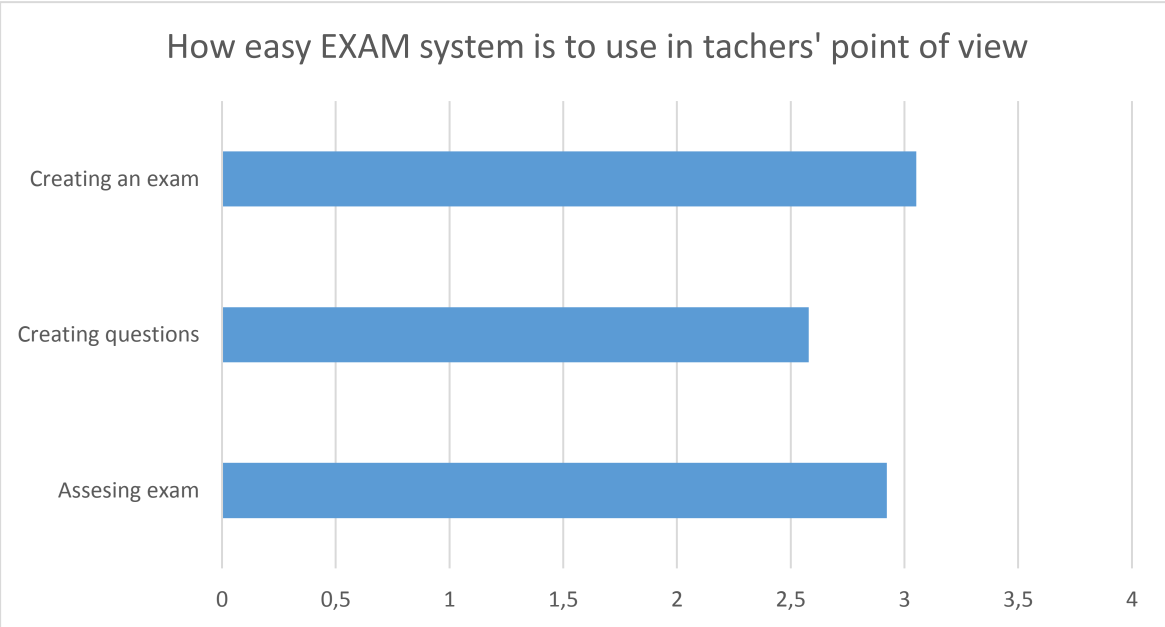

Figure 6. Easiness to use EXAM system in examination on a scale from very difficult (1) to very easy (4).

3.3 Time stamps of exams

The time stamps show that most of the exams were done in May and December, which was expected because at that time teaching periods end and traditional final exams take place at Tampere University of Technology. It also indicates that when talking about exams as an evaluation method, summative assessment still take place at the end of a course at Tampere University of Technology. Naturally, it takes time to change teaching and assessment to more formative in which EXAM system is of great help.

Figures also show that students prefer studying during the working days and hours as seen in Figure 7 and 8. When deploying the EXAM system and opening new exam premises Tampere University of Technology staff assumed more interest in using exam premises during the weekends and evenings. Against the assumption, Saturday and Sunday don't show very popular. Also the beginning of the week is not very busy time at the examination rooms.

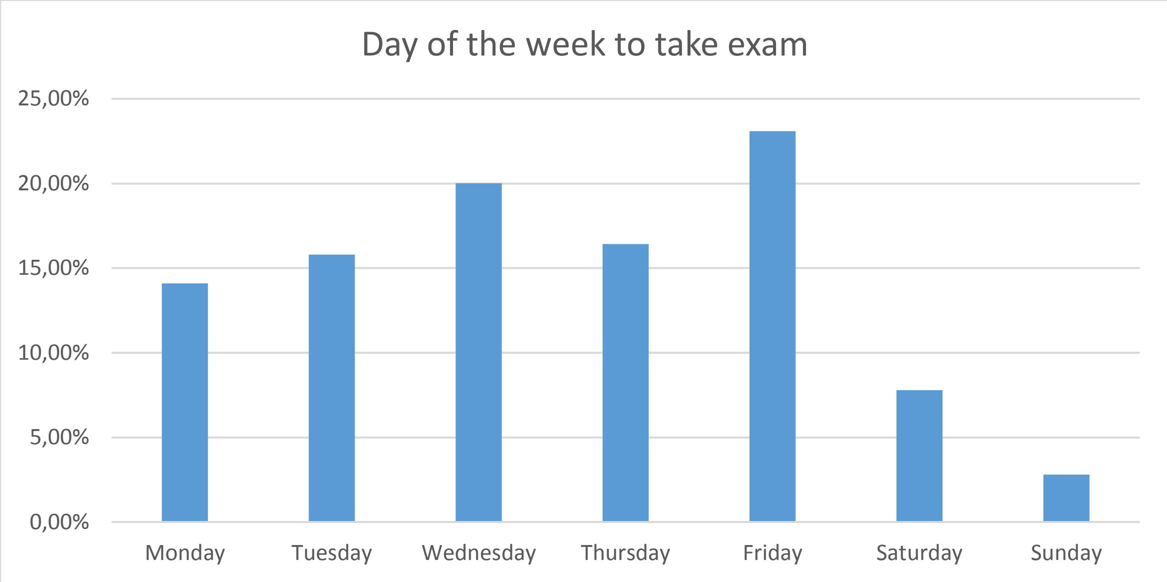

Figure 7. Day of the week to take exam

Most popular times to take an exam are around noon. The examination rooms are open from 8 a.m. until 11 p.m. but as seen in Figure 8, the end times are not too popular.

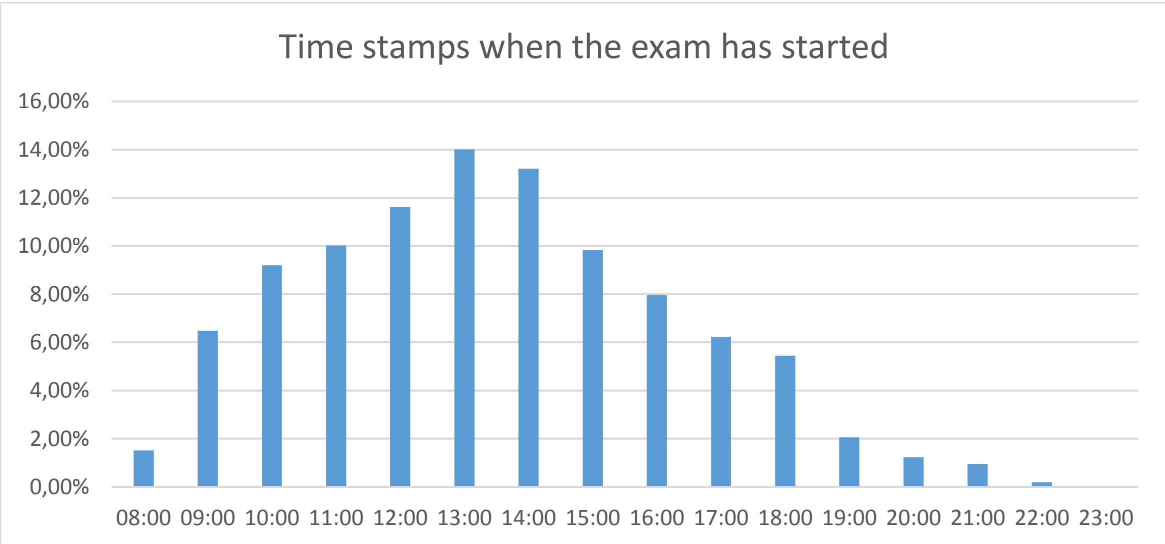

Figure 8. Time stamps when the exam has started

When analysing the results more in detail, it was seen that most of the exams that begin early in the morning were done on Friday and the late exam times were used mostly during the Sunday. Also the no-show rates were higher during the weekends, especially on Saturdays as seen in Figure 9. In general the no-show rate was very small. Students attended more than 93% of the booked examination times.

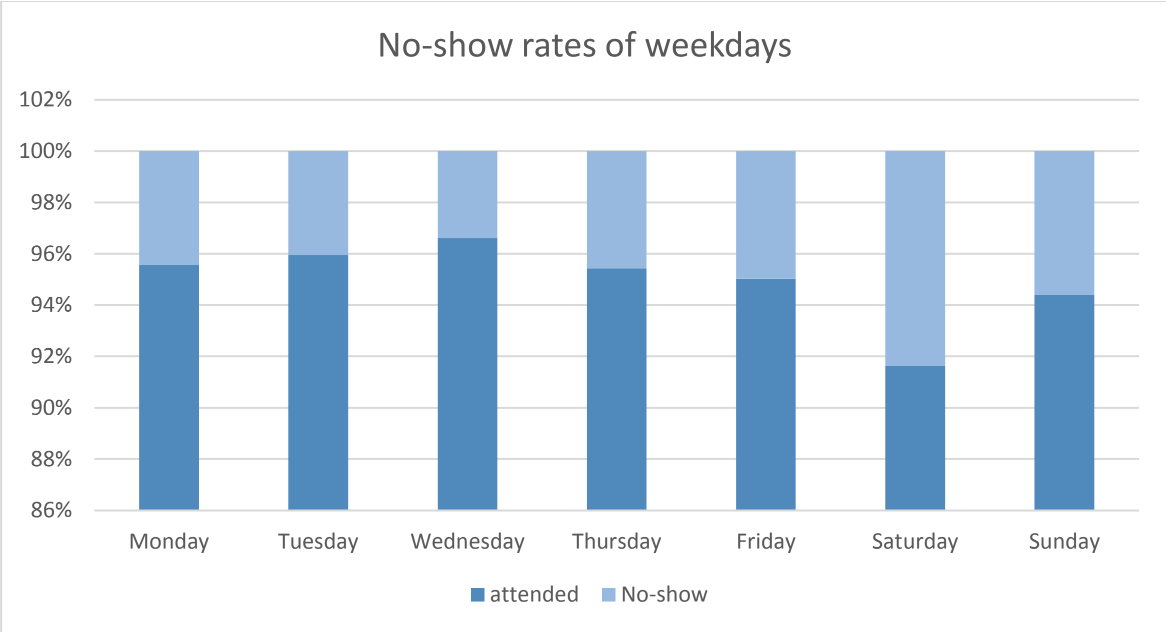

Figure 9. No show rates of weekdays

However, it is still clearly seen from the results that students take the exams every day, also on public holidays, which indicated that they like the flexibility and use the opportunity to study and take exams also during the weekends and late in the evening. This enables students to choose their own study pace more personally and to plan their learning better.

4 CONCLUSIONS AND DISCUSSION

The results of the survey fulfilled expectations. It was slightly surprising that Sundays aren't popular exam days, as expected in the beginning. Also the fact, that the teachers sense of difficultness did not change if they had done one or many exams with system, was unexpected.

The study shows clearly that students prefer electronic exam and are happy with the possibility to choose a time suitable to their own calendar and study rhythm. Neither is the electronic exam system a problem to teachers in technical point of view. The main challenge in increasing the number of exams available in the system, comes down to the attitudes of teachers. There are still many teachers that think that their exam cannot be transferred into electronic format or that are not familiar with the different type of assessment. Also the fact that different type of assessment may require different approach to the whole course can be intimidating [2].

In the future, it would be very interesting to research if the pedagogy of the course changed when the assessment was changed into the electronic format. Likewise, it would be interesting to hear the opinions of students if they have seen any difference in the assessment of the course and if there is a need to study differently for an electronic exam than for a traditional paper-based one. Further it would be interesting to investigate if the time when students book exams are linked to their performance in the exam.

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Senior university teaching qualification via engineering education research and design

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ABSTRACT

Despite decades of calls to engage in the scholarship of teaching [1], university teachers remain challenged to adopt an academic stance toward their education. Three crucial barriers are (1) the academic reward system, (2) the lack of support for teachers to develop such scholarship; (3) the isolation in which most teachers operate. We outline our senior university teaching qualification trajectory (SUTQ) that was designed to address these three barriers. First mid-term evaluation results are outlined showing that this new trajectory is much appreciated. Addressing workload

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issues of participants, enhanced opportunities for peer interaction and streamlining of our program are planned to further improve this new SUTQ program.

Conference Key Areas: Engineering Education Research; Curriculum Development

Keywords: Scholarship of Teaching and Learning; Professional Development; Excellent Teaching

INTRODUCTION

Teaching quality has an important effect on student learning [2,3]. To contribute to this goal, the Senior University Teaching Qualification (SUTQ) is intended to further develop senior teachers professionally. The SUTQ is intended to contribute to educational innovation and continuous further improvement of education. This means that professional development of teachers in the framework of the SUTQ is not only focused on individual development, but also on these teachers functioning as ‘change agents’ in the organization [4].

The target group for participation in the SUTQ program are excellent teachers that have not only obtained their basic University Teaching Qualification (UTQ), but are considered forerunners in their department in terms of teaching. They need to be personally motivated to participate in the program and research and innovate their own teaching to further promote student learning. Participation in the program needs to be personally relevant and related to challenges and questions in participants’ own teaching practice. Moreover, they need to see how their individual activities in the framework of the SUTQ relate to opportunities for improvement in education in their own courses. Their time investment is 160 hours in total in one (academic) year. This paper outlines how we implemented our SUTQ program and what our first evaluation results show.

1 DESIGN OF THE SENIOR UNIVERSITY TEACHING QUALIFICATION

1.1 Orientation on the SUTQ in the Dutch context

Currently 11 out of 14 Dutch universities have developed a SUTQ program including criteria for admission, facilities, program and an assessment procedure [5]. De Jong and Mulder [5] conclude that there is not one standard SUTQ program or profile yet as some different approaches can be distinguished. In their inventory they discern three different SUTQ approaches:

1. **The performance approach** (dossier): Norms and criteria are described beforehand, the dossier demonstrates evidence that a lecturer qualifies for the SUTQ referring to past and recent performance.
2. **The research project approach**: By completing an educational project a candidate demonstrates that he or she qualifies for the SUTQ. Starting point is a research question which addresses a challenge or a problem in the current education practice which is then investigated and evaluated.
3. **The program approach**: The most extensive approach which refers to a one-year development program with advanced courses, invited speakers on educational strategy themes, projects, discussion and peer feedback.

Currently the 3rd approach is most common in the Netherlands and can also be found in the HEA program for excellent teaching in the UK [6, 7]. The University of Twente has chosen the 2nd approach while supporting the research projects with supporting workshops and options for peer interaction. Inspiration for this approach was found at the University of Lund, Sweden [8].

1.2 Rationale of the SUTQ program

Based on a career framework for teaching (Fig. 1) teachers develop their competencies via SUTQ at the level of the 'skilled and collegial teacher' (2nd level), ready to contribute to the pedagogical knowledge in their own field of teaching (3rd level of the 'scholarly teacher'). The SUTQ is envisioned to impact the academic reward system in a formal way although most university boards in our country await evidence of added value before institutionalizing the benefits of SUTQ into promotion trajectories [5]. Therefore, we focus on making visible how the SUTQ design supports teachers in developing scholarship of teaching, in ways that leverage the power of teacher community interaction. A survey among potential candidates and directors of education helped define the SUTQ program. Teaching staff indicated that they would like to improve their skills and be able to approach their teaching in a more evidence informed way. Teaching skills and beliefs are powerfully influenced through an active (re)design and application of educational tasks [9,10]. Besides this design approach we invite staff to use their academic stance also in their teaching tasks that is using existing evidence and literature while (re)designing a course [8].

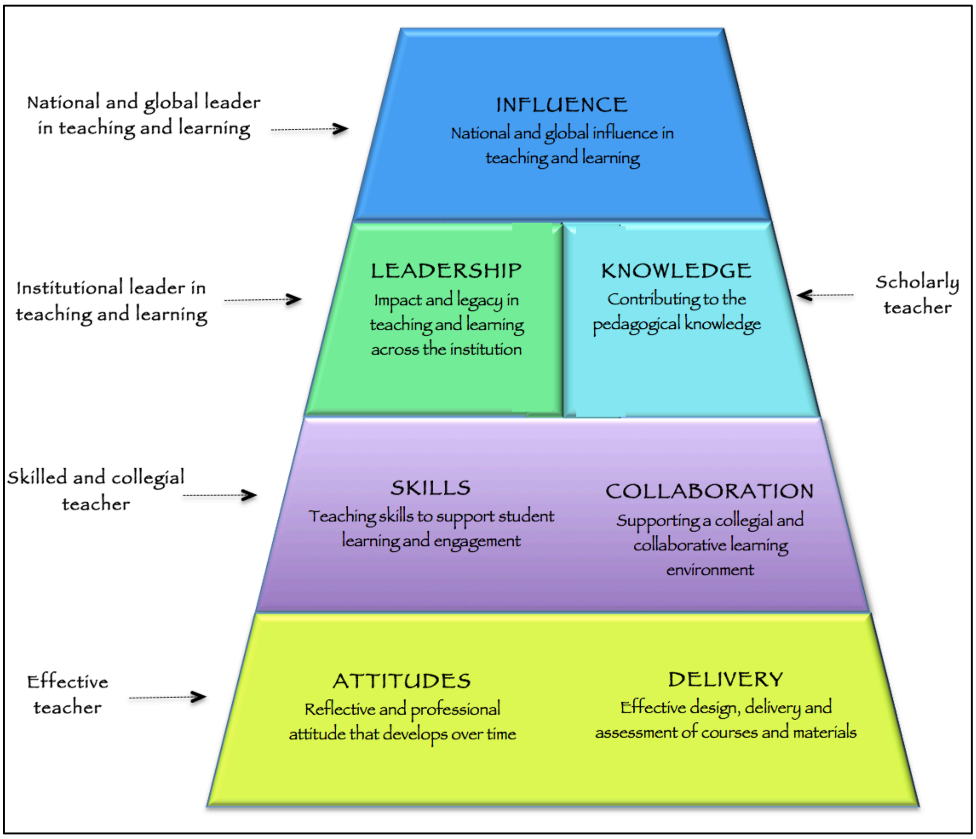

Fig. 1. Levels of teaching achievement [11, reproduced with permission].

1.3 Objectives

Building on the basic skills acquired in the UTQ at the ‘effective teacher’ level, the focus of the SUTQ program is on researching and innovating teaching, participants need to develop the following competencies: the participant is able to …

1. Define a problem or ambition for current teaching in terms of student learning and engagement. The focus should be within the area that the participant works in.
2. Collect evidence and data either in relation to the educational research or as part of the exploratory phase before redesigning a course.
3. Analyze data and connect with literature. This leads to conclusions about the cause and nature of the problem/challenge, or ideas about the design of the intervention to achieve the ambition.
4. Design and implement an intervention or formulate insights to share with peers. Make adjustments based on discussion with peers/formative evaluation of design and present outcomes.

1.4 Initial design

Situated learning as applied in the initial SUTQ design emphasizes learning within the context of real-world situations. When it comes to the professional development of teachers, the need to anchor learning in real-life settings has been highlighted by many [4,12]. Specifically, research shows [13] that successful professional development programs:

- focus on the concrete classroom application of general ideas;
- expose teachers to actual practice, rather than descriptions of theory;
- provide opportunities for group support and collaboration;
- involve deliberate evaluation and feedback by skilled practitioners;
- are accompanied by sustained support;
- build on teachers' current pedagogical and content knowledge (UTQ); and
- allow for observation, critical analysis, reflection, and evaluation.

In the first round we applied these requirements and defined eight components that together make up for the SUTQ program (Table 1.). A special intake session was organised with both candidate and his or her director of education. This setup was supposed to ensure that the candidate would be facilitated with both time and the opportunity to experiment or research in a selected educational setting. The intake discussions also helped to shortlist the topics of interest taking into account available time, faculty priorities and the need for focus when researching their education.

After the intake a first group of 16 participants has started their SUTQ trajectory. During a joint kick-off meeting they met their coaches and peer teachers. Also they pitched their personal project ideas as input for a first peer reflection round in groups. Their project topics range from improved student understanding in a certain science or engineering domain, to integration of mathematics and physics in engineering courses, and new applications of ict. During their 12 month SUTQ trajectory personal coaching, intervision sessions with peer feedback, R&D sessions and inspiration workshops are the building blocks that each of the participants should take part in. To reduce the pressure on the busy timeschedules of our teaching staff the different sessions were scheduled separately and on different workdays or evenings. In the final stages presentations for colleagues in their own departments should help disseminate the outcomes while ensuring that the participants would come to conclusions including reflections on what has been achieved with respect to professional development. For each participant an optional travel budget is available if a work visit, an international workshop or a conference presentation would fit in with the personal trajectory.

Table 1. Components in the Senior University Teaching Qualification trajectory

Senior University Teaching Qualification	**Description**
Intake interview	Identify entry level, personal pursuit options, align with curriculum challenges, availability (160 hrs in 12 months).
Kick-off	Outline of the program. Meeting participants and coaches. Directors of Education present to show commitment.
Personal education project	Personal educational research or design activity. Link to literature and existing practises. Finishes with a reflection and a presentation.
Coaching	Educationalists available to help design, plan and evaluate.
Intervision sessions	Small peer groups supporting and commenting each other.
R&D sessions	Familiarizing engineers with educational R&D methods.
Inspiration sessions	Workshops on ‘flipped classroom’, ‘assessment for learning’ and other topics as suggested by participants.
Personal budget	Funding of a work visit or conference participation (including presentation).

2 EVALUATION OUTCOMES

2.1 Method of evaluation

While the first group is still underway we can already report on the mid-term evaluation which should help us optimise the second cycle of the SUTQ trajectory scheduled for 2018. The evaluation sofar consists of a combination of questionnaires and discussions with both SUTQ participants (n=10) and SUTQ coaches, coordinators and experts involved (n=13). The preliminary outcomes were then discussed in a session with all coaches and experts. Changes that we plan for the second cycle will be presented to the first group of participants for comments.

2.2 Outcomes: priority up, complexity down

Apart from appreciation for the opportunity to progress professionally on the educational tasks, what stands out in the evaluation is that both organisers of the SUTQ and faculties should give high(er) priority to this professional development and its strategic value. Faculties did not always find ways to reschedule tasks of SUTQ participants so as to enable full participation. Early and strict intake with respect to priority and availability is needed. Also, organisers should plan well in advance a number of days on which joint activities are planned. By scheduling different sessions around the normal daily tasks we did not encourage facilitation of time for participants and ended up with participants perceiving the set-up much more like a cafetaria model whereas we had intended it as an integral program.

Second, participants ask for improved opportunities to have peer interactions with other participants. This links to literature that shows that informal professional development is linked to microcultures or networks of colleagues with whom educational issues are discussed [8,14]. By rescheduling the separate sessions in a more clustered way on certain days participants can more easily work together and transfer what has been learned from R&D and inspiration sessions to coaching and peer intervision sessions in which progress and next steps are discussed. Also the sessions in itself will have more time for discussion among the participants who already bring a lot of educational experience themselves.

Thirdly we will reduce the number of coaches and experts involved as there are now many stakeholders involved. This will reduce the complexity. Whereas intakers, coaches, R&D experts and assessors all take part in the program we plan to reduce this to minimise the loss of information if participants are moving from one phase to the next phase. This way participants will much more team up with one SUTQ coach and their fellow colleagues while having access to relevant experts.

Finally, as we expect from our students to take the lead in their project work we had also expected our SUTQ participants to be able to formulate what inspiration sessions with invited speakers would stimulate and support them in their professional development. It turned out that participants did bring forward topics of interest such as flipped classroom implementation, team based learning and assessment for learning. By no means they were interested in selecting and inviting experts. A more facilitating approach from the SUTQ staff is appreciated and has already been implemented during this first execution of the SUTQ program.

3 CONCLUSIONS AND DISCUSSIONS

Teaching staff at universities are eager to embark on senior professional development programs that link to their own personal educational settings. A first execution of the program shows that they try hard but have to manage with many other demands. This also relates to the rewarding of teaching versus research. The debate on that is ongoing [11]. The SUTQ program will be streamlined reducing complexity and improving opportunities for peer interaction. At the intake we have to ensure priority and availability to fully embark on the program. We expect those that will complete their SUTQ program and project to be a source of inspiration both for their direct colleagues and future teaching staff who are working on their teaching competencies in UTQ and SUTQ programs and beyond that in continuing scholarship of teaching networks and projects. For the university as a whole it will be of strategic importance to have a group of dedicated expert teaching staff who can build future science and engineering education that will shape our future students.

4 ACKNOWLEDGMENTS

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Open Data in an Analysis of Higher Education in Engineering and Technology in Serbia

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ABSTRACT

The concept of open data is becoming more popular and better recognized in Serbia. The open data offered by the Ministry of Education, Science, and Technological development provide a good opportunity to investigate the current state of higher education in Engineering and Technology, as the needed data were generally difficult to obtain outside of the official institutions. In this descriptive study, we look into the number and representation of studies and higher education institutions devoted to Engineering and Technology.

Conference Key Areas: Attractiveness of Engineering Education; Engineering Education Research; Open and Online Engineering Education

Keywords: higher education, open data, study programme, higher education institution

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INTRODUCTION

Proponents of the concept of open data have made some big accomplishments over the past decade. In addition to the rising recognition and popularity of open data, many organizations have adopted this concept and freely given some of their data through open data portals on the Internet. These developments may be especially important for researchers studying educational systems because official data about the educational system of a country were usually “stashed” within an institution and difficult to obtain for an in-depth analysis.

In Serbia, the Ministry of Education, Science, and Technological Development (MESTD) has provided some internal data at an open data portal [1]. In this study, we analyse the MESTD open data to better understand the current state of higher education in Serbia with respect to the areas of Engineering and Technology (ET). Our principal data source is a collection of MESTD data sets, of which most relevant for the present study are the data sets about higher education institutions (HEIs) and study programmes organized by these HEIs. In our analysis, we perform the following steps:

- apply statistical methods to create numerical and visual summaries for ET education with respect to study programmes about ET and HEIs that organize such study programmes, including comparisons with other study areas;
- create visualizations that expose discovered patterns with respect to organization and size of ET-oriented HEIs; and
- perform clustering to identify spatial distribution of ET-oriented HEIs.

Specific policies concerning STEM education, of which ET education is an important part, are needed and still developed in numerous countries, including Serbia. To this end, our study may provide some interesting results and observations, which could inspire researchers to conduct similar studies and encourage institutions to be more active in this kind of research.

1 RELATED WORK

Open data are gradually getting more recognition in Serbia. There have already been some attempts at promoting the use of open data in Serbia, mostly through media and sponsored competitions intended for programmers, data scientists, and data enthusiasts in general. An example of a competition aimed at creating software applications based on open data was *Open Data Hakaton* [2], which was held at the end of 2015. During the second quarter of 2016, MESTD organized a competition for students from secondary education and their school mentors. This competition, named *Visualization of Open Data of MESTD* [3], was devoted to visualization of data that MESTD made public at their open data portal [1]. In the last quarter of 2016, the second edition of the *Ministry of Data Challenge* [4] was organized. This competition has a somewhat larger scope. As opposed to the other two competitions, it had an international character since it covered the area of the Western Balkans.

In addition to these competitions, there are also open data portals in Serbia. Since 2015, *Data Centar* [5] has published data on budgets of several municipalities, as well as some data on presidential elections in Serbia. The official portal for open data in Serbia is *Data.gov.rs* [6], which offers data sets from various public institutions. It provides more diverse data sets than Data Centar but it is still being developed and extended. The concept of open data is becoming formally recognized as well. MESTD has included in the draft of the new bill on higher education a requirement for certain official records to be openly available at the Internet web page of MESTD [7].

Stojkov et al. [8] have made a systematic assessment of open data in Serbia, Bosnia and Herzegovina, Croatia, and Montenegro and concluded that there are initiatives supporting open data but also some shortcomings and challenges still waiting to be addressed by the official institutions. Nonetheless, all these developments indicate that the open data system in Serbia and surrounding countries has been constantly growing over the last few years and moving away from the early stages of adoption.

2 DATA AND METHODS

2.1 Data

Data used in the present study stem from the MESTD. They are mostly from the collection available at the MESTD open data portal, with some smaller portions extracted from the official web page of MESTD. However, MESTD offers data in the form of separate data tables, which may lengthen the process of data preparation within data analysis. For this reason, in a separate study [9], we integrated MESTD data tables that are related to higher education and science into a single data store, which is used as a data source in the present study.

Within the used collection of open data, most important data for our study are about HEIs and study programmes. There are records about 1899 study programmes at HEIs in Serbia in 2016, which include information such as name, responsible institution, study field, degree type, duration, area, tuition fees, and student count by study year, funding mode, and student origin. Available data about HEIs comprise 254 records, which include information such as institution name, university name (if applicable), institution type, address, phone number, address of the official web page, and location in the form of GPS coordinates. The complete list of all the tables and all the contained attributes is available as a result of our data integration study [9].

2.2 Methods

The present study is descriptive as we analyse the available data about higher education in Serbia that were collected by MESTD. It has exploratory character since we try to learn more about higher education in ET in Serbia by freely inspecting data without particular hypotheses. However, the results of this analysis, which may be regarded as exploratory data analysis, could serve in generation of new research questions.

Within the open data of MESTD, a study programme is classified as belonging to one of the following six study fields:

- ART – Art,
- TTS – Technical and Technological Sciences (TTS),
- NSM – Natural Sciences and Mathematics,
- MS – Medical Sciences,
- IMTTS – Interdisciplinary, Multidisciplinary, Transdisciplinary (IMT), and Two-Subject Studies, and
- SSH – Social Sciences and Humanities.

For the purpose of data analysis within the present study, we regarded a study programme as ET-oriented if it has been classified by MESTD to be in the field of TTS. In the similar manner, we considered an HEI to be ET-oriented if the majority of the study programmes it organizes are ET-oriented. The field of IMTTS may include some studies connected to ET, but since the available data do not support identification of ET share in a study programme, we did not consider IMTTS to be related to ET.

We analysed the representation of ET-oriented study programmes within the whole body of study programmes. We also looked into the representation of students enrolled in ET-oriented study programmes and how the shares of different funding modes of students differ across study fields. The funding modes recognized by MESTD in their open data comprise budget-funded (BF) students, self-funded domestic (SFD) students, and self-funded foreign (SFF) students.

Additional analysis was performed to identify which HEIs are ET-oriented, how they are grouped into universities, and how they are geographically grouped, i.e., which cities are centres of ET studies in Serbia.

The data analysis was conducted using R [10], an environment for statistical computing, and various R packages from the official R repository (dismo, geosphere, png, raster, rgdal rgeos, sp, and treemap). The map of Serbia was prepared based on spatial data from the GADM database of administrative areas [11].

3 RESULTS AND DISCUSSION

3.1 Study programmes

Within the collection of MESTD open data, there are 1899 study programmes, including all study fields and degree types. These study programmes are organized by 175 different HEIs. The distribution of study programmes across the six study fields is given in Figure 1. In Serbia, the largest group of study programmes is offered in the SSH field, closely followed by the study programmes in the TTS field, i.e., ET-oriented study programmes. There are 609 ET-oriented study programmes, i.e., 32.1% of all study programmes are ET-oriented. The study programmes in the other four study areas constitute approximately one third of all study programmes. There is a great imbalance in study field share in favour of SSH and TTS studies.

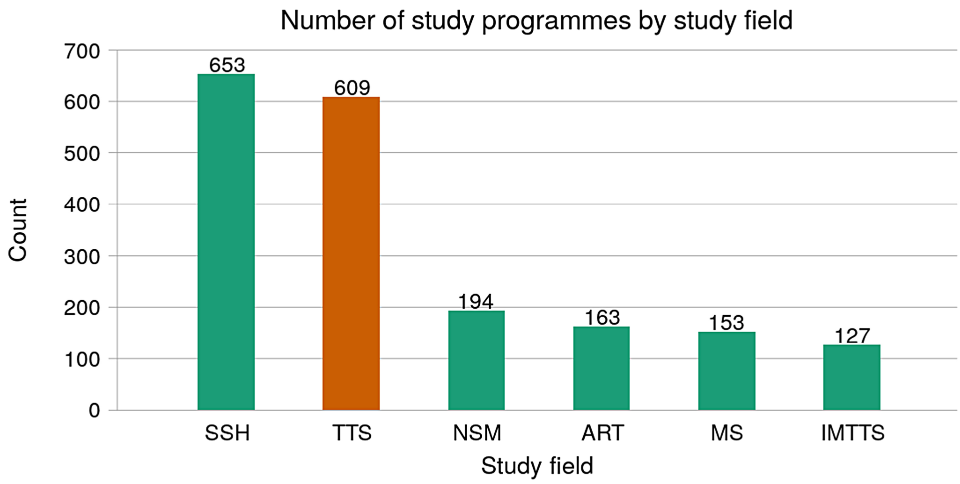

Fig. 1. Distribution of study programmes by study field

In total, there are 247402 students enrolled at HEIs in Serbia. The distribution of enrolled students across different study fields is shown in Figure 2. As it could be expected based on the distribution of study programmes, the majority of students are enrolled in SSH study programmes, i.e., 110732 students. There are 75749 ET students, i.e., they make up 30.6% of all students, which is in line with the share of ET-oriented study programmes. However, the distribution of enrolled students among the other study areas does not completely follow the distribution of study programmes by study area. The differences in shares of students for the MS, NSM, IMTTS, and ART fields are greater than it could be expected based on the distribution of study programmes. This might be a consequence of varying enrolling policies between different study areas, e.g., fewer students get enrolled per study programme in the ART field than in any other study field.

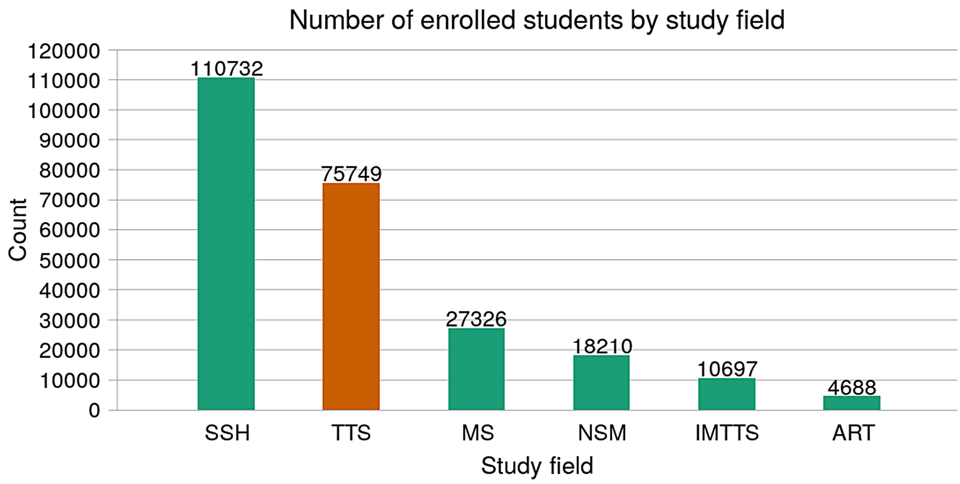

Fig. 2. Distribution of enrolled students by study field

The distribution of enrolled students within a study field with respect to funding mode is presented in Table 1. The share of ET students in the group of budget-funded students is 34.9%, which is more than expected. More than half of ET students are budget-funded, namely 52.8%. This is the best ratio of budget-funded students in a study field, except for the ART studies, which typically have a considerably smaller number of students. This high rate of budget-funded students in ET studies, which feature such a high share of students in the total student population, is a strong pattern showing that ET-oriented studies have a major funding support from MESTD and the government. This is also noticeable in the high ratio of 1.12 budget-funded students per one self-funded student.

Table 1. Distribution of enrolled students within a study field by funding mode

Study field	BF		SFD		SFF		BF / (SFD+SFF)
	Total	%	Total	%	Total	%	
SSH	44157	39.88	66263	59.84	312	0.28	0.66
TTS	39999	52.80	35426	46.77	324	0.43	1.12
MS	13690	50.10	12969	47.46	667	2.44	1.00
NSM	8773	48.18	9317	51.16	120	0.66	0.93
IMTTS	4780	44.69	5832	54.52	85	0.79	0.81
ART	3160	67.41	1509	32.19	19	0.41	2.07

3.2 Higher education institutions

Out of 175 HEIs that organize at least one study programme, there are 56 ET-oriented HEIs. If the institutions that offer at least one ET-oriented study programme are included in this count, there are 62 HEIs that offer ET education to students. The six institutions that have ET-oriented studies but are not predominantly devoted to ET comprise three higher schools, two rectorates, and one faculty. The distribution of ET students by ET-oriented HEIs is depicted using a treemap visualization shown in Figure 3. The institutions are grouped by the university of which they are part, except for higher schools, which function independently. The institution with most ET students is the Faculty of Technical Sciences of the University of Novi Sad, which has 11824 ET students. The next five largest ET-oriented HEIs are all part of the University of Belgrade.

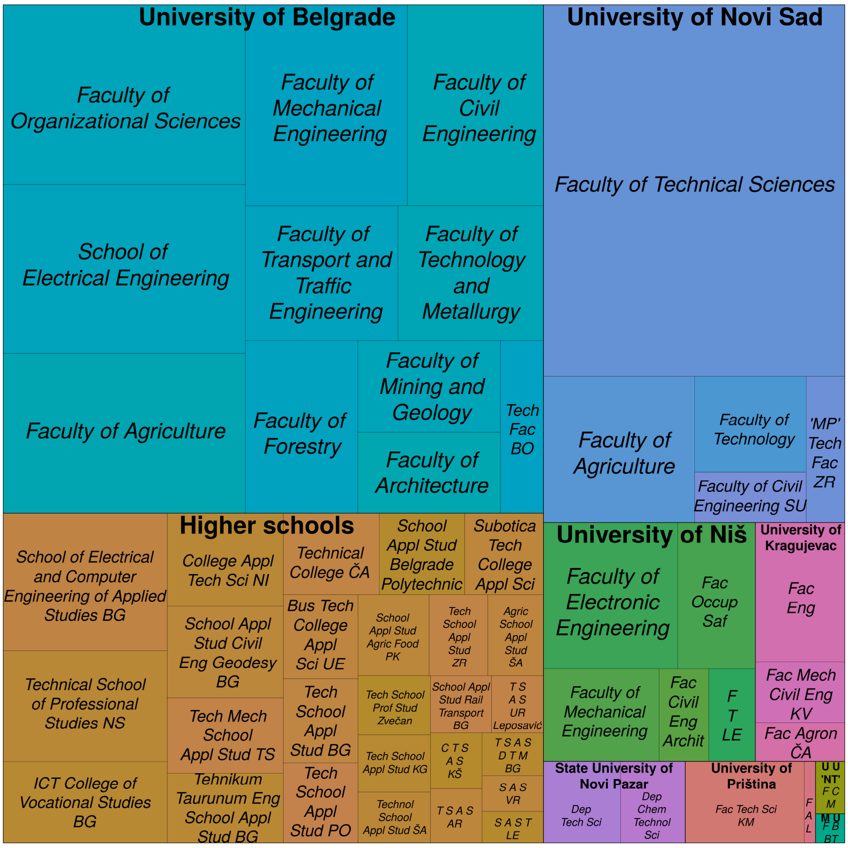

Fig. 3. Treemap for ET-oriented HEIs based on the number of students enrolled in ET-oriented study programmes

A map of higher education centres for ET is shown in Figure 4. All ET-oriented HEIs except two small HEIs of unknown location were clustered by proximity using hierarchical clustering. The map includes the name of the city, or multiple cities close to each other, and the number of ET students enrolled at ET-oriented HEIs there.

4 SUMMARY

In the Strategy on Scientific and Technological Development [12], the Government of Serbia focuses on increasing the share of students studying Natural Sciences and Engineering. Although the analysed data do not provide records over several consecutive years, the presented results suggest that ET studies play a very important part in the higher education system of Serbia. With respect to the number of available study programmes and the number of enrolled students, the ET field is second only to the field of Social Sciences and Humanities. Moreover, with respect to the share of budget-funded students, it surpasses all the other fields except the field of Art, which traditionally offers only a low number of positions for students.

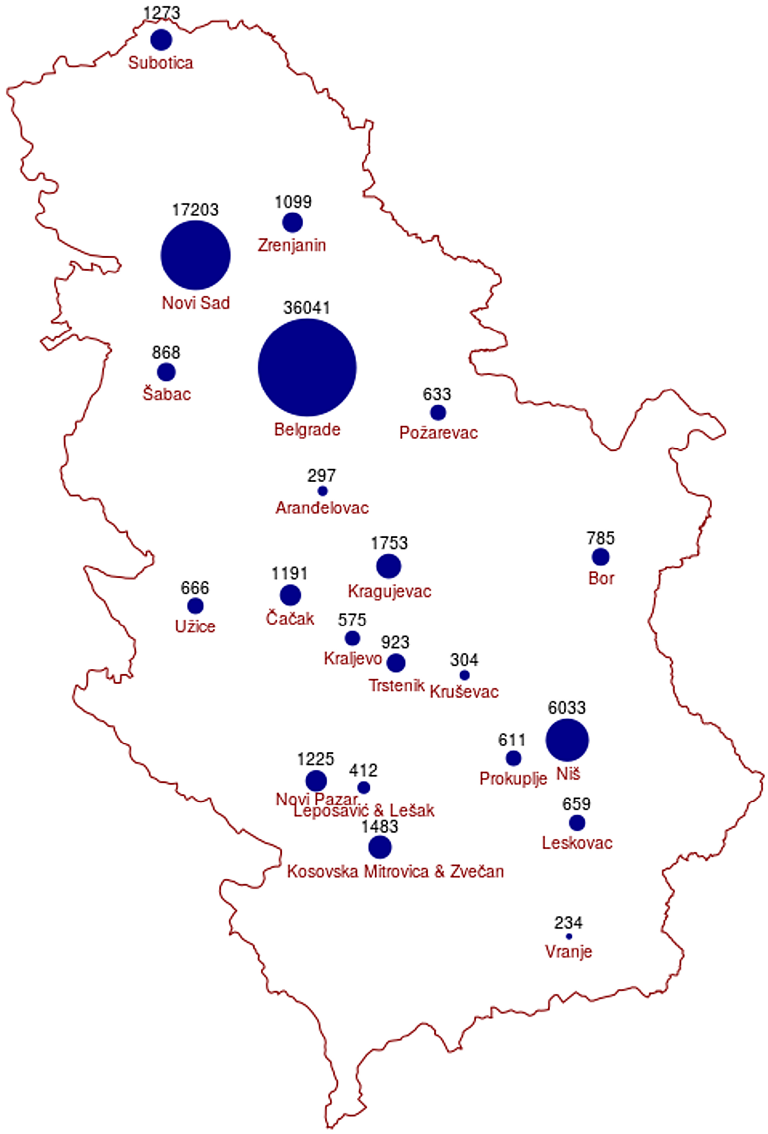

Fig. 4. Centres for higher education in ET in Serbia

As expected, the main centres for higher education in ET are the largest cities, namely Belgrade, Novi Sad, and Niš. If population levels are taken into consideration, then Novi Sad in particular has a prominent role in ET education. The special status of Novi Sad in this regard may be primarily attributed to the Faculty of Technical Science of the University of Novi Sad, which is the largest ET-oriented HEI in Serbia. On the other hand, throughout Central Serbia, there are smaller higher education centres offering ET studies, many of which are organized by higher schools.

The MESTD open data present a unique opportunity to analyse data previously reserved primarily for MESTD and the Statistical Office of Serbia. The veracity and completeness of analysed data are closely tied with the usefulness of the results. However, given the official character of published records and their extensive coverage, there should be good confidence in the findings. Our plan for future research is to analyse also the state of science and research activity in Serbia.

5 ACKNOWLEDGMENTS

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The Circular Economy
In Practice-focused Undergraduate Engineering Education

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ABSTRACT

The growth of the planet’s population makes the traditional industrial model of “take, make and waste” unsustainable. The circular economy, in which resources are continuously reused, offers a solution. For manufacturers of durable goods the circular economy requires a well-functioning circular supply chain that includes reverse logistics, product recovery operations, development of markets for recovered products, and integration of reuse and product recovery into the firm’s daily operations. How to educate undergraduate practice-focused engineers in the design, implementation, and operation circular supply chains is un-explored and the purpose of the paper is to identify a suitable teaching method. Because courses in circular supply chain topics are currently non-existent, the paper first develops a set of learning goals based on the skillset necessary to design, implement, and operate a circular supply chain. Second, the paper examines whether the teaching method of a similar cross-disciplinary course in innovation can be successfully applied. This teaching method is based on cross-disciplinary team projects that work with innovation in cooperation with a participating firm. The study concludes that the teaching method can be (largely) applied. However, future research should test the paper’s results with studies using data from circular supply chain courses.

Conference Key Areas: Sustainability and Engineering Education, University-Business cooperation, Engineering Skills

Keywords: Circular economy, circular supply chains, engineering education, undergraduate education

INTRODUCTION

The traditional “take, make and waste” industrial model first extracts resources from the planet (e.g. in quarries, mines, the ocean, farmlands and woods). Second, the model turns these resources into materials, components, and products, which are used and then discarded. Finally, discarded products end their life in scrapyards or as CO2 resulting from either decay or incineration. With the growth of the planet’s overall population and the increasing middle-class population, this traditional industrial model makes resource scarcity one of the planet’s greatest future challenges. An emerging concept that offers a solution to the resource scarcity challenge is the circular economy, in which resources are continuously reused (Ellen MacArthur Foundation, 2015a). In addition to solving the planet’s resource scarcity problem, reuse offers firms a wide array of business opportunities (e.g. Larsen and Jacobsen, 2016).

The circular economy concept covers circular routes for products, components and materials. Among these circular routes are sharing resources (cars and production equipment), repairing functioning products, refurbishing and remanufacturing products, and recycling of materials. For manufacturers of durable goods the circular economy requires a well-functioning circular supply chain that includes reverse logistics, product recovery operations, development of markets for recovered products, and integration of reuse and product recovery into the firm’s daily operations. In a study from the Ellen MacArthur Foundation (2015b) the primary barrier for implementing and operating circular supply chains in the manufacturing sector is the lack of skills, capabilities, and the basic knowledge of the possibilities inherent in circular supply chains. The antidote to overcome these barriers is education. Education can provide these lacking skills and capabilities to future employees of all kinds. Engineers have the perhaps greatest influence on product and process design and work with both implementation and operation of processes. Therefore, providing engineers with the skills and capabilities to design, implement, and operate circular supply chains will deliver a competence base that supports a transition towards the circular economy.

Extant literature within engineering education does not prescribe how educational systems can effectively provide students with the necessary skills to design, implement, and operate circular supply chains. Searching the digital library of the Technical University of Denmark using the search string (circular AND "engineering education") results in 183 hits. The library’s search engine searches in both academic databases and conference proceedings. One paper among the 182 hits explicitly concerns circular supply chain education. This paper written by Pereira and Frederiksson (2015), which is part of the conference proceedings of the 43rd SEFI Conference, discusses the use CES EduPack in teaching evaluation of resource usage. The paper focuses on milk bottle reuse. A few other papers resulting from the search discuss resource usage in the built environment. The search leads this study to conclude that that the question of how to educate engineers in the design, implementation and operation of circular supply chains is under-researched.

The study adds to the understanding of engineering education within the circular supply chain discipline by examining how universities can facilitate learning of the design, implementation, and operation of circular supply chains.

The study will specifically examine how the subject can be taught within a 10 ECTS-point course frame, corresponding to one third of semester student work load. The study focuses on undergraduate practice-oriented engineering educations. Therefore, the study focuses on teaching methods that integrate a high level of industry involvement.

The remainder of the paper is structured as follows: Section 1 will extract a set of learning goals for a 10 ECTS course from a literature based understanding of the circular supply chain. Section 2 will detail the methodology for how the study evaluates teaching methods for the course. Section 3 conducts an analysis of a potentially useful teaching method and discusses the applicability of this teaching method for the 10 ECTS credit course about the circular supply chain. Sections 4-5 discuss results and provides future research suggestions and conclusions.

1 LITERATURE REVIEW

This section will first define the circular supply chain and its constituent components through circular supply chain literature. Second, from this definition of the circular supply chain, the section will extract the necessary skillset that enables practice-focused undergraduate engineering students to design, implement, and operate circular supply chains. Third, from the skillset the section will develop a set of learning goals for a 10 ECTS credit course. The later sections of the paper will use these learning goals to examine a suitable teaching method for the course.

1.1 The circular supply chain

For manufacturers of recoverable products the circular supply chain consists of two overall components: the forward supply chain and the circular supply chain (Larsen *et al.*, 2017). Figure 1 illustrates these two supply chains. The forward supply chain begins with materials manufacturing and component fabrication, continues with finished product assembly and ends with marketing products to customers. The circular supply chain begins with acquiring used products from the market. The circular supply chain then moves these products from customer locations two the firm's inspection and sorting facility. Products sorted for recovery are recovered and remarketed.

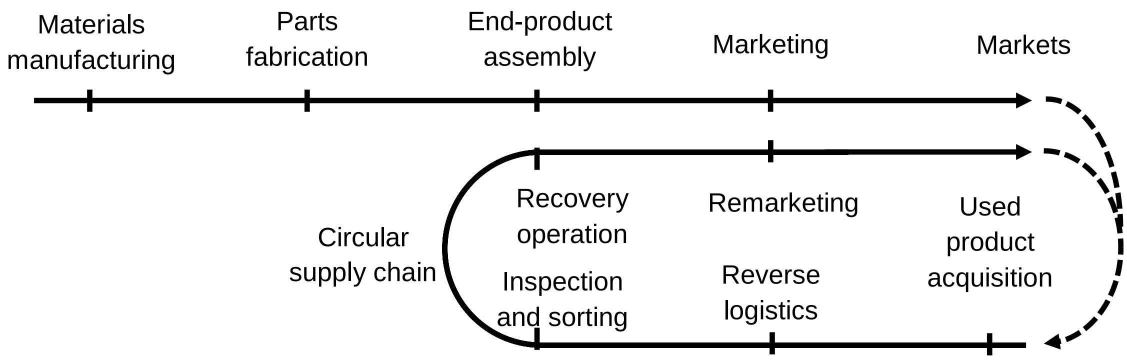

Fig. 1. The circular supply chain (adapted from Larsen *et al.*, 2017)

The circular supply chain circular supply chain can conduct several functions for the firms simultaneously. Figure 2 shows a circular supply chain that conducts the following five functions: 1. Refurbishment of end-products for resale in primary markets as a low-cost version of the virgin product, 2. Refurbishment of end-products for resale in secondary markets, 3. Refurbishment of components for reuse in refurbished products, 4. Refurbishment of components for resale as spare-parts in the aftermarket, 5. Resale of core materials upstream in the supply chain to current suppliers of virgin materials.

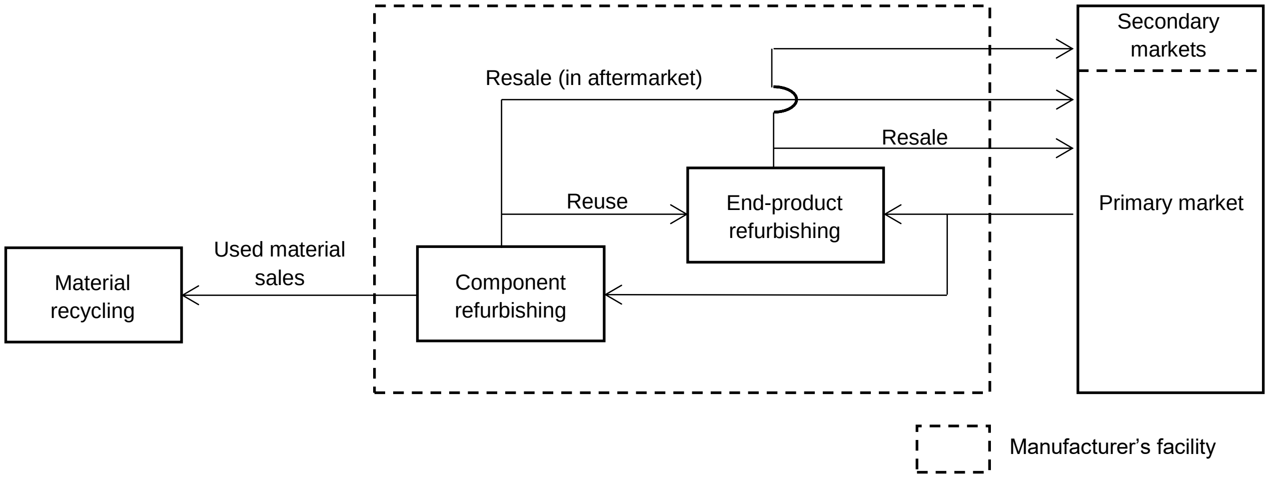

Fig. 2. A five-function circular supply chain (adapted from Larsen, 2017)

1.2 The necessary skillset for engineers

The variety in necessary tasks to design, implement and operate a circular supply chain as depicted in Figure 2 requires a skillset that transcends the curricula of any individual engineering education (chemical engineering, civil engineering, mechanical engineering, etc.). Operating a successful circular supply chain requires skills in logistics and production processes, purchasing, developing potential new markets, as well as risk assessment and product design. A course that facilitates learning of this skillset must therefore contain a set of learning goals as the following set in *Table 1*.

Table 1. Learning goals for circular supply chain course

#	**Learning goals** ***The course should enable the student to:***	**Traditional engineering education that relates closest to learning goal**
1	Understand how product design impacts product disassemblability, recoverability, and ability to function through several use cycles	Mechanical and electrical engineering
2	Design logistical systems that can take back used products and deliver them at the firm's facility	Manufacturing engineering
3	Identify the whereabouts of the firm's installed base of products, which constitutes the pool of input for the circular supply chain	Information and systems engineering
4	Select and develop manufacturing technologies and processes for recovery of products and components (e.g. refurbishing or remanufacturing processes)	Manufacturing engineering
5	Develop markets for recovered products and components	Export and marketing engineering
6	Identify and implement business models that fit with take-back and recovery processes	Business development engineering
7	Understand the managerial and financial impact of circular supply chains on the firm's profit and competitive strategy	Business development engineering
8	Managing the daily operation of logistical, manufacturing, and sales processes	Manufacturing and business engineering
9	Work in cross-disciplinary teams with members from different engineering backgrounds	All engineering degrees

10	Interact with a firm for the purpose of scoping a project, gaining access to data, cooperating with firm employees in e.g. workshops and problem solving	All engineering degrees

2 RESEARCH DESIGN

The emergent nature of the circular economy (and circular supply chains in particular) means that experience in teaching the subject is currently non-existent. This eliminates the traditional research method of studying teaching methods in previous circular supply chain courses. Therefore, the study will instead examine the teaching methods used in teaching a topic that is similar to circular supply chain design, implementation and operation. This is the topic of innovation. The study has chosen to study the teaching method of an innovation course for three reasons: 1) universities have a much longer experience in teaching innovation that circular supply chains, 2) teaching innovation often occurs through the use of team-based project conducted in cooperation with industry, and 3) innovation usually demands cross-disciplinary cooperation across engineering education programs. Among the cross-disciplinary innovation skills are idea generation, conceptualization, technical problem solving and commercialization. Innovation is often taught through cross-disciplinary projects that deliver useful results for the participating firms from industry.

Specifically, the paper examines the teaching method of a large scale innovation course at the Technical University of Denmark labelled “Innovation Pilot”. The study evaluates whether the teaching method applied in this course can be successfully applied to teaching design, implementation, and operation of circular supply chains. Figure 3 depicts the study’s research method. The study evaluates whether the teaching method used in the innovation course aligns with the learning goals of the circular supply chain course in Table 1.

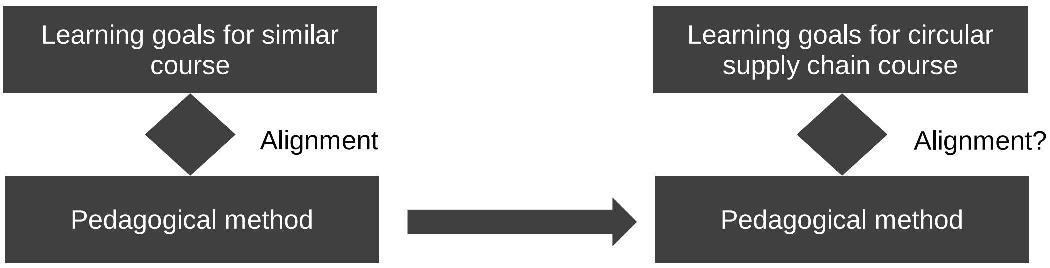

Fig. 3. Research method

3 CASE STUDY ANALYSIS

This section will first describe the learning goals of the Innovation Pilot course; second, the course’s teaching method; and third, the section will evaluate whether the teaching method can be successfully applied in a course with the learning goals in Table 1.

3.1 The learning goals of the Innovation Pilot course

The Innovation Pilot course has among others learning goals related to collection of diverse sorts of information, developing products to fit defined needs and specifications, considering an idea’s or concept’s implementation requirements as well as financial impact and customer perspectives. The students will learn basic theories about business and management, conduct interdisciplinary cooperation in a project context, and cooperate with a pre-selected firm

The Innovation pilot course differs from a course about circular supply chain design, implementation and operation in two particular ways. 1. In the innovation pilot course students begin the project with a completely open problem definition, while the circular supply chain course is limited to circular supply chains. 2. The innovation course focuses (most often) on developing a sellable product or service, while the circular supply chain course focuses on developing a set of processes.

3.2 The teaching method of the Innovation Pilot course

The course has around 250-400 students per semester. Before the course begins an industry coordinator, who works exclusively with this course, has engaged firms willing to participate in the course with one or more cases. The cases are open-ended, but are defined so the firm benefit from participating.

Students divide themselves into groups, which must be cross-disciplinary, and choose a case from a firm. Two or three groups work on the same case. Every Wednesday from 8 am to 17 pm the students are present either at the university working on their case, visiting their case firm, or conducting research with e.g. customers or potential users.

The students learn basic theory of the course via e-learning (YouTube videos) or through traditional text reading. Watching videos or reading texts is done at home as preparation prior to class participation. During the semester, students spend each Wednesday with workshops, where students learn theory active learning (e.g. idea pitching or feedback sessions). During the first weeks of the course, the students work on a "training case" used for the purpose of learning theory. The training case is labelled "the first loop". For the training case the work period is short and expectations are lower than for the following second loop. For the second loop the students begin working on their selected case. During the second loop period, the students meet with the firm a number several times. Three of these firm-student interactions are formal meetings: At meeting no. 1 the firm present their case, at meeting no. 2 students present their take on the problem that needs solving, and at meeting no. 3 students present their solution and prototype for the firm. The students receive access to relevant data through a contact person at the firm. The course is evaluated through a multiple choice test of e-learning videos and an assessment of a final presentation of the project, which includes a prototype. Table 2 summarizes the elements of the teaching method in the Innovation Pilot course.

Table 2. Elements in the teaching method of the Innovation Pilot course

#	Elements of teaching method
1	Cross-disciplinary teams of students from all engineering degrees
2	Agreements with participating firms prior to the course beginning
3	Development of cases in cooperation with firms prior to the course beginning
4	Learning of basic knowledge through e-learning (YouTube videos) prior to class
5	Problem-based project work that represents most of the students' workload
6	Structured learning flow beginning with training period followed by the core work
7	Continuous interaction between students and case firm for e.g. data collection
8	Evaluation of both basic theory knowledge and the deliverables of the project

3.3 Evaluation of teaching method for a circular supply chain course

The purpose of the course that this study seeks to identify a suitable teaching method for concerns the design, implementation, and operation of circular supply chains. Table

1 presents the learning objectives of the course, while Table 2 summarizes the teaching method of the Innovation Pilot course.

Table 1 shows great disciplinary variety within the set of learning goals, which requires cross-disciplinary student skills. The table shows that the ideal project group consists of five students: one manufacturing engineer, one mechanical engineer, one export/marketing engineer, one business engineer, and one information or data management engineer. Element no. 1 in Table 2 facilitates having cross-disciplinary skills embedded in each project team, but the circular supply chain course must apply a stricter group formation rule to ensure groups with the particular skillset presented in the previous sentence.

The students learn basic theory through YouTube videos and tradition written texts. Students prepare prior to class. The subject matter will change from innovation related subjects to circular supply chain related subjects. However, the range of subjects between innovation and circular supply chain overlap considerably, which suggest that requiring undergraduate engineering students to learn basic theory as preparation for classes is possible without much teacher guidance. Examples of subject matter topics are cost-benefit calculations, basic business understanding, market research skills, product design principles, teamwork, and industry cooperation. A circular supply chain course could adopt this method, but could also use the traditional method of reading articles and book chapters as preparation and then conducting active learning style classroom teaching for deeper learning of theory application.

Working with the design, implementation, and operation of circular supply chains requires the same type of cross-disciplinary team cooperation as innovation. In addition, both courses require involvement of industry. The innovation course integrates industrial firms as project customers and students primary workload concerns fulfilling the need of firm. An industry coordinator identifies firms prior to the course's beginning and each firm expects value from participating. This method can work for the circular supply chain course. However, while the innovation course has considerable amounts of freedom concerning the direction of each project, the circular supply chain course has a predetermined goal from the beginning (the design and implementation of a circular supply chain).

The evaluation form of the innovation course can be directly applied with the circular supply chain course because project groups deliver a supply chain design and implementation plan, while individual students' knowledge of basic theory can be evaluated through a multiple choice test.

4 DISCUSSION, LIMITATIONS, AND FUTURE RESEARCH SUGGESTION

The ideal dataset for examining the effectiveness of a teaching method contains detailed descriptions of teaching methods, exam results, assessments of long term retention of the course's content, and measurements of a student's ability to apply the content of the course. In 3-4 years this data may be available for courses in circular supply design, implementation and operation.

One particular challenge for the course is how to ensure that students can meet the learning goals that are not directly related to their individual engineering degree. For example, how can the course ensure that a business development engineer learns to design a logistical system, when the group includes a manufacturing engineer, who already possesses expertise in logistical systems design? This problem differs from the innovation course where the innovation discipline is new to most students. How to solve this problem with the course's teaching method is suggested for future research as well. The problem may be researched already, so a review of the literature may yield useful results.

5 CONCLUSION

The question that this study has answered concerns how universities can facilitate learning of the design, implementation, and operation of circular supply chains. The study has examined whether the teaching method of a similar course in innovation can be successfully applied, the study' results suggest that it can. Table 2 summarizes the method. However, the method needs one addition concerning how to handle situations where students perform only the tasks they already master from their own education at the expense learning other tasks in the design, implementation and operation of the circular supply chain.

In addition to proving insights into how universities can teach design, implementation and operation of circular supply chains, the study's results are expected to contribute to theory about effective teaching of cross-disciplinary subjects that require a high degree of industry involvement (e.g. close industry-university relations and positive outcomes for students and participating firms).

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Since we are using double-blind reviewing process, also references revealing the identity of the author(s) should be made anonymous until the final paper.

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360 degree peer assessment to train engineering students in giving good quality feedback

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ABSTRACT

Engineering degrees need to incorporate activities to develop the students' skills and confidence in constructing quality feedback, and ability to critically analyse someone else's work. These skills are highly linked with what industry expects from graduates, and implicit requirements to gain accreditation from UK professional bodies such as The Institution of Engineering and Technology. This paper reports how a novel method of peer assessment called *360 degrees peer assessment (360PA)* was used to train students to give good and insightful feedback to a piece of work, while addressing some of the traditional peer assessment limitations. 360PA was successfully applied to a variety of typical engineering assignments (technical reports, research dissertations, presentations and mathematical problems). Students and staff's quantitative and qualitative feedback were collected. Our experience suggests that the incorporation of various 360PA assignments during the degree is beneficial. Staff praise the method, students feel that 360PA has better prepared

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them to construct feedback (score 4.0/5), and the quality of the feedback provided by the students is consistently high (~85 ± 5%). Recommendations for practice are given. Our approach is scalable and should appeal to anyone interested in improving students' engagement with their feedback, or in helping students to develop such critical skills, regardless of class size.

Conference Key Areas: Engineering skills, Continuing Engineering Education and Lifelong Learning, Engineering Education Research.

Keywords: critical thinking, feedback, peer assessment, research based education.

INTRODUCTION

Engineering employers expect graduates to have a good technical knowledge, but also other important engineering skills such as a strong ability to critically analyse their own and others' work and articulate meaningful and constructive feedback [1,2]. Peer assessment has been increasingly applied in Engineering degrees because it enhances students' learning and development of professional skills [3,4,5,6], promotes self-reflection [7], encourages students to engage in constructing feedback, and helps learners to understand expectations and standards [8]. This provides students with lifelong skills, preparing them for continuing professional development throughout their careers as engineers. In addition, peer assessment facilitates prompt feedback in large classes [9]. The peer assessment approach is also increasingly used in industry as part of the performance measurement of their workforce [10], e.g. HSBC, PepsiCo, and Exxon.

Despite the strong benefits of peer assessment within engineering education, its use raises various concerns. On one hand, some engineering students feel unprepared to make fair and critical judgements of technical work [11,12], but this just highlights the need to train them in preparation for their future career. On the other hand, students might lack motivation or engagement with peer marking, feeling that they could spend their time more productively elsewhere [6,13]. We have tackled these concerns by introducing a 360-degree peer-assessment method (360PA) [5]. In this approach, which we have run successfully for the past 3 years in engineering, students are peer assessed not only on their work, but also on the quality of feedback that they provide. This ensures that students make a greater effort in critically analysing their peers' work, generates feedback that is more reliable and of higher quality, and engages students with the feedback received [14].

This paper describes how we have incorporated 360PA in a variety of assessments during an engineering programme of study, from year 1 to a research skills course in the final year. This trains and aids the development of engineering students' skills for constructing good feedback. The strengths and limitations of the approach will be shared, as well as instances when it may be beneficial to include 360PA in the curricula. Evidence was obtained from teacher observations and discussion with students.

1 PROJECT METHOD

1.1 What is 360PA?

The 360° peer assessment (360PA) was developed by UCL Medical Physics & Biomedical Engineering Dept and the UCL Institute of Education to address various challenges that traditional peer marking present as found in the literature [5], such as poor student engagement and consequently poor quality feedback provided to peers.

Traditional peer marking requires students to give formative (and often summative) feedback to a piece of work done by their peers, and that is the end of the process. The 360PA method is more advanced; it first runs the traditional peer marking, and then adds two extra layers to encourage engagement and address students' perception on mark reliability. The whole process is anonymous and as follows:

1) The students peer mark a piece of work, giving relevant summative and formative feedback.
2) The students receive the feedback provided by their peers, and then read and assess the quality of this feedback. At this point, students might raise any concerns they have about the mark they were given for their work.
3) The tutor moderates students' marks both for their assignment and the quality of feedback provided when required.

Therefore, when using the 360PA the students are assessed both for the piece of work submitted, and on the feedback they provide to their peers. This has various pedagogical advantages. However the research of this paper focuses on how this system motivates and trains students to assess their peers thoroughly and provide good and relevant feedback as now this is peer marked in return by the recipient – hence the 360° aspect.

1.2 Overview of 360PA incorporated within the programme

A range of activities assessed via 360PA were incorporated within the Biomedical Engineering BEng programme (BME) (https://goo.gl/pfMTPa), part of the Integrated Engineering Program at UCL, UK. These were progressively introduced starting in the 2014/15 academic year, and span a wide range of different assessments as described below. Note that modules 1-2 and 3-4 are equivalent to 7.5 and 15 European Credit Transfer and Accumulation System (ECTS) credits respectively.

<u>(A) In-class lab report in Module 1:</u> This is the first instance when students are assessed using the 360PA, early in term 1 of year 1, and it is used to introduce this new method. It carries little weight towards the module mark, and it is done entirely in-class except for the tutor moderation which is done later. Full guidance and support from the tutor and other members of staff is provided, both in terms of understanding the marking criteria and solving technical problems with the electronic system. At the end of the activity, the students have completed their first peer assessment, but most importantly, they are aware of the process and what it entails. This was done in academic years 2014/15, 2015/16 and 2016/17, and it follows the typical 70 and 30% mark allocation for product and feedback respectively.

<u>(B) Lab report in Module 1:</u> This is the first meaningful instance when students are assessed using the 360PA. This takes place in year 1, term 1, and it carries 20% of the total module mark. Students complete a practical activity and generate a lab report. After submission, the marking criteria are discussed in class, and then the students carried out the 360PA in their own time. This was done in academic years

2014/15, 2015/16 and 2016/17, and it follows the typical 70 and 30% mark allocation for product and feedback respectively.

(C) Mathematical coursework in Module 2: This takes place in year 1, term 1, and it carries 10% mark of the module. Students complete maths coursework which includes traditional analytical calculations, and the development of some Matlab code and data presentation. Students scan (if hand-written) and submit their work, and proceed with the 360PA in their own time. This was done in academic years 2014/15 (for two assignments) and 2016/17 (one assignment), and it follows the typical 70 and 30% mark allocation for product and feedback respectively.

(D) Small section of the 3rd year research/design project dissertation in Modules 3-4: This takes place in year 3, term 1. All 3rd year students in the department are required to undertake a *research skills course (RSC)* as part of their research/design project carrying a total of 10% of the final mark. This course aims to support students in the development of the necessary skills for a successful completion of their projects. One of the covered topics is *scientific writing*, which looks both at the macrostructure of a written piece, but also at the microstructure such that the text is coherent, engaging, and ideas well linked throughout. The assignment for this topic (20% of the RSC) consists of the 360PA of a small written piece related to their respective projects, hence encouraging them to start their project writing and providing them with relevant feedback. In this instance, emphasis is given to the quality of feedback provided, i.e. only formative assessment is done for the work while formative and summative assessment is done for the feedback, with the latter providing 100% of the mark. Submission is required for completion.

(E) Draft of final project presentation in Modules 3-4: This takes place in year 3, late term 2, as part of the previous *research skills course*. The 360PA assignment is done under the topic *presentation*, and it is worth 20% of the RSC. Students submit a draft of the pdf or ppt presentation they intend to present for formal tutor assessment and perform the 360PA. This encourages students to plan their presentation in advance (about 10 days before the actual event), gauge their presentations against their peers, and allow them to get relevant feedback in time to implement changes for the final deadline. As in the case above, 100% of the mark is allocated based on the quality of the formative feedback provided to the work, although submission is required for completion.

1.3 Research question and data collection

The research questions are:

(i) Are students capable of providing good quality feedback to their peers?

(ii) Does the 360PA in particular engage students into providing good quality peer feedback?

Data was collected and analysed from three fronts, covering quantitative and qualitative analysis from third year students and staff.

(i) Student quantitative assessment via anonymous questionnaires.

(ii) The quality of feedback as assessed by students in 2016/17 for the described assignments is presented, i.e. the marks that each student obtained for the feedback provided. The original marks given by the students quantify how they felt about the feedback they received, if they found it useful and accurate. Those cases where concerns were raised by the students were moderated by the staff, who adjusted both the mark for the work and the mark for the feedback accordingly. Marks are presented both before and after moderation.

(iii) Student and staff qualitative analysis/point of view via quotes.

Modules 1-2 and 3-4 had 23 and 33 students respectively. A total of 5 members of staff were involved.

2 RESULTS

Students' feedback via questionnaires is presented in *Table 1*. The average peer feedback quality as assessed by students for various activities taking place in the academic year 2016/17 is presented in *Fig. 1* along with the marks after tutor moderations for the same assignments. The number and depth of the moderations differ among the assignments, but in most cases the final average marks do not differ significantly. A sample of students and staff point of view on peer assessment is given within the discussion.

Table 1. Students' responses to questionnaire (N=9 final BME students).
Scale: 1- not at all, 2- not very, 3- fairly, 4- significantly, 5-very.

Question	Vote /5 Mean (SD)
How confident are you on your ability to construct feedback for peers and junior students?	3.9 (0.6)
Since you started your degree, have you developed or improved your ability to construct feedback for peers and junior students?	*4.2 (0.8)*
Has peer assessment helped you to develop your ability to construct feedback?	*4.0 (0.7)*

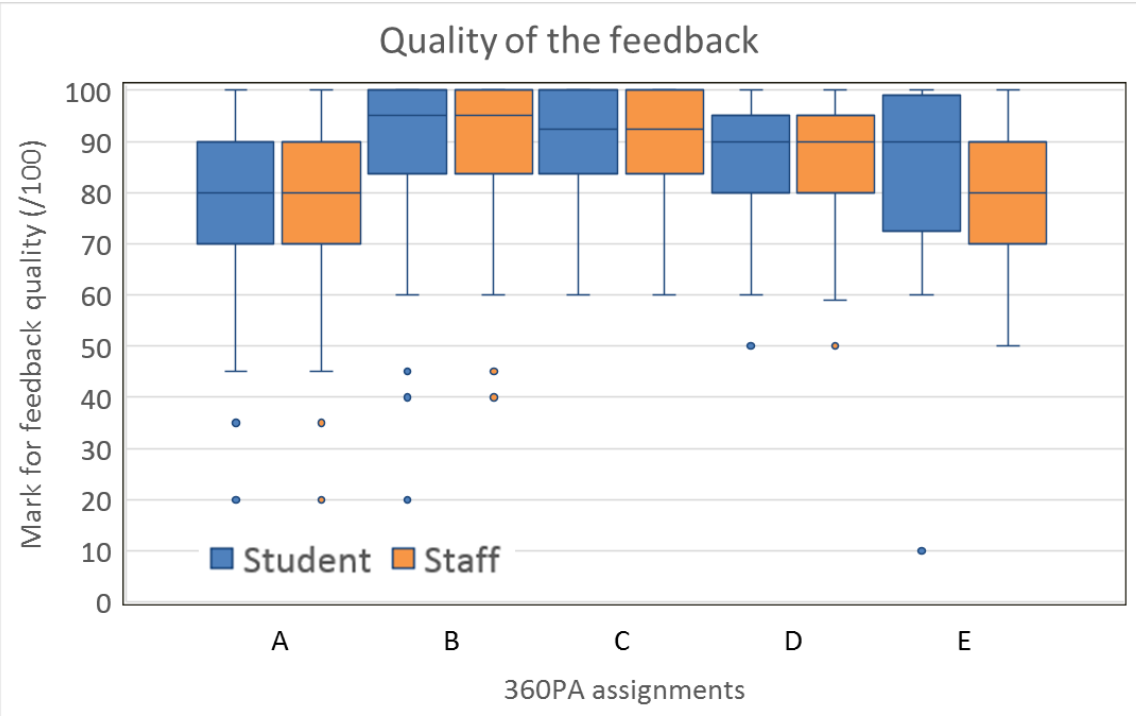

Fig. 1. Peer feedback as asssessed by students and after partial moderation by staff
$N_{A\text{-}C}$ = 23 students, $N_{D\text{-}E}$ = 33 students

3 DISCUSSION

We first look at whether students are capable of providing good quality feedback when participating in the 360PA. Staff seems to be in a general agreement that this is the case, which is supported by the high scores that students give when rating the feedback received (86 ± 4%), and the feedback marks after tutor moderation (85 ± 6)% across the reported assignments. Students also say that by the end of their 3rd year, they feel confident on constructing feedback (score 3.9/5), improving since they started they degree (score 4.2/5).

Lecturer 1: "The effort expended by the majority of students on the feedback was impressive, and quality of the written feedback itself was generally very good".

We questioned if the 360PA helped students to gain the ability to construct feedback. The responses from the students via the questionnaire were positive (score 4.0/5) while the students' quotes show that opinions are varied (note quotes by student 1 and student 2). Some students believe that it was a helpful exercise, improving not just their ability to write feedback but also to critically analyse someone else's work and to engage with feedback; while others thought that it did not contribute much and might see it as the job of the tutors which clearly needs clarifying. A common comment is that peer assessment adds to their workload, which is already significant. One student thought that s/he was not prepared to give feedback even though s/he is known to be academically successful and peers found her/his feedback useful, so there is room to improve the confidence of students in performing such tasks.

Student 1: "Peer assessment helped me learn how to critically analyse someone else's work and ensure I give good feedback, as well at utilising the feedback I was given."

Student 2: "Peer assessment is helpful but is also time consuming so make this as simple as possible otherwise students will not engage with the activity properly."

The 360PA compared with traditional peer assessment is more successful in that it engages engineering students more in the construction of good quality feedback (note quote by lecturer 2). It increases slightly (<10%) the workload compared to traditional peer assessment as students need to read the feedback received and score it. However, this (i) engages students into reading the feedback received which otherwise they do not do as commonly as lecturers would wish; and (ii) allows students to raise any concerns over their marks as a part of the normal procedure, making it less stressful and subjected to the student's character. The quality of the feedback is comparable across the modules, even though the assignments are of different difficulty and require of different knowledge and skills. It is even suitable for mathematical type assignments (note quote by lecturer 3). It is important to note that most of the students taking assignments D and E had not done peer assessment before, and this might account for the greater variability. Finally, tutor moderations were done to different levels depending on the assignment (at the choice of the lecturer) but in all cases, there were no student complaints after the moderation had taken place.

Lecturer 2: "I think the 360PA was a good incentive for students to focus on trying to provide good quality feedback.".

Lecturer 3: "The online and text based format may not have been the most suitable methods for correcting some of the most formula heavy questions, but this did not significantly impact the detail of their responses".

The use of the 360PA method to mark some of the assignments is overall beneficial to engineering students, supports the development of skills required by employers, and addresses some of the skills development and assessment required by accrediting bodies such as IET in order grant accreditation to the degree [15].

Recommendations of practice

Our practice suggests that it is beneficial to integrate assignments assessed using 360 degrees peer assessment in engineering programmes. This improves the quality of the feedback provided by the students and their engagement with the feedback received. It also improves the students' experience as requests for moderation are possible within the standard procedure, which improves the students' confidence in the accuracy of the marks.

The 360PA seems to work with a variety of typical engineering assignments (reports, presentations, mathematical problems). Therefore, it is believed to be suitable for a wide range of contexts and degrees that incorporate elements such as written reports or discussions of a wide nature, presentations, technical calculations, etc. Even when students do not feel comfortable criticizing someone else's work (such as perhaps in Asian's cultures) this brings a good opportunity for students to develop the necessary skills on pieces of work that were written to their similar level of knowledge. Although there are advantages in exposing students to a range of peer assessed assignments, students and some staff believe that it might be more relevant in assignments with less prescriptive solutions (hence it should not be used with straight mathematical questions with only one possible method to reach the correct solution).

The added workload for students when using such method should be considered, perhaps decreasing the workload elsewhere. The 360PA can be used to assess soft students' skills such as ability to construct feedback, which are often required by engineering employers and professional bodies.

4 CONCLUSION

We have showed how the 360 degrees peer assessment method can be specifically applied and how it can benefit an engineering programme. Students have assessed engineering technical reports, sections of research dissertations, presentations, and mathematics coursework using this method. This has helped them to progressively build up their skills and confidence in constructing feedback, and ability to critically analyse someone else's work. These are directly related to the engineering professional skills which are necessary for accreditation, and expectations from industry.

Our approach is scalable and should appeal to anyone in engineering interested in improving students' engagement with their feedback, or in helping students to develop such critical skills, regardless of class size.

5 ACKNOWLEDGMENTS

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How Entrepreneurial are Project-based Courses in Engineering Education?

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ABSTRACT

This paper addresses the ongoing integration of entrepreneurship into engineering education and investigates the relationship between inductive teaching methods and teaching through entrepreneurship. The potential for learning experiences leading to the development of entrepreneurial capabilities in project based courses is investigated, through a qualitative multi-case study of eight courses, applying effectuation and new value creation to assess ways in which project-based learning is 'entrepreneurial'. It is found that even in cases where students are engaged in new value creation towards an external actor, the structure of projects seems to mainly call for students to enact a causal rather effectual logic in their actions and strategies. Pedagogical implications for educators wanting students to develop entrepreneurial capabilities are discussed.

Conference Key Areas: Engineering Education Research, Engineering Skills, University-Business Cooperation

Keywords: Project-based learning, Entrepreneurship, Inductive teaching, Effectuation

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INTRODUCTION

Entrepreneurship is being increasingly infused in all educational levels and across a wider set of disciplines [1, 2], including engineering education [3]. In engineering education, entrepreneurship has shown potential in increasing student engagement, creativity and perceived relevance of courses [4, 5], proven effective in imparting professional skills [6], and has been advocated as a key part of preparing engineering students for contemporary working life [7]. While this gives legitimacy to endeavors aiming to include entrepreneurship in engineering education, research on the subject is still in a nascent phase and there is still major conceptual confusion regarding how ‘entrepreneurship’ in engineering education should be understood.

In any case, the discourse regarding integration of entrepreneurial activity into engineering education shares many aims with inductive teaching and learning approaches, such as inquiry-, problem- and project-based learning [8]. Contrasted against more traditional deductive methods used in engineering education, where instructors introduce theory that students are then asked to apply to constructed problems, inductive teaching methods are more student-centered and use authentic problems as the starting point for learning. This has generally been found more effective than deductive methods [8]. In entrepreneurship education, a similar comparison is often made between on one the hand teaching *about* or *for* entrepreneurship and on the other teaching *through* entrepreneurship [9], which has recently been deemed preferable. Teaching *through* entrepreneurship is facilitated by engaging students in self-directed action and creation within dynamic environments, with the aim of developing entrepreneurial capabilities [10, 11]. Teaching *through* entrepreneurship aligns with the theory of effectuation, conceptualizing the expertise of entrepreneurs who are found to rely upon *effectual* logic (based in iterative creative action) rather than *causal* logic (based in linear planning and prediction) [12]. Thus, teaching through entrepreneurship could be regarded as giving students opportunity to enact an effectual logic in decisions and actions during a course.

In this paper, we explore similarities and differences between an inductive teaching philosophy and teaching through entrepreneurship, by investigating eight project-based engineering courses, posing the question “How entrepreneurial are project-based courses in engineering education?”. As active, experiential and student-centered approaches to infusing entrepreneurship in engineering education have been found effective [13], project-based engineering courses could potentially serve as a training ground for entrepreneurial capabilities. It has, however, been suggested (but not substantiated) that engineering education rely predominantly upon causal rather than effectual logic [14], which could potentially hinder such development. With this study, we draw conclusions in regards to how project-based courses are already ‘entrepreneurial’ (i.e. gives students opportunity to enact an effectual logic), and ways in which they may become more ‘entrepreneurial’. Pedagogical implications are briefly discussed, intended to guide engineering instructors wanting to support the development of entrepreneurial capabilities among their students.

1 METHODOLOGY

This paper is based in a qualitative multi-case study [15] of eight project-based engineering courses. This allows for cross-case analysis, where earlier work on entrepreneurship in engineering education seems to be dominated by single case studies. Using an analytical framework, described in Section 1.1, the extent to which the examined courses are ‘entrepreneurial’ was assessed. The courses and data collection is briefly presented in Section 1.2.

1.1 Analytical framework

To assess entrepreneurial activity in the project courses, we first had to decide upon a perspective on entrepreneurship to adopt, as the research field of entrepreneurship has yet to converge upon a clear definition of 'entrepreneurship' as a phenomenon. Bruyat and Julien [16] propose a conceptualization of entrepreneurship as a field of research focusing on the continuous interplay between an individual (the entrepreneur) and a project of *new value creation*. This definition presents entrepreneurship as a system in which the individual creating new value is, at the same time, being constructed (shaped, influenced) by the new value. This process of dual influence, over time, constitutes an entrepreneurial process, which is situated in a dynamic and uncertain environment, both influencing and being influenced by the ongoing creation process. The value created is manifested in a created object (often an innovation, product or solution), and in terms of 'exchange' value – i.e. value that is determined inter-subjectively rather than objectively set. Entrepreneurship as new value creation has been presented as a useful definition when intending to infuse entrepreneurship in education [17], and is applied here as a conceptualization for the nature of an entrepreneurial project-based course. Building on this new value creation definition of entrepreneurship, the theory of *effectuation* [12] is used to guide the analysis of how entrepreneurship could be enacted in decisions and behavior in the context of a project-based course.

Effectuation is an entrepreneurship theory which presents the decision-making logic applied by entrepreneurs [18]. Sarasvathy [18] studied experienced, serial entrepreneurs to determine how they acted in order to create value under dynamic and uncertain conditions. Accordingly, if students are given opportunity to enact an effectual logic in their courses, they are in a sense 'acting like an entrepreneur' and might then develop entrepreneurial capabilities.

Sarasvathy [18] found that entrepreneurs focus more on what they can and want to do with available resources, and less on fixed end goals. As follows, "Causation processes take a particular effect as given and focus on selecting between means to create that effect. Effectuation processes take a set of means as given and focus on selecting between possible effects that can be created with that set of means" [18]. In Sarasvathy´s definition [18], causation is the classical way to make business or management decisions, focusing on "predictable aspects of an uncertain future" (p. 252). Effectuation, instead, focuses on "controllable aspects of uncertain future" (p. 252). Hence, rather than resting upon the logic of prediction ("to the extent we can predict future, we can control it"), effectuation instead builds upon the logic of control ("to the extent we can control future, we do not need to predict it") (p. 251). An effectuator then approaches a decision starting from 'Who I am', 'What I know', and 'Whom I know' and imagines potential ends that can be created with these resources, choosing amongst these imagined effects. Moreover, an effectuator experiments with many strategies to approach an unpredictable future instead of trying to optimize one single strategy and aims to find strategic alliances and early commitment from potential stakeholders.

Value creation [16] and effectuation [18] were broken down into key themes and organized into a framework, as presented in Figure 1. The framework is built upon the notions of *decision, action* and *re-evaluation*, where both decisions and actions can deemed be 'entrepreneurial' as guided by the theory of effectuation. The general idea is that in order to enact an effectual logic, students need to be given freedom to make choices regarding what to do, act upon those decisions, and get to re-evaluate and re-direct their focus and strategy (c.f. pivoting [19]).

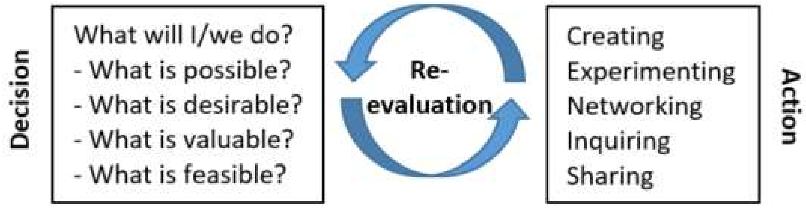

Figure 1: A graphical representation of the analytical framework, capturing key aspects of entrepreneurial decision and action

'Entrepreneurial decisions' is used here to discuss the nature of the choices students get to make while engaging in a project-based course, and questions they need to relate to in order to make such a decision: *i) What is possible?* relating to open and self-directed ideation or visioning, e.g. in the choice of focus or problem to take on; *ii) What is desirable?* taking into account internal contingencies, e.g. own commitment and motivation, in order to engage in self-directed action in uncertain or complex situations, *iii) What is valuable?* explicitly taking into external contingencies in the form of the perspectives of others (e.g. external receiver) on the quality and value of solutions, and *iv) What is feasible?* relating to both internal contingencies, in terms of own resources, such as knowledge, skills and networks, and external contingencies, e.g. taking into account constraints put up by teachers or other involved actors.

'Entrepreneurial actions' is used here to discuss the nature of project activities and actions taken by students. Aspects of entrepreneurial action include: *i) creating* - having an emphasis of the creation of something, e.g. a design, solution or product; *ii) experimenting* - investing time and effort in several ways to approach undertaking a project or solving a problem, 'keeping several doors open', and slowly converging on a single way by continuously evaluating what focus and strategy is useful; *iii) networking* - communicating with external individuals in order to build commitment to project or retrieve resources to use; *iv) inquiring* - searching for new information and input that can help evaluate what strategy is most useful, and in realizing this strategy; and *v) sharing* - continuously showing, presenting or performing the outcomes of current and planned activities for internal and external individuals while communicating ownership of created outcomes, in order to get input on further activity, e.g. in term of what is valuable for someone else.

1.2 Data collection and courses

Eight courses were sampled by examination of course documents for all courses at Chalmers University of Technology, aiming to find courses which might follow an effectual logic and purposively surveying courses across educational areas, including those with and without 'entrepreneurship' in the course name. The resulting sample includes courses ranging in class size from 10 to 100 students and course credit from 6.0 to 15 credits (hec). The eight projects range in extent and complexity from straightforward task projects, e.g. investigating the materials and production of a product, to more complex projects where students e.g. develop a technical solution in co-creation with an external actor, or design and build an entire car.

Semi-structured interviews were conducted with the eight educators responsible for the project-based courses. The interviews focused on learning environment, teaching and learning activities, assessment, and aspects relevant for an entrepreneurial experience (e.g. uncertainty, teamwork). The interviews were transcribed and analyzed using the framework delineated in the previous section, assessing the extent to which the students were given opportunity to engage in 'entrepreneurial' decision and action, i.e. activities guided by an effectual logic.

2 RESULTS

The result of the analysis is presented in Table 1.

Table 1: The extent to which students get to relate to a number of decisions and engage in specific actions in project based courses. Here, a small circle indicates that the specific aspects is possible, and a larger circle indicates an emphasis on this decision or activity.

Aspects		Courses							
		1	2	3	4	5	6	7	8
Decision	Possible?		●	●	•		•	•	●
	Desirable?		•	•	•		•	•	•
	Valuable?		•	•	●	•	●		•
	Feasible?	•	●	●	●		•	•	•
Iteration			●	•	●				•
Action	Creating		●	•	●	•			•
	Experimenting		●	•	●	•			
	Networking		•	•	•	•	•		
	Inquiring	●	•	●	●	●	●	●	•
	Sharing	•	●	●	●	•	•	•	•

2.1 Entrepreneurial decision

The degree of freedom to choose *what* to do, and *how* to work is central to enacting effectuation, since it rests upon a logic of control. In many of the courses, students are given freedom to decide upon what problem or product to choose (Possible?). Three courses are especially open for students to introduce own ideas (2, 3, 8). However, the *nature* of the project seems to be defined mainly by teachers. I.e., the students do not seem to be engaged in defining what kind of endeavor they will undertake (e.g. through setting objectives) to a larger extent (course 3 is an exceptions). This could hinder enactment of effectual logic, and moreover affect students' motivation, commitment and ownership of projects and outcomes. The students are frequently asked to make decisions regarding *feasibility*, both relating to *focus* of their project and to some extent *actions* taken towards finishing the project (mainly courses 2, 3, 4). However, this seems to be mainly focusing on external contingencies (e.g. time-constraints, picking an invention which 'will work' for achieving the project task), rather than internal (such as identifying own resources and knowledge). Similarly, it seems uncommon that students get to explicitly relate to what they desire and are committed to doing, i.e. not starting from questions such as: 'What do I want to do? Who am I?'. Starting from one's own commitment and resources is central to effectuation, connected to ability to create something in conditions of uncertainty and coping with acting and creating in a dynamic environment. Explicitly taking into consideration the perspectives of someone else on quality and value of solution (Valueable?) was slightly more common, emphasized in two of the courses (4, 6).

In some of the courses (especially 2 and 4), the students get to search for input that can redirect their decisions regarding their solution or product, i.e. engaging them in explicit iteration on this level. However, none of the courses includes iteration on the level of project definition. The project is most often set from the beginning by teachers (in course 3 defined by students), but there is no re-evaluation on this level, i.e. not re-posing the question “is this the right project to do?” and redirecting action accordingly. Iterating on a project level, enabling students to do real pivots, could be needed for an effectual action logic to be enacted, as it does not rely primarily on fixed end goals.

2.2 Entrepreneurial action

The courses seem to be mainly engaging students in some kind of self-directed inquiry. Some of the courses also engage students in creation (of products, design or solutions), either as a core activity (courses 2, 4) or as a side activity (courses 3, 5, 8). These two aspects give students the possibility to enact specific aspects of an effectual action logic. Moreover, all courses give the opportunity for students to share their work, although most presentations are internal and do not explicitly call for students to ‘defend’, ‘pitch’ or ‘own’ their project outcomes. Students do need to communicate with external individuals in many cases (courses 2-6), for example reaching out to external researchers to get input, or interacting with an external stakeholder with which the students have been put in contact by their teacher. However, there is only one case (course 2) where networking was discussed, for students to build commitment or retrieve resources from an external individual. However, even in this case it was not a necessary activity. Another potential barrier for enactment of an effectual logic is that students seem to be investing their time into only one path or strategy, experimenting in some courses (mainly 2 and 4), however only on a problem or product level, and not on a project level, choosing among different ways to approach their endeavor.

3 DISCUSSION

New value creation and effectuation was applied here in order to assess ways in which project-based courses are entrepreneurial. The results indicate that three courses stand out in engaging students in projects through which effectuation could be enacted (courses 2-4). One of these courses (course 4) explicitly involve creation of an artefact (a software application) in relation to an external stakeholder, while the other two engaged students in highly self-directed inquiry, creation, experimentation and sharing of results. Involvement of an external actor as a receiver of students’ solutions creates natural opportunities for students to inquire into and reflect upon what is valuable for that person or company, and opportunities to share and communicate ownership of project results. This has earlier been advocated as a key part in enhancing engagement in student-centered learning [20]. Arranging project activities around real-world problems and having students co-create and present to external stakeholders could increase the level of authenticity of projects. Accordingly, project-based engineering courses with external actors could potentially provide students with opportunity to engage in entrepreneurial decision and action.

It seems however, even in courses involving external stakeholders and creation of new value, that *i)* lack of explicit recognition of own commitment and resources, *ii)* lack of iteration and experimentation on a project definition level, and *iii)* lack of networking activity and external sharing of project outcomes, constitute barriers for the enactment of an effectual action logic in project based courses. This analysis suggests that engaging students in new value creation for or together with external individuals could be seen as necessary but not sufficient criteria to enable the enactment of an effectual action logic. Overcoming the three barriers stated above puts demands on self-direction, flexibility and management of uncertainty on part of the students, to be able to handle open and dynamic projects and to dare to engage in networking activities. This would indicate that trying to achieve a proper enactment of effectual action logic might be more suitable in later years of engineering programs, or in early years with thorough use of scaffolding techniques. Furthermore, open and complex projects call for a teacher to manage designing course structure and assessment able to account for large varieties in project processes and outcomes. We propose here that such course design and assessment should rely predominantly on recurring reflection assignments (featuring reflection and evaluation of new knowledge gained, decisions made and actions taken), instead of large product, project or reflection reports only at the end of the course. Similarly, we believe that such a course should focus on implementation of methods, processes and strategies to improve these, rather than on developing a nice product, and on what is purposeful and valuable rather than technical details. Through this, project-based courses could give students further opportunity to enact effectual action logic, and could also contribute to the development of adaptive and flexible mindsets, and help students get accustomed to managing and coping with uncertainty.

We have investigated here the relationship between an inductive teaching method, the project-based approach, and learning through entrepreneurship, which has gained prominence in later years following a substantial amount of initiatives for the inclusion of entrepreneurship into education. We believe that the shift from casual to effectual modes of teaching is in line with the shift from deductive to inductive teaching in engineering - especially sharing an emphasis of student-centered and self-directed learning and inquiry. In the context of project-based engineering courses investigated here, we also found a shared emphasis on creation, indicating that through some strategic changes in course structure, these courses might be potential training ground for entrepreneurial capabilities.

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What can a child's experiences tell us about engineering education activities?

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ABSTRACT

This paper presents the emergent findings from a current PhD study exploring children's experiences of 'active' engineering education. The study aims to develop a deeper understanding of the outcomes of participation in such activities for children in rural schools, and collects data from the first person perspective to enable this. The literature suggests that career aspirations may be formed by children as young as 8 years, however current debate largely overlooks the experiences of children at this age. The study presented takes a qualitative methodological stance and, adopting an approach based upon grounded theory, uses observations and semi-structured interview data to analyse participation in an engineering activity. The emergent findings suggest that many sources inform a child's knowledge of engineering, contributing to their view of engineering; it is a child's *a priori* perceptions of engineering and engineers which ultimately 'frames' how they experience organised engineering education activities. Simply, a child's view of their engineering suitability is influenced by a range of factors prior to formal engineering education being introduced. Formal engineering education activities have a role, but often these simply reinforce previously held beliefs. The implications of this finding are of great importance for the field.

Conference Key Areas: Engineering Education Research, Attractiveness of Engineering Education

Keywords: qualitative; primary school; group interviews; aspirations

INTRODUCTION

The lack of recruitment and retention of engineering students and issues faced by industry when recruiting STEM (Science, Technology, Engineering and Mathematics) skilled individuals is recognised globally[1]. Previous studies identify the ages of 8 – 11 as being fundamental in the development of career aspirations[2], with children already constructing ideas about what subjects are 'not for me'[3]. However, the area of engineering education at this age (UK Primary school) is rarely the focus within research. Government and media attention has resulted in engineering education initiatives being offered to UK schools (for example STEM Ambassadors[4] and the STEM Directories[5]) and there is support for STEM enrichment activities as a means to engage young people with STEM careers[6]. However, there has been minimal monitoring of these activities and the lack of 'impact' that current (and past) engineering education initiatives has had on the number of young people studying to become engineers is now being highlighted by professional bodies[7, 8]. An understanding of how these activities are experienced by the children participating in them is currently missing in the literature and is crucial if we are to develop our understanding of the influence these activities have on the awareness and perception of engineering that children hold.

1 METHODOLOGY

The lack of exploration in this field influenced the choice of methodology with a grounded theory approach[9] being employed in this PhD study. This choice of methodology follows from the constructivist paradigm that this research is conducted under and allows the topic to be explored from the children's perspective. Whilst it has been argued that grounded theory aligns with a post-positivist viewpoint[10], Charmaz[11] has demonstrated a strong use of this approach when carried out from a constructivist stance. The value of exploring individual conceptual awareness of an experience rests on the process of data collection and analysis. The grounded theory approach allows concepts to emerge directly from the data and, through constant comparative analysis, be explored in more detail in subsequent data collection. Memoing is utilised to build a picture of the relationships between concepts (and their sub-concepts). These relationships are considered from the outset of data collection, continuing throughout the entire study to enable the construction of theory from the data. Whilst this approach gives researchers and practitioners the opportunity to understand what children at this age are experiencing in terms of engineering education, the limitations of this approach need to be recognised. The research contains inherent inequalities of power, the researcher-participant relationship is not an equal one, this is amplified when an adult conducts research with child participants[12, 13]. Interpretation of the data is necessarily carried out by the researcher, regardless of the clarification sought during data collection. These concerns are minimised through researcher awareness and reflexivity[9, 11] but can never be removed completely from a study of this nature. The individual experiences and perspective of the researcher adds both a strength and a limitation to the research and it is accounted for through being 'self-aware' throughout the research.

2 ETHICS

The university ethics committee granted ethical approval for this study, however ethical mindfulness is required throughout the study due to the age of the participants[12, 13]. The researcher drew on her experience of working with young people in schools and as a Brownie leader to understand the interaction between herself (as an adult and a researcher) and the children (as children and participants) and be aware of the safeguarding required, such as the requirement to hold a valid Disclosure and Barring Services (DBS) check. This knowledge and experience was also beneficial when gaining informed consent which was sought from the schools, the parents of the children and the children themselves. Information sheets and forms were created for each group and were tailored to provide the required information in an accessible format.

3 DATA COLLECTION

To date, data has been gathered from observations carried out in two schools, one a primary school and the other a middle school. The schools are both located in rural areas of Staffordshire, UK. Each school facilitated a different engineering focused educational activity, one was delivered by the class teacher during Design and Technology lessons and one was provided by an external company in an off-timetable session. The observations were followed by group interviews with some of the children who took part, the data collected from the observations was used as context for the initial interviews. Semi-structured interviews were carried out and photo elicitation was used when necessary with photographs that had been taken by the researcher during the observations. The interviews were held in the school that the children attend, some interviews were carried out in the same room as the observed activity however the majority were carried out in either the computer room or the conference room of the school. In total 48 children participated in the first set of interviews.

A semi-structured interview guide was used, this was divided into five thematic areas: Aspirations, play/interest, awareness/perception of engineering, engineering role models, and hands-on engineering experience. This approach benefited the research as it allowed the interviewer to focus on the issues identified as important within the study whilst also giving the children the freedom to discuss their own thoughts. The children could raise matters which were not covered in the interview guide meaning that new concepts could be identified during the interviews. Grounded theory allows for this by using constant comparative analysis from the outset, once new concepts emerge the approach allows for these to be explored in subsequent interviews.

The data collection process was challenging, this was mainly due to the nature of the research participants. Identifying schools who engaged in engineering education activities was initially difficult and access to schools relied heavily on their being a known ‘gatekeeper’ who could be contacted directly. Secondly, encouraging schools to participate in the research process, which included administration of many consent forms, meant that multiple schools declined to participate. Once access was negotiated challenges were faced with observing and interacting with the children through interviews, these are akin to those described in existing literature[12, 13] and were not unexpected.

A second round of interviews is currently being carried out to explore the children’s views and experiences months after taking part in the activity. A third round of interviews is scheduled to be conducted in the early part of the next academic year when the children have progressed to Year 7.

4 FINDINGS

Data from all participants has been combined for the purposes of this paper and the emergent findings from two of the interview concepts are presented here; awareness and perception, and aspirations. A third concept is also presented which emerged during the interviews, framing. The analysis is still being undertaken and so these should be viewed as a snap-shot during the analysis of the data.

4.1 Awareness and perception of engineering

The initial interview questions explored engineering from the child’s point of view and what children think engineers do. However, the children’s perception of engineering and what is means to be an engineer appeared throughout the interviews and was revisited by the children throughout their narratives. Only a minority of the children expressed a confident view of what engineering is and what engineers do, the majority of children expressed their thoughts as questions directed at the interviewer. The context in which the interviews were carried out may explain this, the implicit expectations about the adult-child relationship and research setting, but it also suggests that the children are unsure of their own knowledge about engineering. Some children voiced that they had no knowledge about engineering and others input little of their own perception of engineering at the start and later mentioned their limited knowledge. However, most of the children held perceptions about engineering whilst simultaneously having little awareness of what ‘being an engineer’ involves. This mismatch of awareness and perception surfaced in the data multiple times and was also displayed as children having no ideas about engineering but offering their opinion about what an engineer does at work.

What does it mean to be an engineer?

When talking, children tend to refer to engineering in terms of physical artefacts (transport was mentioned frequently) or describe engineering in terms of the skills involved or the knowledge required by an engineer:

> *You would also know like how to build stuff and…erm you know how stuff works.*
>
> *I think engineering could be like, like finding something out maybe.*

Very few children referred to engineers and engineering in terms of the role they play in society:

> *They help the world move on to like high tech stuff.*
>
> *Is engineering like some kind of way of using something out of electricity and power to help you in your everyday job…?*

The influence of social and multimedia

The interviews explored how the children constructed their view of engineering and the importance of the concept of *knowledge acquisition* came to light through the children’s narratives. Many of the children spoke about things that had led to their current thoughts, the role of media and gaming was a recurrent theme in the interviews:

> *…I’ve never experienced it but it looks fun, the stuff I watch on telly like Top Gear.*
>
> *I think it’s the game that’s put me into it, it’s fascinating.*

Whilst reference was made by some children to television programmes and games that explicitly linked themselves with engineering through the title or description, often the programme or game being referred to did not have a specific engineering focus.

The importance of role models

In addition to the media, role models from the children’s families were also mentioned by many children when thinking about what engineering is:

> *I don’t really know anyone who does engineering or anything.*
>
> *I think, well my dad […] his first job was as an engineer but it wasn’t for very long so I still don’t know much about it.*

Interestingly, children view role models as a reason they know (or should know) about engineering and also their lack of engineering role models as a reason for not knowing about engineering. Some children also expressed that although they had access to engineering role models, these role models were not always utilised. This is illustrated in the interview excerpt below, as well as in other children’s narratives (names are pseudonyms):

Interviewer: What does your Dad do?

Pete: Erm, well he's designed, I think he's doing a helicopter and he's done like a ride, I think he is either doing or done the ride, and yeah.

Interviewer: Does he tell you about his work?

Pete: Erm no not really, I don't pay much attention.

4.2 Aspirations: Engineering as a future career

The majority of children at this age hold career aspirations however only a minority of the children hold engineering focused career aspirations. A mixed response to engineering as a possible career was exhibited, the limited knowledge that the children have became evident and was recognised by some as hindering their ability to consider engineering as a career:

I don't know what certain jobs you could get for engineering so I'm not quite sure.

I don't really know because I don't really know much about engineers so I dunno what it would be like to be one…

For those children that considered themselves able and willing to be engineers, engineering was not their priority career:

I'd have it as a backup job.

If like maybe when I get a bit older like after if I am an RAF pilot I might be an engineer for the RAF or something so I can fix the planes and stuff.

The career aspirations that the children displayed varied with sports and animal care being dominant career aspirations. Many of the children who held strong career aspirations do not consider the possibility of becoming an engineer as they 'want to do something else'.

4.3 Framing

Career aspirations

The concept of *framing* emerging when the children talked about their views of engineering as a potential career as well as when they discussed the engineering activity they had participated in.

When talking about career aspirations, the children described themselves as either able to be an engineer or not. This differentiation was based on their perceived knowledge of engineering and their view of their own knowledge and abilities in relation to what they considered engineering to be:

…because I don't really know much about cars and stuff.

I like cars as well so maybe engineering might be like something that I want to do.

Contemporaneous views of engineering education activities

During the interviews the engineering content of the activity that the children participated in was explored as perceived by the children themselves. The resulting data displayed a split between those who thought they had done 'actual' engineering and those who thought they had not:

It's not like actually engineering, like a proper car or something like that.

…cos you had to figure out like where to put stuff…and where to like, how to make it work.

The perceptions that the children hold about engineering influenced how they framed the activity, as engineering or not engineering. In one interview Matt holds a firm belief that engineering is about cars, this had been informed through TV shows such as Top Gear. When discussing the activity that they had participated in, Matt was unsure about the engineering content of the activity until it was framed in the context of his existing perception of engineering, cars (names are pseudonyms):

Interviewer: The activity that you are doing, do you think that's engineering?

Matt: a little bit…

Bryn: yes, yeah.

Matt: …but I don't know why.

Jane: it's designing and making.

Becka: designing and making, yeah.

Matt: I mean you could design a new Lamborghini but…

Becka: yeah and you could like design a new engine.

5 ANALYSIS AND DISCUSSION

The main concepts that emerged from the data are those of *Framing*, *Perception* and *Knowledge Acquisition*. The children framed themselves as either capable of being an engineer or not, they also framed the activity as being engineering or not. This framing occurred largely from the perceptions that the children held about engineering which were formed based on knowledge acquired from a variety of sources. Figure 1 shows a conceptual model of the data, at this early stage of the analysis this should be regarded as a working model which will form the basis of future analysis.

At this stage in the study it is interesting to note the similarities between the emerging concepts and the literature where role models and media are cited as influencing a child's awareness and perception of engineering/engineers[14, 15]. As relationships between the emergent concepts are constructed it appears that children acquire their knowledge about engineering from a range of sources, with the influence of TV programmes, gaming and the internet not to be underestimated. The importance that children place on role models as sources of information about the world is high, this fits with the findings of Archer et al. who identified the influence of social capital on an individual's ability to consider science as a potential career[16]. The current study finds that engineering specific social capital does inform a child's perceptions of engineering (which influences how they frame themselves as an engineer) however, access to role models does not mean active engagement with them; having access to social capital is not the same as utilising social capital. Whilst many of the children know family members who are or have been engineers, this does not correlate to obtaining knowledge of engineering or an aspiration to engineering. Although this may be the case, many of the children who displayed a lack of engineering social capital referred to this when talking about their inability to make informed career decisions regarding engineering. It is important to note that the child determines who they regard as an engineer. This, along with the link between social capital and engineering aspirations is an area that will be considered further in future analysis.

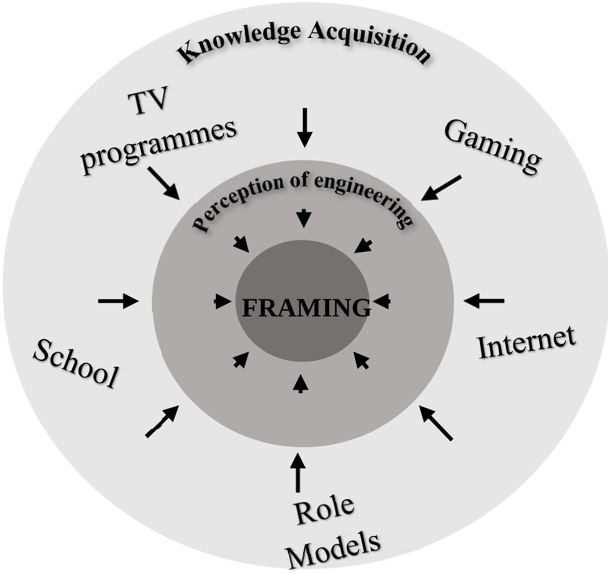

Figure 1: Emergent conceptual framework depicting children's experiences of engineering education activities within English schools.

An unexpected emergent finding is that of how the children 'frame' the activity. This study finds that rather than the engineering activity altering or informing the child's view of engineering, many children who participated in these activities either dismiss such activities as 'not engineering' or frame them within their existing world-view of engineering (which may or may not be accurate).

6 CONCLUSION

In conclusion, this paper presents the emergent findings from the first round of interviews conducted as part of a longitudinal study. Of interest is that it is the perceptions of engineering that children already hold at age 8-10 which are used to frame any subsequent engineering education activity. Whilst further analysis is required to examine the relationships between the concepts displayed within the data, the emergent finding of this paper is of great importance. It indicates that engineering activities are currently introduced at too late a stage to have the desired impacts on children's awareness and career aspirations; formal engineering education needs to be introduced at an earlier stage to make the required difference. This research provides a previously unexplored perspective of current engineering education provision which challenges the perceived purpose, delivery strategy and evaluation of engineering education delivered to this age group.

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"Real" experiments or computers in labs – opposites or synergies?

Experiences from a course in electric circuit theory

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ABSTRACT

In this study we report from our experiences designing and re-designing a lab where engineering students studied transient response in electric circuits. In the first version of the lab students had difficulties doing the mathematical modeling of the experimentally measured graphs as it required students' to link the time- and frequency domains as well as the object/event and theory/model worlds simultaneously. In the re-designed lab some computer simulations were included together with the original experiments on real circuits. The simulations opened up for learning and enabled students to establish links that are hard access directly with real experiments. Still doing real experiments is important to secure students ability to make links between models and theories and the physical reality. This study demonstrates that synergetic learning effects can be achieved by a careful design using an insightful combination of real experiments and computer simulations. Hence, we propose that the question of "real" experiments or "virtual" labs using computer simulations are best for students' learning is not an either or question. Rather, it is a question of finding the right blend to achieve synergetic effects.

Conference Key Areas: Engineering education research, curriculum development, physics and engineering education

Keywords: Interaction analysis, experiential learning, modeling, simulations.

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INTRODUCTION

A common question in the context of lab instruction is if "computer simulations can replace real experiments"? However, the results from earlier research contrasting similar labs using real versus virtual environments have been contradictory. Some studies have reported better learning results with simulations, while other studies have reported that there is a risk that simulations become a world in itself and that students' do not develop links between theories and models to objects and events in physical reality [1–4]. In this study our question was not about replacement, but instead if "real" experiments and computer modelling and simulations could supplement each other, i.e. if synergetic effects could be achieved (cf. reference [5]).

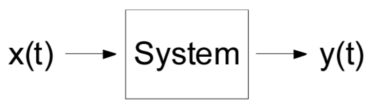
This paper is organized as follows: Section 1 describes the setting of the study, the object of learning and the purpose of the study; Section 2 describes the theoretical framework and the qualitative methodology used, i.e. design-based-research, variation theory, interaction analysis, and the learning of a complex concept model; Section 3 presents the findings of the current study; finally, Section 4 presents some conclusions and a summary.

1 BACKGROUND AND SETTING

1.1 Setting

Students' learning in an electric circuit theory course was studied. The electrical engineering students took this course during the whole spring semester in their first year of studies when this study was undertaken. The first part of the course covered standard DC- and AC-theory, while the second part of the course covered electric circuits with periodic, non-sinusoidal signals, using Fourier series and transfer functions and transient response using Laplace transforms. This study is part of a series of studies aiming at developing insightful learning in physics and electrical engineering through conceptual labs [5]. The focus in this study will be on students' learning and understanding transient response in one of the labs. We have previously reported on the design of tasks using variation theory (see section 2.2) in this transient response lab [6]. In the present study a special emphasis will instead be on the question if simulations could be used to achieve additional learning effects.

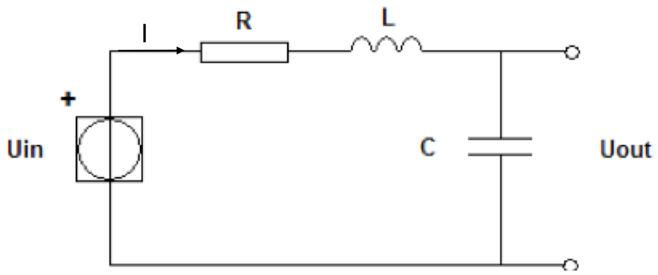
1.2 Object of learning: Transient response



$Y(s) = G(s) \cdot X(s)$

$G(s) =$ transfer function

a.



b.

Fig. 1. a) A circuit viewed as a system where $X(s)$ and $Y(s)$ are the Laplace transforms of $x(t)$ and $y(t)$.
b) The electric circuit investigated in the transient response lab.

The input voltage is in this lab a step (practically achieved by a square wave with low frequency). *L* and *C* are kept constant and the value of *R* is varied. One of the explicit task posed in the lab instruction is to make a curve fit to the measured graphs of the current through the circuit for various values of *R*. This basically comes down to find an appropriate mathematical expression to cause a calculated graph to give the same curve as the measured graph, and to show both in the same figure. It was possible to do this in the same computer program – *Data Studio* – that was used to control the computer interface that generated the input voltage to the circuit and measured the current through the circuit and the output voltage.

The system in Fig. 1b is a second order and if the output signal $y(t)$ is taken as the current through the circuit the transfer function will be

$$G(s) = \frac{1}{L} \cdot \frac{s}{s^2 + \frac{R}{L}s + \frac{1}{LC}}$$

If the input signal $x(t)=u_{in}(t)$ is a voltage step applied at t = 0, depending on character of the roots of the denominator (poles) of $G(s)$ – i.e. if they are complex-conjugated, double real, or two real – the resulting current $i(t)$ will have the form

$$\begin{cases} i(t) = ae^{bt}\sin(ct) \\ i(t) = ate^{bt} \\ i(t) = a(e^{bt} - e^{ct}) \end{cases} \quad \text{when} \quad \begin{cases} R < 2\cdot\sqrt{L/C} \\ R = 2\cdot\sqrt{L/C} \\ R > 2\cdot\sqrt{L/C} \end{cases}$$

The resistance R is made up of a varying resistor resistance R_{res} in addition to a resistance R_{coil} ≈ 6 Ω from the inductor coil. Experimentally measured curves are displayed in Figure 2.

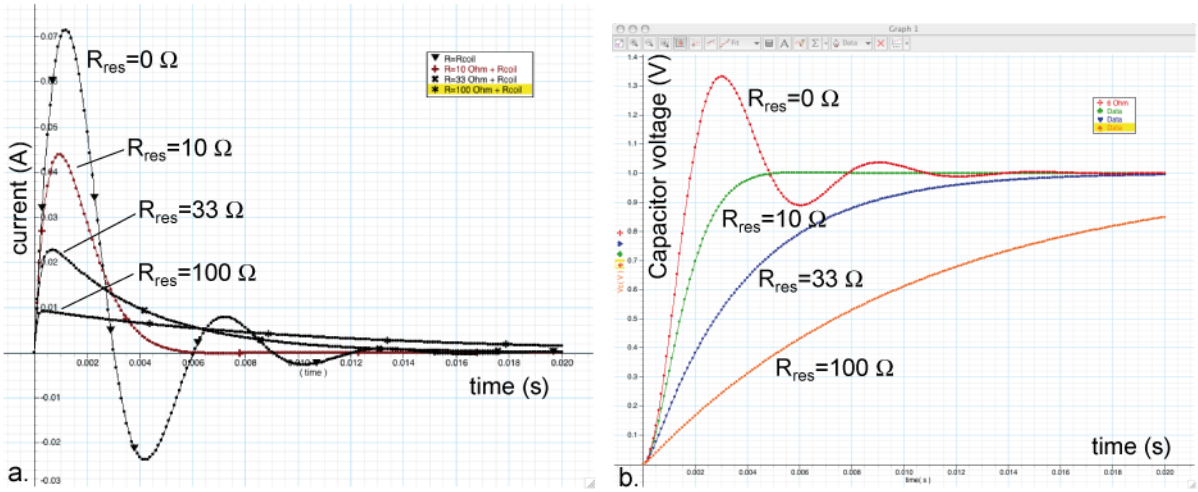


Fig. 2. Experimental curves for *a)* the current and *b)* the capacitor voltage for different values of R_{res} (L=8.2 mH and C=100 µF) when the input voltage is a unit step.

1.3 Purpose and research question

The original purpose was to design a lab to enhance students' understanding of transient response in electric circuits and to study students' learning process while doing the lab to evaluate the success of the design and any needs for improvements.

Students' observed difficulties in the first version of the transient lab as is described below in section 3.1 led to the following revised research question: To investigate if a re-design of the transient response lab to include computer simulations, together with experiments on real circuits, could improve students' learning? I.e. could links be made across the circle in Fig. 3a, and not only along the perimeter? The hypothesis was that the simulations could open up for learning and enabling the students to establish links that are hard access directly with real experiments.

2 THEORETICAL FRAMEWORK AND METHODOLOGY

2.1 Design-based-research

The empirical study described in this paper has been conducted within a series of projects [5] aiming at improving physics and engineering education that can be described as examples of design-based-research [7–9]. According to Lo *et al.* [10] the "benefits of design experiments are that we will be able to contribute to theory development, and improve practice at the same time". It is thus "a systematic attempt to achieve an educational objective and learn from that attempt". In a design study educational activities are investigated in cycles of design, enactment, analysis, and re-design where the development of educational designs goes hand in hand with the development of theories and methodologies. Using the methods of design science we present in reference [11] a more thorough description of this simultaneous development than can be described in this short paper.

2.2 Variation theory

A framework that was used in the design of the labs was *variation theory* [12, 13]. According to this theory, it is important to ensure that the learning environment enables students to focus on the object of learning and discern its critical features to promote effective learning. Central to variation theory is the notion that we discern certain aspects of an environment by experiencing variation, rather than by recognizing similarities. Important concepts are hence *discernment*, *simultaneity*, and *variation*. When one aspect of a phenomenon or an event varies, while one or more aspects remain the same, the aspect that changes is the one that will be discerned. One of the main themes of variation theory is that the pattern of variation inherent in the learning situation is fundamental to the development of certain capabilities. Experiencing variation amounts to experiencing different instances of the object of learning simultaneously. This simultaneity can be either *diachronic* (experiencing, *at the same time*, aspects of something that we have encountered at different points in time), or *synchronic* (experiencing different coexisting aspects of the same thing at the same time).

Marton related learning to what students could *possibly* experience in a particular classroom situation, stating that in a learning situation "the critical aspects that it is *possible* [for a student] to discern … make up the *enacted* object of learning" [13, p. 27]. Another important distinction in a learning situation is the difference between the *intended* object of learning (the knowledge, values, and skills the teacher or curriculum designer wants the students to learn) and the *lived* object of learning (the critical aspects that *could be discerned* and that the student *actually discerns*, i.e. what the student learns in the end).

2.3 Interaction analysis and learning of complex concepts

Analysis of the learning that occurs in the different versions of the transient lab was performed in several steps: First, to study students' interactions [14] and their in situ development of their lived object of learning some lab-groups (each comprising 2-3 students) were recorded using a digital camcorder, obtaining a total of 80 h of video from the original and the re-designed versions of the transient response lab. This data was subsequently used to detect typical interaction patterns. We were particularly looking for what the students' did during the labs, what resources they used, what they made relevant, and how they oriented themselves towards the object of learning. After repeated viewings, some episodes were found to contain more interesting and comparable activities. These episodes were originally transcribed to allow for detailed examination of interactional patterns.

The results of our analysis of the enacted and lived object of learning in the first version of the transient lab were, in line with the methods of design-based-research, used as an input and point of departure in the revision of the transient response lab.

As already mentioned (see section 2.1) one feature of design-based-research is the simultaneous development of educational practice *and* theories and methodologies. To represent students' courses of action in complete lab-sessions we have further developed the notion of "practical epistemologies" [15, 16] into a graphical model - tentatively named the "learning of a complex concept" (LCC) model [17–19]. The LCC-model was suitable for our analysis as the transcription of, analysis of transcripts from, labs lasting several hours is awkward and it is difficult to get a good overview. In this model "single concepts" are illustrated as nodes or "islands" that may be connected by links, while the links students actually make (identified by analysing the lived object of learning), or are supposed to establish (identified by analysing the intended object of learning), are represented by arrows. The nodes in our model are found by looking for "gaps" in the actions and conversations of students. A gap corresponds to a non-established link, and when a gap is filled and the students establish a relation between two nodes this is represented by an arrow indicating the direction of the link. The LCC-model also extends Tiberghien's [20] model of object/event and theory/model 'worlds'. In Fig. 3 and 4 entities analytically categorised as belonging object/event world are shaded and those categorised as belonging to the theory/model world are un-shaded.

The idea behind the LCC-model is that knowledge is holistic. The learning of the whole object of learning – the complex concept – is made through making explicit links. Thus the more links that are made, the more complete knowledge becomes.

3 RESULTS

3.1 Student learning in first version of transient lab

One of the intended objects of learning in transient lab is that students' should understand that the characteristics of the poles of the transfer function $G(s)$ determines the characteristics of the response (output signal). In this case, that varying values for the resistance will result in different types of responses.

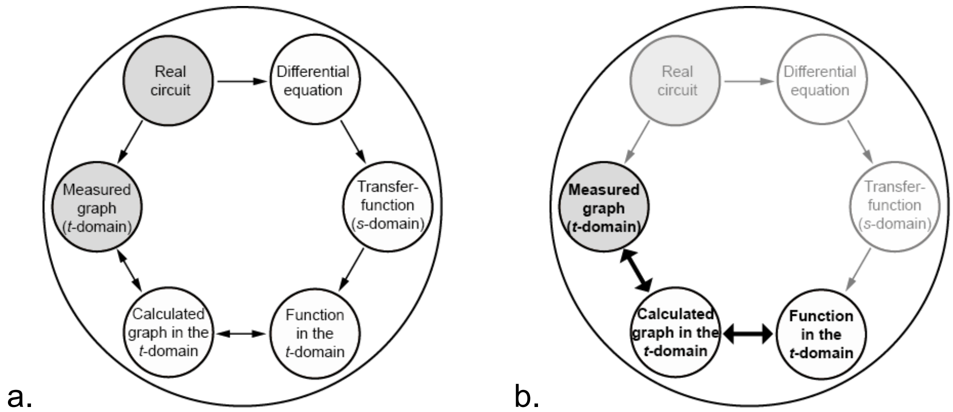


Fig. 3. a) Enacted and lived object of learning in the first version of the transient lab. *b)* Students' focus when making curve fits using *mathematical functions* to model the response in the time-domain in the first version of the lab.

Furthermore, the students were instructed to make a curve fit to the experimental curves for $i(t)$ (see Fig. 2a) for varies values of R_{res} and from the curve fit determine the values for R, L, and C in the circuit (see Fig. 1b). This turned out to be a very difficult task for most students. This requires that the students identify what type of function the different curves in Fig. 2a correspond to. However, although the students in practice only had two functions to choose from – either $ae^{bt}\sin(ct)$ or $a(e^{bt}-e^{ct})$ for $t>0$ – they used all types of functions as an onset. Analysis of the videotapes recording students' discourse in this first version of the lab, and observations, revealed that students during the lab mostly worked with one concept/entity (see Fig. 3a) at a time. Students avoided, or postponed, to do the necessary mathematics. It was commonly done after the lab-instructor had pointed out its necessity and only as late as possible. Students' discussions were focused on the process and a typical question was "is this good enough for the report?"

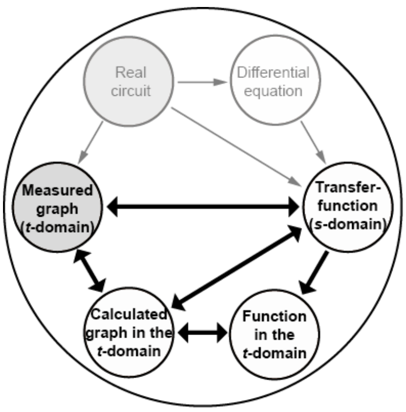
A more detailed analysis revealed that, when making curve fits, students only focused on the measured graphs, the calculated graph from the curve fit, and the function used to make the curve fit (See Fig 3b). No links were made to the transfer function.

In the first version of the transient lab the task structure (i.e. the *enacted* object of learning) followed a circular path as displayed in Fig. 3a. Consequently students' learning trajectory (i.e. *lived* object of learning) followed this pathway. As is discussed in section 3.1 students had difficulties to mathematically model the step response in an appropriate way and to draw conclusions from their model. Although the *intended* object of learning was that they should be able to make a link between the measured graphs this was not apparent in the task structure. Actually, as can be seen in Fig. 3 it was only possible for students to make links between the object/event and the theory/model world at two places.

3.2 Student learning in the re-designed version of the transient lab

Thus, the objective became to design tasks that would facilitate making links across the circle. By using, for example, Simulink® it is possible to simulate the step response to various transfer functions and get the results in a graphical form.

It was decided to include simulations using Simulink® in the revised lab. In line with Variation theory [12, 13] the transfer functions were systematically varied. For example, three forms for the denominator were used (s^2 + 2s + 5, s^2 + 2s + 1, and s^2 + 2s + 0.75) with complex-conjugated roots, a double root, and two real roots respectively. In the initial trials, two numerators were used (5 and 3s + 5) giving 6 combinations of numerator and denominator. In subsequent revisions, 3s was added as a third numerator.



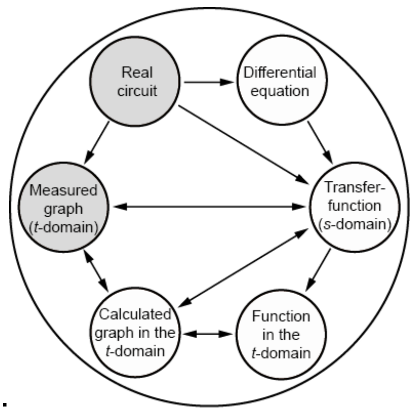


Fig. 4. a) Triangular routes enabled by the inclusion of simulations in the revised version of the lab. *b)* Students' lived object of learning at the end of the revised lab.

Classroom observations and the video-recordings revealed that the students participating in the revised version of the lab worked in a rather different way. The simulations enabled students to see where they were heading with the mathematics as the simulation outputs had similar forms as the experimental curves. However, it appeared that the mathematics felt easier for the students to start with as the transfer functions used in Simulink® had “nice numbers” (the denominator roots for the different transfer function were -1 ± 2*j*, -1, and -1 ± 0.5 respectively). Actually, in the original version of the lab completely analogous mathematics was involved in the modelling of the step response and measured graphs. However, as the numbers involved were not “nice”, it become a threshold for the students to overcome and in the first version of the lab students’ therefore dared not to start with the mathematics.

Our analysis is that the inclusion of simulations enabled the students’ to establish a triangular route between the *measured graph*, the *calculated graph*, and the *transfer function* and another triangular route between the *calculated graph*, the *function in the time-domain*, and the *transfer function* as is shown in figure 4a. As a result the students were not afraid of the mathematics and started with it from the beginning. Discussion centred on the underlying content of the lab. During the lab students noticed the relationships between different experimental graphs instead of looking only at one curve at a time. Throughout the lab they made links between the “single concepts” and at the end of the lab all the observed students had established the links displayed if Fig. 4b indicating a richer understanding.

4 SUMMARY AND ACKNOWLEDGMENTS

Variation theory, was indeed, applied also in the design of the first version of the transient lab. However, according to our analysis the students’ were not able to discern the critical features of the object of learning. The inclusion of the simulations enabled students to focus on the object of learning and discern its critical features.

The result of this study and other studies by us demonstrates that “real” experiments versus computer simulations may not be an either/or question. The study demonstrates that by careful design synergetic learning effects can be achieved by an insightful combination of real experiments and computer simulations. Simulations can, for example, reveal aspects that may be difficult visualize or achieve experimentally while doing real experiments secures students’ ability to make links between models and theories and the physical reality (i.e objects and events). Furthermore this study, and other studies, points to the importance of the appropriate design of task structures in labs; i.e. the pedagogical design of a lab may be more important for learning outcomes than if it is “real” or “virtual” (cf. reference [21]).

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Designing blended engineering courses

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ABSTRACT

Universities have to deal with larger differences of engagement between students and more need for outcomes-based teaching and learning that allows for differences in learning styles. In addition for engineers, the rapidly changing world brings the need to engage students in diverse learning.

Wageningen University & Research is experiencing these trends. It tackles them with outcomes-based teaching and engaging students within a rich setting of blended learning. The resulting education programmes are rated as the best in the national surveys of the last twelve years.

This paper describes how to design such blended learning courses based on literature. It also reflects the experience of Wageningen University & Research with its successful approach.

The prerequisites for course design are a well-constructed curriculum and properly formulated Intended Learning Outcomes (ILOs). The core of course design consists of selecting and combining different types of online and on-campus Teaching and Learning Activity's (TLAs). Generally a smart design of a combination of (many) types of TLAs is needed to create top-quality blended engineering courses. Student motivation and higher level Intended Learning Outcomes for engineering require rich on-campus TLAs that cannot be completely offered online.

Conference Key Areas: Open and Online Engineering Education; Curriculum Development; Attractiveness of Engineering Education; Gender and Diversity

Keywords: Course Design, Online, Diversity

INTRODUCTION

Biggs and Tang [1] have analysed changes in the nature of higher education and they see them causing more diversity among students. Consequences are that universities have to deal with larger differences of engagement between students and more need for outcomes-based teaching and learning that allows for differences in learning styles. In the last five years the increased use of blended and online education has caused new diversity and learning style issues. In addition for engineers, the rapidly changing world brings the need to engage students in diverse learning [2].

Wageningen University & Research is experiencing all these trends. It tackles them with outcomes-based teaching and engaging students within a rich setting of blended learning. That approach is part of the University Teaching Qualification Programme for new lecturers and also a focus for education innovation projects. Examples of those projects are shown on the innovation map of the 4TU Centre for Engineering Education [3]. The resulting education programmes are rated as the best in the national surveys of the last twelve years [4].

This paper describes how to design such blended learning courses based on literature in combination with the experience of Wageningen University & Research.

THE DESIGN OF BELENDED COURSES: LITERATURE AND EXPERIENCE.

The approach of Wageningen University & Research with designing blended courses, matches the literature findings described below.

Prerequisites

Course design should be based on a well-constructed curriculum and properly formulated intended learning outcomes (ILOs). This is not easily attained. An option is to use the CDIO Approach [5], which should yield the four levels of ILOs shown in Figure 1.

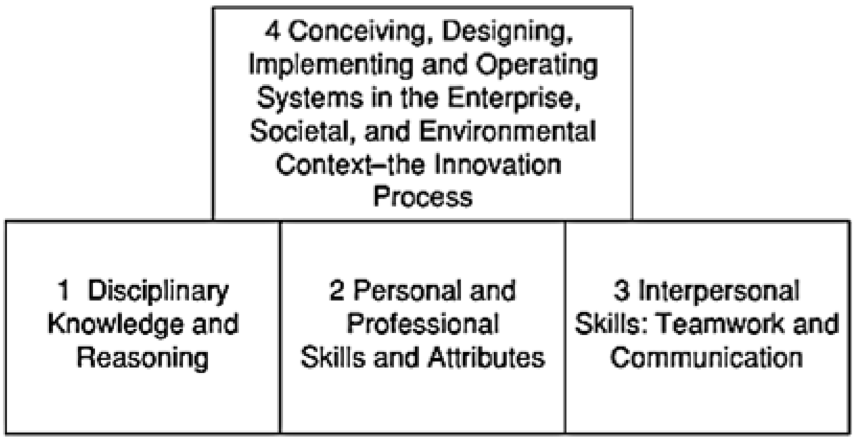

Fig. 1. Four levels of ILOs [5]

There are many other approaches that usually yield ILOs on different levels, such as knowledge, skills and integration. The ILOs are the starting point in creating Teaching and Learning Activity's (TLAs) as well as Assessment. ILOs, TLAs and Assessment should be aligned [1], as shown in a clip [6] of Delft University of Technology.

Selecting TLAs

The core of course design is selecting TLAs. That requires an open mind on how students learn and considering the use of each available type of TLA. Laurillard [7, 8] synthesised a list of TLAs from theories of learning:

Acquisition:	reading, watching, listening.
Inquiry:	using resources to develop an evidence-based output.
Discussion:	debating, questioning, answering, negotiating ideas.
Practice:	acting, in the light of feedback, to achieve a goal or output.
Collaboration:	working with others to achieve a joint output.
Production:	making something for others to evaluate against agreed criteria.

All types of TLAs can be seen in traditional campus education and they can also be supported online. In both cases, the processes shown in Figure 2 are supported.

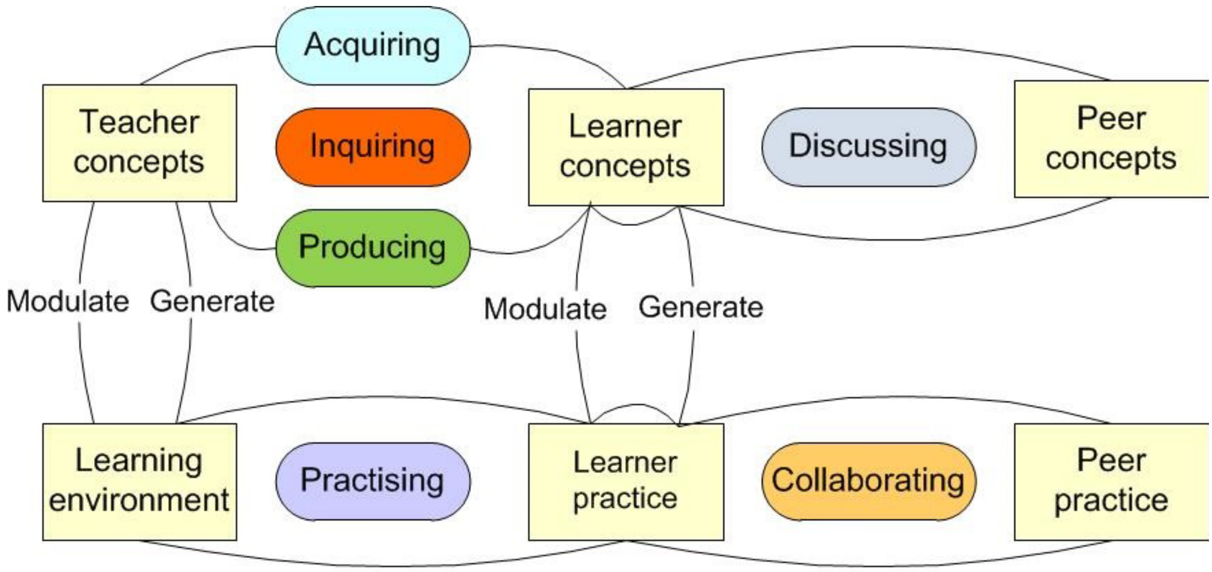

Fig. 2. TLAs and supported processes (based on Laurillard 7,8)

Support of Learning Management Systems

Most Learning Management Systems (LMS) were developed to support the TLAs shown on the left side of Figure 2 (acquiring, inquiring, producing and practising) and sometimes they extend to those on the right side of Figure 2 (discussing and collaborating) in newer versions. However, a separate, specialised LMS might still be required for the best options with the TLAs on the right side.

Combining TLAs

Often, a large part of Figure 2 needs to be included in a course. One ILO might require different types of TLAs and the course set of ILOs might require more. In addition a workflow of TLAs (such as reading, developing evidence-based output, debating) might be needed to reach an ILO, especially for engineering. Differences in learning styles and learning theories also point in the direction of combining different TLAs. Last, but not least, combining TLAs is necessary to engage students and keep them surprised!

Limits to the use of online TLAs

Part of a smart design is the choice between on-campus and online versions of each TLA. Practical reasons (group size, available time, facilities, and curriculum standards) might dictate that choice. In general, the TLAs on the left side of the Figure 2 can be achieved with media resources (online, books etc.). Most universities have a long tradition in this and new developments, such as knowledge clips and Massive Open Online Courses (MOOCs), are creating more options.

In the last years Wageningen University & Research has introduced a lot of knowledge clips and other online teaching methods. For instance the first half of the second year Food Technology use mainly knowledge clips instead of lectures, and most courses with practical's or tutorials have replaced parts of the activities with knowledge clips (clips on how to use equipment for example). The results show that students not always appreciate many knowledge clips, especially when the clips replace real classes and they feel a lack of teacher-student contact. In addition higher level engineering ILOs require on-campus collaboration work that cannot be completely offered online. Wageningen University & Research has therefore started a project to evaluate the balance between online and on-campus TLAs.

Combining evaluations of projects on innovative course design

Wageningen University shares the information on new design of its courses, together with Delft University of Technology, Eindhoven University of Technology and the University of Twente using the online innovation map [3] of the 4TU. Centre for Engineering Education. For each project information on approach, objective, strong points and recommendations is available. The combined evaluations of all projects constantly yields new lessons learned; like the ones described in this paper.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are based on this literature review and the experience of Wageningen University & Research.

Course design should start with a well-constructed curriculum and properly formulated Intended Learning Outcomes (ILOs).

There are many types of Teaching and Learning Activity's (TLAs) and they can be grouped into TLAs involving acquisition, inquiry, discussion, practice, collaboration and production.

A smart design of a combination of (many) types of TLAs is needed to create top-quality university courses.

All types of TLAs can be seen in traditional campus education and they can also be supported online.

There are limits in replacing on-campus TLAs by online versions. It seems that students need a minimum amount of on-campus teacher-student contact and higher level engineering ILOs require rich on-campus collaboration work that cannot be completely offered online. Wageningen University & Research has started a project to investigate this.

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Towards a new curriculum to support the changing front end innovation landscape

Educating engineering students to effectively participate in iterative data-enabled product development processes

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Conference Key Areas: Curriculum Development, Engineering Education Research, Skills and Engineering Education

Keywords: Data-enabled Design, Fuzzy Front End, Product Specifications

ABSTRACT

The new generation of Internet of Things product offers exciting opportunities to design and develop highly personal and adaptive products. Engineering students are traditionally not trained to use user data, generated by prototypes, as creative material for ideating the Fuzzy Front End phase of the design process. In this case study, Philips Design and Fontys Engineering propose a change for the current Fontys engineering curriculum to prepare engineering students for this new way of defining innovative, connected products. For these new challenges, we argue that the focus in educating engineers should be changed from starting with product specifications and "first time right" towards data-enabled design (user feedback) and iterative design cycles to come to product specifications and maturing prototypes. A survey amongst 73 Fontys engineering students shows that approximately 20 percent of the current engineering students are interested in, and have affinity with, this new way of working.

INTRODUCTION

Innovation is more and more concerned with the development of 'data intensive' smart connected products [1], [2], [3]. These products have the potential to incorporate a more personalized understanding of their users, their usage and their context. Examples are the Fitbit [4] that provides you with personal coaching according to your physical activity; the Nest Thermostat [5] that adapts room temperature to your way of living; and the Philips Hue [6] whose functionality can be programmed to user's personal preferences.

This new generation of Internet of Things (IoT) products offers exciting opportunities to design and develop highly personal and adaptive products. However, defining, exploring, and developing these products introduces new levels of complexity to the innovation processes of which challenges are less defined. Especially in the *Fuzzy Front End* (FFE) process [7], the phase where new product concepts are ideated and explored, it is hard to imagine how different users will experience different versions of the same concept as tailored by unique personal data. Innovation teams are traditionally not trained to use user's data, generated by prototypes, as creative material in the FFE process to explore these tailoring features. Still many companies design data-intensive innovations by imagining technical possibilities to personalize products. *Data-enabled Design* [8], an approach extensively used by Philips Design, is one of the new approaches that uses data as creative material in the iterative FFE process.

This user data is gathered through sensor-equipped prototypes which are put to use in their intended context. Engineers are highly valuable in this Data-enabled Design process to facilitate the creation of sensor-equipped prototypes while maintaining a sense of scalability, by continuously reconsidering and updating product requirements.

In our daily practice, at Philips Design, we noticed that this Data-enabled Design process requests new competences of engineers that are currently not part of their educational curriculum. It's our experience that engineering students in general are educated to develop products based on given specifications and on the "first time right" principle. To come to specifications, it turns out that it is required to put more emphasis on iterative design and the use of quick prototyping. As research shows [9] data, on what engineering graduates will be doing during their professional life, is essential information in educating future engineers. Therefore, in this case study, Philips Design and the Electrical Engineering department of the Fontys University of Applied Sciences started a collaboration to answer: **how should the current Fontys engineering curriculum change to prepare engineering students to facilitate Data-enabled Design in the FFE innovation process?**

To answer this question, we take three perspectives into account. First, we dive into the detailed competence request from the *industry*, represented by Philips Design. Secondly, we focus on a *student* perspective in which they share their interest to join such explorative innovation environments. This is done by a survey amongst Fontys Engineering students. Thirdly, we reflect from an *educational* perspective on how the current curriculum can facilitate this new competence request.

The aim of this paper is not to present a final list of future competences, nor to validate a new educational model. Instead, with this case study, we set out to start a discussion with the educational community about the future role and competences of Electrical and Electronic Engineering in the domain of innovation in the FFE process.

1 INDUSTRY PERSPECTIVE: NEW COMPETENCE REQUEST

1.1 Data-enabled Design

In the quest of new FFE processes for 'data-intensive' products, dealing with complexity, many have acknowledged the value of incorporating users. User-centred design [10], participatory design [11], consumer-oriented innovation [12] and many more, set out to have participants (potential end-users, stakeholders and other non-designers) actively thinking along in the innovation process [13]. These approaches also outline involvement of participants in their natural environment to manage complexity. However, asking participants to actively contribute to the innovation process of ‘data-intensive products is more challenging as these concepts often are outside their frame of reference [14].

Data-enabled Design [15] involves the participants in the innovation process through experience by objecting them to design exploration situations. Thus, instead of inviting participants to imagine a futuristic concept, participants receive sensor-equipped prototypes to experience the concept. The data generated, by using these prototypes, is used as a dialogue facilitator. Namely, the data helps the participant to recall the experience of using the prototype and helps the innovation team to explore the data relevancy in real contexts. This is a continuous dialogue where user’s insights (distilled from data) lead to optimized concept ideas, resulting in prototype updates which will then generate new insights again. In this agile-like process [16], the product specifications become more mature. Note, the more scalable the sensor-equipped prototypes are designed, the easier these can be updated remotely (e.g. over-the-air firmware updates or adding new sensors) the quicker the situated exploration iterations will be.

1.2 Role of the engineer in Data-enabled Design

The FFE process with a Data-enabled Design approach strongly builds on the act of making sensor-equipped prototypes and trying things out in the field. The development of these data-intensive prototypes iteratively moves from a very explorative artefact to materialization of the final concept. The role of the engineer is to facilitate the creation of these prototypes and to contribute to the explorative process of iteratively advancing the concept where the definition of feasible specifications becomes increasingly important. This process takes place in a multidisciplinary team, consisting of designers, user researchers, strategists, and data scientists where the engineer plays an integral role.

1.3 Detailed competence profile

Based on experiences at Philips Design, where the Data-enabled Design approach has been utilized for about two years, we defined a competence request for engineers being part of this FFE process. We conducted in-depth semi-structured interviews with seven project members that run Data-enabled Design projects on a daily basis (2 designers, 2 user researchers, a project manager, software engineer and a prototyping engineer). We requested them to describe a competence profile for engineers. Afterwards the overall competence request for engineers from an industry perspective was discussed within this team. This profile, consisting of three main requests is illustrated in the first column of Table 1. The three major categories are: 1. Participating in the explorative Data-enabled Design process, 2. Creating sensor-equipped prototypes that iteratively advance and 3. Being part of a multidisciplinary team.

2 STUDENT PERSPECTIVE: INTEREST AND AFFINITY

2.1 Survey setup

Via an online survey, we asked fourth year engineering students (N=259, n=73, response rate 28.2%) of the Fontys University of Applied Sciences in Eindhoven to respond to the profile description defined by industry. Each of the three categories were translated into survey questions for engineering students. Firstly they were asked to respond to items that describe what type of engineer they are (e.g. *I learn best by making and doing rather than reading and analysing*); secondly, what type of project characteristics they prefer (e.g. *I prefer questions with a clear scope, a point to go to*);

thirdly, how their ideal working environment looks like (e.g. *working in a big team of mainly engineers where I have individual tasks*); and what preferences they have concerning the different phases of the innovation process (e.g. i*ntroduction phase: action steps where production and marketing launch occurs, service and installation starts*).

The outcome of this survey is given in column 3. In the fourth column, the current situation of Fontys Engineering is described and in the last column (5) the gap between industry requests and current curriculum is indicated and will be discussed in chapter 3.

Table 1. Overview of three perspectives: industry, students and education

Competence request from *industry*		**Interest and affinity of *students*** (N=259, n=73)	***Educational* perspective**	
			Current curriculum	**Curriculum gap to competence request**
Participating in the explorative Data-enabled Design process	Become part of innovation process in which product specifications will be defined	92% are interested in developing new innovations. 41% are interested to work in the FFE. 12% is open to work without a clear scope	Education which is focused on developing from specifications onwards	1. More open product innovation 2. New development methods 3. Collaborate interdisciplinary
	Questioning specifications	44% like to start small not knowing where it may lead to. 82% prefer designing in an iterative way from quick and dirty prototyping, reviewing and customer feedback.	Taking specifications for granted	Bring awareness to unspecified and unknown requirements which may affect specifications
	Dealing with uncertainty	16% like to work without clear specifications	Thorough design mind set	Make students more comfortable with uncertainty in Project Based Learning (PBL) [17]; how to change grading of PBL to emphasis?
Creating sensor-equipped prototypes that iteratively advance	Hacking mind set, use existing tools to quickly try and learn	73% prefer to learn by doing.	Development mind set, start from scratch to build exactly what you need	1. Use existing boards, products to develop very fast working prototypes 2. Develop these into real products in an iterative way
	Fast prototyping to unravel specifications	49% prefer to develop review based (when specifications do not change).	First time right, electronics to validate.	Make students aware of the different tools of prototyping. Arduino, Raspberry Pi, Edison' boards are great starters, 3D printing for anyone!
	Open design construction (platform design)	Not questioned in survey.	Single-purpose design	Teach how to grow from (available) platform designs to single-purpose dedicated designs

	Iterative and increased learning: start small	12% like to work in projects that do not have a clear, predefined scope	V-model [18]	Start with the FFE as early as possible
Being part of a multidisciplinary team	Taking into account an end-user and business perspective (Questioning approach, opportunity searching)	29% like to question more than to listen	Try to meet specifications (listening approach, problem solving)	Make user contact essential in the PBL so engineers become more critical
	Multidisciplinary team: software & hardware developers, data & ethnographic scientists, designers, marketing managers etc.	37% are interested to work in a multidisciplinary team of which 48% prefers a small team where they are the only engineer.	Project based learning with mainly engineers	1. work multidisciplinary or 2. make people responsible for different jobs with a project 3.Teach students to communicate across disciplines
	Independent working	Not questioned: is general competence requirement	Project based learning	This is a general applied science university competence

2.2 Survey results

Almost all engineering students (see Fig.1) want to work in an innovative environment (92%) with clear specifications (84%) and a clear scope (88%). Another item showed that the main preference is to work in a small engineering team that has one common task (49%). For the project process, there is a split among the students who prefer an iterative process (79%) and those who prefer designing "first time right" (50%). Besides, most students like to listen more than to question (45%) and learn by doing over reading and analysing (73%). However, from responses to the preferred role that engineers have in a team (questioned through Belbin's description of team roles), about all roles are preferred equally. Finally, the majority of the current students (73%) indicates to be happy with the way of education and working environment created nowadays.

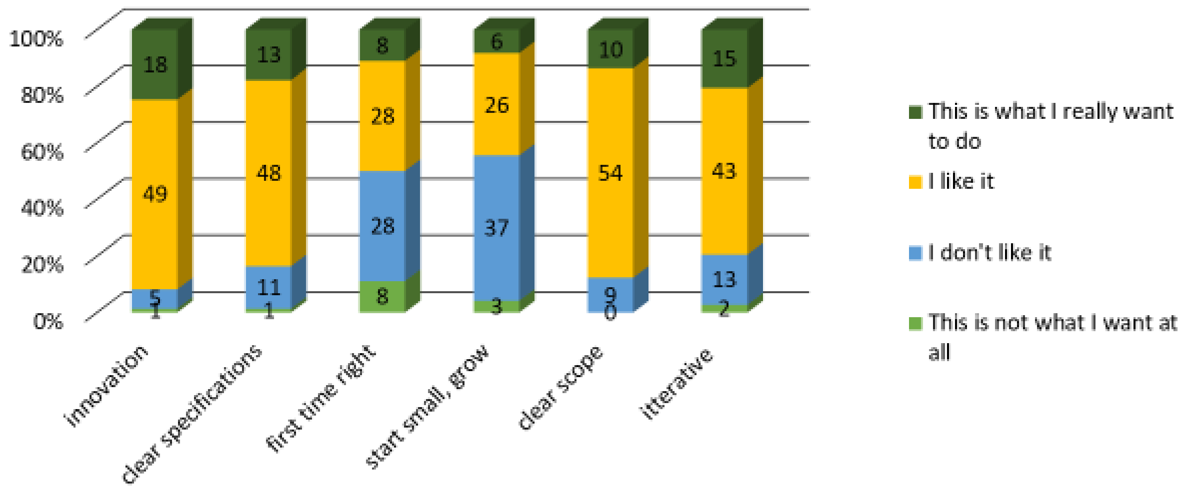

Figure 1 shows survey results of students (n=73).

2.3 Survey conclusions

After interpreting the survey results we draw the conclusion that about twenty percent of the current engineering students at Fontys is interested and has affinity for working according to the requested competence from the industry. As one can see in the last column of figure 1, 15 students out of 73 (20%) indicated to really prefer designing in an iterative way: from quick and dirty prototyping (using Arduino's, 3D printing and wood when needed), reviewing and customer feedback and in this way improving and in a few cycles coming up with a solution and so product specifications.

Meaning, these students are looking forward to work in the FFE phase of product specification: multidisciplinary, uncertainty, data-enabled design and work on fast prototyping rapidly changed on user data input. The main reasons for having no interest or affinity with the formulated engineering competences are: not preferring the open and undefined process searching for specifications and not preferring to work in a multidisciplinary team without other engineers, so working on their own. Interestingly, the request to iteratively build and improve their prototype is valued by many. We expect that the students might have referred to iteratively building and reviewing their prototype in the case of given, fixed specifications as they are used to. However, the survey question was meant for the iterative design on searching for interesting specifications and not solutions.

3 EDUCATIONAL PERSPECTIVE: CURRENT CURRICULUM AND GAP

3.1 A fixed development process to fulfil specifications

Fontys'technical education system teaches students how to tackle engineering problems using structured design methods. Students apply these procedures step by step, according to the waterfall model [19] or the V-model [18]. These structured processes do fit very well in projects where specifications are clear and students work towards solutions. The FFE processes which are uncertain, iterative, open and flexible and where the specifications are not known is not practiced in our curriculum.

In dialogue with colleagues and graduates we note that our grading system highly impacts students' preferences on the project's starting point. Namely, PBL grades of students are highly related to the expectation of fully finished prototypes. This makes the students not to like working without a clear list of specifications and a clear deliverable. It might be that, without knowing the specifications, the process to unravel what is relevant takes (too) long and might not lead to a fully finished prototype, and thus might affect their grades and points.

3.2 Doing things the "first time right"

Several studies [20], [21] have proven that PBL is a suitable method for attaining the engineering competences that are suitable for today's world outside the faculty. Fontys has been integrating the PBL concept, in company projects, in each year of the education for decades. The students are taught how to develop "first time right" products. Besides, the problems and solutions are often so specific (in-depth engineering questions) that the quick prototyping is quickly overseen. In the FFE the engineering requests are much broader, more explorative and they need to be finished quickly. Therefore, it would be better to get students also acquainted with fast prototyping skills, with foresight towards in depth, thorough design solutions.

3.3 Not working in multidisciplinary teams

PBL combines learning and application attributes, however, at Fontys Engineering, it misses the fundamental process of understanding the multidisciplinary skills needed to come to the product specifications of innovative products. The project descriptions, which students receive, often come from company clients (that do work in multidisciplinary teams). However, these clients create the project descriptions as design requirements targeted to a team of engineers. This means that the engineering request is put in isolation from the original project. In the Fontys engineering situation, students do not get to know other disciplines (besides their major discipline) and thereby hardly develop inter-disciplinary languages.

4 THE RECOMMENDED CURRICULUM

Within Electrical and Electronic (E&E) engineering, a discussion has been started on how to alter the curriculum in order to facilitate the wishes of the different students. Of course, not all engineering students are needed as designers in the FFE phase. Most of the students are needed in the design processes after the FFE phase and the majorityof the current students (73%) indicates they are happy to work in these phases. But only 20 percent of the engineering students wants to explore the opportunities of Data-enabled Design.

As found in practice it is of great importance to work in a multidisciplinary team with open assignments. And more time is needed within their education to realize enough iterative, data-enabled design cycles.

The current idea within the E&E Engineering department is to start a pilot and educate students from the second year onwards in a specific stream with more focus on the FFE environment. Starting with around 20 percent of our student's population, they will work for approximately one fifth of their time in data-enabled, agile, multidisciplinary, business oriented product specification developments and realisation. This provides the students with more time (ECTS) to explore the Data-enabled Design in the second year of their study. In the minor (the third year) they can apply their knowledge and skills to a real-life problem. The other engineering students' education will not be affected, we continue preparing them for the post-FFE phase in design.

When designing optional courses in Data-enabled Design the students of these latter stream can "meet and greet" one or more courses of the FFE environment just to get informed and experience this new way of defining and specifying data enabled products. Fontys engineering sees this development as the start of educating the new generation engineers for the industry 4.0 [22] and cyber physical systems environment as shown in a previous research on Fontys Electrical and Electronic Engineering [23].

5 CONCLUSION

Industry nowadays creates 'data intensive' products and services that are tailored to the user. A promising innovation approach for these new types of product is Data-enabled Design. Data-enabled Design projects at Philips show that this approach benefits from having engineers as an integral part of the multidisciplinary innovation team. The competence request from industry in these situations is an engineer who can iteratively develop data-intensive prototypes that can be put in context and iteratively move into a final prototype and setting specifications. A collaborative research programme, by the industry (Philips Design) and the education (Fontys Engineering) explored the possibilities of preparing this new type of engineer required in the FFE phase, gave positive results and a direction to go to.

We argue that in a new program set up, the engineer should not receive a list of specifications of the new product, but should be part of the process to unravel which specifications are relevant. A survey (N=73) at Fontys engineering has shown that approximately 20% of the current engineering students is interested in, and have affinity with, this new way of working. They indicated to look forward to work in the FFE phase, multidisciplinary, with moving specifications and many iterations in the prototyping. The curriculum does not yet provide these students the ability to learn these competences required by industry. Therefore, it is proposed to make a new structure in the educational program for students who are interested in Data-enabled Design. A dedicated stream for FFE interested students will have courses in the second year linked to companies' projects. In this way, it is assured that theory and practice are well aligned and enough time is available to explore Data-enabled Design in the FFE phase for those students willing to innovate and create in the industry 4.0 way of innovating new products.

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A project-based-learning approach to teaching first-order and second-order differential equations to engineers

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ABSTRACT

In an attempt to increase engagement in a third-year mechanical-engineering mathematics module, a project was introduced in 2015/16. Students were asked to use the solution of a second-order differential equation (previously introduced in lectures) to solve a problem in which they must design a simple spring-damper system for one of a lorry, digger, truck, tractor, car, motorbike or pogo stick. In 2016/2017 this approach has been extended to a second project to use a first order differential equation to design a parachute. These projects were worth a total of 20% of the module. A detailed description of the implementation of this assessment is given along with an analysis of how students perform on questions on similar topics in the terminal examination for this module. Secondly we outline feedback received from a survey of the students. Finally we discuss the possibility of teaching the entire maths module via a project based learning approach.

INTRODUCTION

Many engineering students struggle to see the relevance of mathematics (Hidi and Harackiewicz 2000). This is turn may lead to low levels of engagement. A recent study of the First Year Experience (FYE) in the eight third level institutions in the Dublin Regional Higher Education Area (DRHEA) found that one of the key problem areas identified by academics across all eight institutions was lack of “student engagement” (Roper et al 2013, Cusack et al 2013). This lack of engagement often results in poor performance and ultimately impacts upon retention. Since September 2012, incoming first-year students to higher education in Ireland have studied a revised mathematics curriculum (Project Maths) in second-level (Jeffes et al 2013, Prendergast et al, 2017). This new approach to the teaching and learning of mathematics in Ireland aims to situate mathematics in everyday contexts where possible, so that students will be better able to understand the uses and relevance of mathematics. However, these students entered a higher education system that was accustomed to a mathematics curriculum that had not changed substantially in almost fifty years. Much of the material taught in the early years of mathematics is not explicitly mapped at that point to modules or applications in later years, making it difficult for students to understand the importance of what they are learning at this early stage in their careers. It is commonly the case that, in later years, lecturers will refer back to material covered in first year and show students how they will now use this mathematics in more advanced applications. However, from the point-of-view of student engagement and retention, this seems to be done at too late a stage, and needs to be dealt with in early years instead. This is particularly important in engineering as it relies heavily on mathematics throughout the degree programme. Successful service-teaching of mathematics relies heavily on a “sufficient supply of discipline related problems” (Yates 2003). This changing mathematical landscape in Ireland provided the motivation for the development of the project-based-learning approach described in this paper.

Engineering mathematics is generally either taught by engineering lecturers (who are usually not experts in mathematics) or by lecturers from mathematics departments who are not embedded within the students' home departments, and naturally may not be experts in the overall discipline being studied by the students. As a result, the balance between theory and practical applications is often skewed (Sazhin 1998, p.145). Lecturers may forget the significance of students "getting a feeling for the importance of the subject" (Rota). The level of interaction between mathematics lecturers and staff members in the students' home departments can vary widely from institution to institution.

In Dublin Institute of Technology, students are offered two main routes to obtain a Level 8 engineering qualification: via direct entry onto a four-year Honours degree programme (Level 8) or alternatively through a three-year Ordinary degree programme (Level 7) followed by a transfer into third year of the Honours degree (Llorens et al. 2014, Carr et al. 2013). This project is thus an attempt to evolve the teaching of engineering mathematics at Level 7 to both improve the engagement of students in engineering mathematics classes and to provide a deeper understanding of the material, which may ultimately help these students to progress onto a Level 8 degree programme if they so desire.

BACKGROUND

There exist many examples in the literature on the need to make the mathematics we teach to engineers more applied. The development of such examples and projects can be challenging for those teaching engineering mathematics as they may not be engineers or familiar with all aspects of engineering. However, there is a full spectrum of initiatives available in the literature, from improved examples in the classroom (e.g. Helm, Young et al 2012, Robinson 2008) to teaching the material via problem-based learning (e.g. Rooch et al. 2012). We provide a brief overview of some of these approaches.

Helping Engineers Learn Mathematics (HELM) is a major curriculum development project undertaken by a consortium of five English universities - Loughborough, Hull, Reading, Sunderland and Manchester - led by Loughborough. This project provided a huge list of engineering mathematics resources including a set of good examples of engineering applications of mathematics (http://helm.lboro.ac.uk/). Although this work is of a high standard, many of the examples contained therein are more relevant to later years of a Level 8 engineering programme, and the examples suitable for Level 7 students are limited in number.

Young et al (2012) at the University of Central Florida developed a bolt-on single-credit module called "applications of calculus", taught in parallel with their calculus modules. This has been shown to be effective in terms of retention of students within STEM subjects, although there are no projects introduced, simply a range of problems completed in class that are relevant to applications.

Robinson (University of Loughborough) used sports-based group projects for undergraduate students in sports science (Robinson 2012). These projects consisted of teamwork, use of software and application of mathematics to realistic problems. This not only improved engagement, it also introduced a range of important skills for engineers, such as technological and communication skills as well as collaborative and analytical techniques.

Rooch et al. (2012) developed a series of projects (ribbed cooler and a Segway) for teaching mathematics to first year engineering students in Germany. However, the mathematics required is quite involved in each case, meaning that they must supply the students with a number of different formulae in order to allow them to complete the projects. This is a common difficulty when designing “real-life” mathematics projects for students to attempt, due to the scaffolded nature of mathematical knowledge.

Within Dublin Institute of Technology itself, some example of project-based learning already exist. For example, design projects were introduced into first-year physics lab sessions for engineering students. These projects relied upon material covered in mathematics, physics and mechanics modules, bringing them all together in a single design project (Sheridan et al. 2010). A range of other variations exist between teaching applications and full problem-based-learning from Verner et al. (2008) and Mills and Treagust (2004), through to Abramovich and Grinshpan (2008).

AIMS AND SCOPE

In a move towards a more student-centred-learning approach for the teaching of engineering mathematics across all three years at Level 7 we have piloted a project based learning approach in the third year of the programme (Carr & Ni Fhloinn, 2016). We ultimately will work backwards to first year, once initiatives have proven to be successful. Much work has been done on using project-based/application-based learning as a method for teaching mathematics in higher education, but in the main, these modules have many mathematical pre-requisites, so they are in essence only suitable for later years of a programme and/or essentially being “bolted on” (Young et. al 2011) to pre-existing modules. Similar work has been done in the third year of the Level 8 degree programme to teach mathematical modelling with good success (Keane, Carr and Carroll, 2008), so it was of interest to introduce at a similar stage in a Level 7 programme and monitor its impact. Given that the standard of first year in a Level 7 programme is not high enough for many of these existing resources to be used, by trialling this approach in third-year, we can learn valuable lessons before considering earlier years.

The aim of this work is to use a hybrid approach to “project-based-learning” where a significant amount of the pre-requisites is taught over several weeks in a more standard approach and then a realistic project is introduced that consolidates the material that has been covered in class and provides an opportunity to learn applications of the material.

In 2015 one such project was introduced. Given the success of such a project we have introduced a second project this year.

The objectives of the projects are to improve engagement and ultimately retention of students; to give students a deeper understanding of the material; to introduce problem-solving, teamwork and communication skills; to move towards a more student-centred environment within the existing structure of lectures and tutorials; and to create a series of resources that could be used by lecturers teaching at Level 7.

PROJECT OVERVIEW

A series of two-hour group-work sessions were introduced, focused on the topic of second-order differential equations. Following a number of standard lectures, students were assigned to groups of four to work on a short project together during the group-work sessions, with additional work to be completed outside of class time.

The outline of the project given are listed on the website below. We hope in time to populate this website with more examples

PROJECT 1

As a group derive the first order differential equation for a falling body. Your derivation should include a diagram of the forces acting on this body. You will then solve this equation and use the result to design a parachute for one of the following an aid cargo, a large man on a charity jump, a small woman on a charity jump, a tandem jump, a paratrooper, a sky diver or a BASE jumper.

After a break of several weeks the groups were assigned a second project.

In order to design the parachute, needed to consider the mass of the jumper, what sort of velocity would be appropriate on landing etc.

PROJECT 2

In the second project we asked students to use the solution of a second order differential equation (previously introduced in lectures) to design a simple spring-damper system for a vehicle from the following list: lorry, digger, truck (large), truck (small), motorbike, motorbike (scrambler), bus (large), bus (small), moped, quad bike, tractor, tractor (seat), car (large), car (small), pogo stick, racing bike or standard bicycle. No two groups were assigned the same vehicle, and the different masses, number of wheels involved and type of damping required meant that the projects were sufficiently different that each group had to work independently on their solution.

The full details of the projects given may be found here

(https://sites.google.com/site/ditprojectbasedlearning)

We also intend to publish sample examples of students work on this website once we have received the permission of the students.

The projects were worth 10% of the students' final grades for that module, with the marks awarded per group. At the end of three weeks, each group presented their solution to the class during a ten-minute presentation slot, as well as handing up a short (four-ten page) report. The variation in report-length was chosen to allow students to include detailed diagrams and additional information where needed. The mixture of assessment methods included within the project gave students the opportunity to display their skills in a range of areas, while providing them with useful practice of presenting technical data in a clear and coherent manner. Students were obliged to attend all the presentations given, which also provided a valuable opportunity for peer-learning, as they heard how different groups had approached a similar problem, and allowed for some class discussion about optimum approaches afterwards.

In order to design a simple spring-damper system, students needed to first consider the mass of the vehicle, calculate an appropriate spring constant, and decide on what type of damping would be ideal for the vehicle in question. For example, the damping needed by a scrambler motorbike is different from that of a family car, where a smoother ride would be required. This was a multi-layered problem, which allowed students to investigate a number of areas in greater depth, considering aspects relevant to the generation of the second-order differential equation. Once they had solved the differential equation, they were then required to sketch the analytic solution by hand, to investigate if the resultant sketch resembled the type of damping they hoped to produce. If so, they then needed to plot a graph of the analytic solution and relate these back to the original problem, giving an interpretation of their results.

OVERVIEW OF PREVIOUS WORK

In our previous paper on this topic (Carr & Ni Fhloinn, 2016) and analysis was carried out examining the relationship between project mark and exam result.

When each student's project mark was plotted against their performance on this exam question, the result was statistically significant, with a Pearson correlation of 0.453 found with p=0.006. Similarly, when each student's overall performance was plotted against their performance on this exam question, another statistically significant correlation was found, with a Pearson correlation of 0.71 with p=0.000. While this is not surprising, showing that the most capable students performed well on all components of the assessment, it does contrast with previous years, when even strong students avoided or did poorly on the differential equations question in the examination.

To complement this work this year we have carried out short survey of the students to get their opinions of this approach.

OVERVIEW OF THE SURVEY QUESTIONS

The participants were approached during class and were given a paper survey with 4 questions addressing the project objectives of increasing student engagement, identifying the value and relevance of mathematics in the engineering discipline and improving basic communication and teamwork skills. They were given an explanation at the start of the survey capturing its purpose and stating that the information would remain anonymous, participation was voluntary and that it would not affect their module grade. Each thematic question consisted of three or four subsections. Three questions were structured using a likert 5-point scale with a comment section provided for respondents to explain or justify their selection. A final open-ended question required students to sum up their overall experience in completing the mathematical projects; what they particularly enjoyed and what they found challenging.

The development of the survey questions targeting engagement, value, relevance and teamwork was influenced by the work of Clem *et al*, (2014) who developed and validated an experiential learning survey, who used Carver's (1996) four pedagogical principles that help outline experiential learning[1] as their guiding framework. Predominantly this influenced the questions around value and relevance. This research also highlighted the importance of the project tutor in the effectiveness of student engagement. Lin & Huang's (2017) work focused on course engagement in general whilst Burch *et al* (2014) concentrated specifically on engagement and experiential learning. Both these influenced the identification of questions around student engagement. From a teamwork perspective, Lurie *et al's* (2014) 'reliable five –question' survey was partially applied along with Hughes & Jones (2014) work, who clearly define teamwork as a set of critical skills that can be developed and the need to focus on the process and provide 'meaningful feedback' during administered assessments.

In total there were 19 respondents, giving a 47.5% response rate. Below is a synopsis of the responses under each theme.

The full list of questions asked can be viewed here (https://sites.google.com/site/ditprojectbasedlearning/student-survey)

Theme 1: Increased level of Student Engagement

Students agreed (3.6 average) that they took the time to look over the class notes in order to ensure they understood the material before attending the class where teams were allocated time to work on the mathematical project. The comments captured such as *"it was necessary to complete the project"* and "*the notes contained the material I needed*" also gives somewhat of an indication of the importance and effectiveness of the class material. Nevertheless, some students stated they didn't bother at all with the notes with one identifying their Youtube preference! The project also encouraged attendance with a 4.5 average of students agreeing they always attended class during project time offering two main reasons. One centred on the point that it was the best way to get the work done and the other reason identified was that they didn't want to let their teammates down.

Students were in strong agreement (4.05 average) that the project gave them the opportunity for greater interaction with the material as it facilitated greater ease to ask questions to help understand the material than during normal class sessions. Students also agreed that they were fully absorbed in the activities and discussion enabled by these sessions.

Theme 2: The Learning Value and Relevance of Mathematics in the field of Engineering

Having practical examples was a consistent reason given as to why students strongly agreed (4.5 score) that learning mathematics in this format assisted in

[1] – authenticity, active learning, drawing on student experience and connecting that experience to future opportunity.

greater understanding of its relevance in their engineering discipline "*it gives a stepping stone into what you will be doing in engineering*". Students also agreed (4.2) that this approach helped to stimulate their thinking due to the hands on approach and the clear overlap with other engineering subjects. From a terminal examination viewpoint students were neutral (2.57) as to how this activity helped them prepare for their exams. Notwithstanding this however, some students who had agreed that it was difficult to see how the project based approach helped in exam preparation made comments that did not align to the Likert score for this question. It may in fact highlight a limitation with the use of reverse questioning.

Theme 3: Improving Communication and Teamwork skills

Students responded with a broad range of answers when asked to describe the role they played on their project team. From designing the poster presentation to solving the equations and plotting the graphs to project manager. It indicates somewhat the range of work tasks involved in a project of this nature and the breath of distribution amongst teams.

Students agreed (4.15) that they were encouraged to share their ideas and commented on the "*friendly"* environment in general indicating a healthy working team, although some students "*didn't understand what was going on"* and therefore got carried by the team. In relation to problem solving, students strongly agreed (4.4) that they made a consorted effort to overcome problems they encountered with comments such as "*the team pulled together*" emphasizing positive teamwork in action. Students disagreed (2.15) with the question that it was challenging to get their point across with comments such as "*we all listened to each other*", confirming positive teamwork.

Overall Student Experience

The main theme emerging when asked about the positive aspects of their experience was that the students really appreciated the opportunity to work on a real world problem. All of those who commented referred to this "*hands-on approach"*. Only one comment emerged around the appreciation towards getting the opportunity to practice presentation skills.

On the flip side, students found many aspects of the project difficult. There was a multitude of challenges captured with no dominant theme emerging. The issues captured were around those not attending class sessions, uneven effort of team members, the fact that a lot of the information provided wasn't specifically required to solve the problem and the variation across sources on the letters used to symbolise the same things caused confusion. Students found it difficult to wade through all the information and sift out the relevant parts. Another difficulty they captured was beginning the derivations required as they needed to apply information in the notes rather than just directly copying the derivations. The information captured in this section of the survey highlighted some additional skills that are not necessarily required or acquired in the traditional classroom.

RESULTS

As part of analysis we plotted the marks the students received for project 1 (first order differential equations) against the exam (figure 1) and project 2 (second order differential equations) against the exam (figure 2).

In figure 1 we see very little correlation between the project mark and the exam mark (R^2= 0.006). By the time of the second project we are seeing a much stronger correlation between the exam mark and the project mark (R^2=0.24) . One explanation of this may be that the project work requires a different skill set to standard exams but already by the second project, the more conscientious students are starting to develop this skill set, or at least or working hard at developing this skill set.

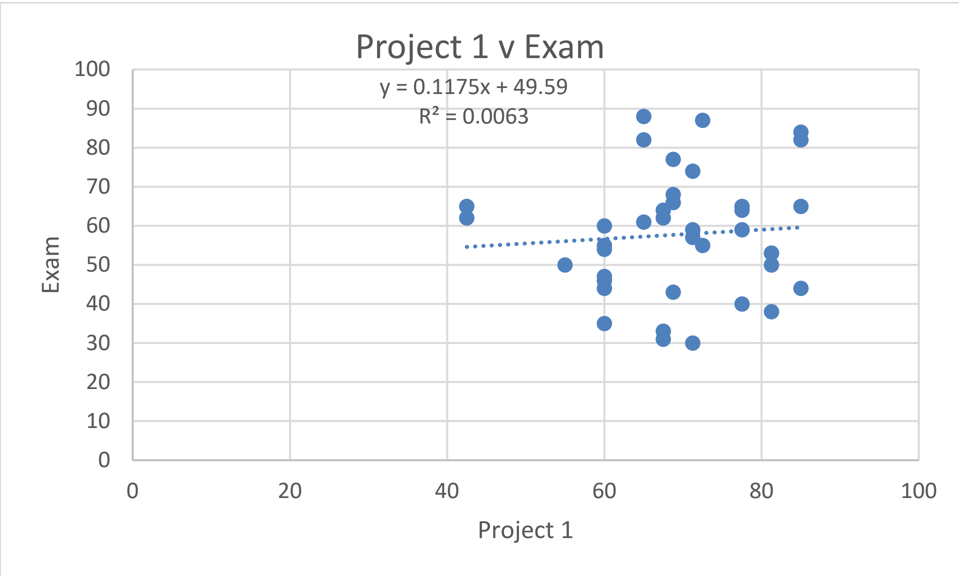

Figure 1: Project 1 (first order differential equations) against the exam

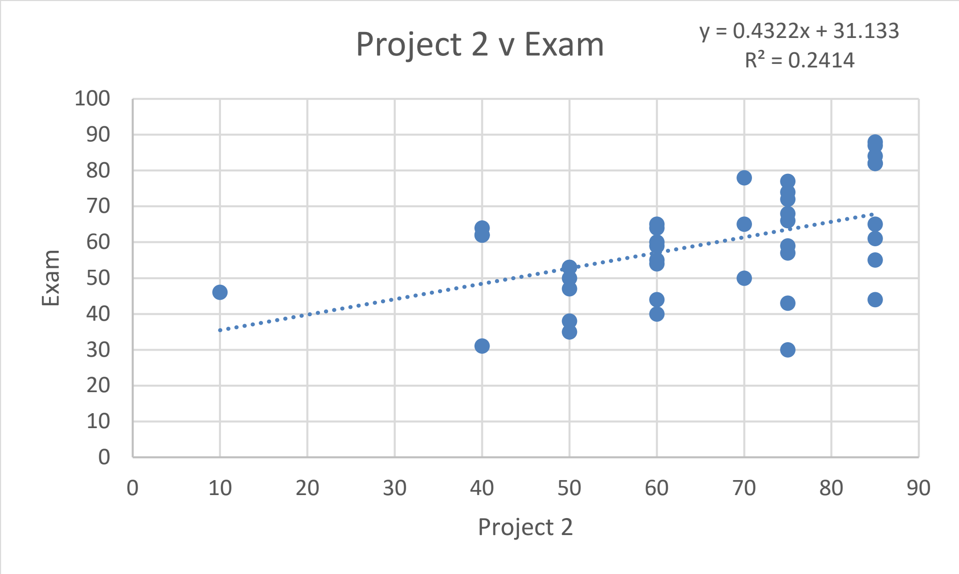

Figure 2: Project 2 (second order differential equations) against the exam

CONCLUSIONS AND FUTURE WORK

In our previous paper we looked at the introduction of a short project-based-learning element into a mathematics module for third-year Level 7 mechanical engineering students. This was well-received by students and resulted in greater engagement with examination questions on the same topic in comparison with previous years when this material was taught in a standard lecture environment. Student performance on these examination questions was also improved which is consistent with the findings of Reyes, M. R., Brackett, M. A., Rivers, S. E., White, M., & Salovey, P. (2012). However, the strongest students overall performed the best on these questions. Through the inclusion of a presentation element within the project assessment, the "*active verbal involvement*" of students advocated by Kwon (2000) was addressed, allowing students the opportunity to explain and justify their thinking, which is particularly important for engineering students while studying mathematics. This year we introduced a second project. We surveyed the students on four themes namely engagement, the learning value and relevance of mathematics in engineering, teamwork skills and the overall experience.

Students felt the project increased their engagement by giving them the opportunity for greater interaction with the material and agreed that they were fully absorbed in the activities and discussion enabled by these sessions.

The students agreed that having practical examples of engineering mathematics assisted in greater understanding of its relevance in their engineering discipline and that this approach helped to stimulate their thinking due to the hands on approach and the clear overlap with other material from other engineering subjects.

Students were generally positive about the value of working on real world problems, this was commented on by a large number of responders. There was a wide variety of difficulties in transitioning away from a structured environment to more open ended questioning

In terms of teamwork they were happy with the environment in general indicating a healthy working team, although some students admitted to being carried by the team. In relation to problem solving, students strongly agreed that concerted effort was made to overcome problems they encountered and with their supporting comments emphasized positive teamwork in action. This highlights the value of this approach and some of the limitations of the pure classroom approach.

Although it is challenging to develop projects of this type, the aim was to create a scenario that would be "experientially real to students and…take into account students' current mathematical ways of knowing" (Rasmusen & Kwon 2007). We will now introduce a further project into the module in third year and then proceed to introduce this approach to earlier years of the programme. In addition further quantitative analysis of the performance of the students is required and we hope to complement this with focus groups and in depth interviews.

Kaur (2010) concludes that in order to work towards excellence in teaching mathematics, dual responsibility between the teacher and learner needs to be encouraged. This classroom project, which encourages the students to take ownership for finding and presenting a practical solution to an engineering problem using mathematical theory, is a step in the right direction.

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Breaking the Barriers in Language Learning
New Methods for Engineering Students to Learn Foreign Languages

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ABSTRACT

Language skills are very important to a global engineer. There are many new ideas and methodologies which can be imported and used in developing the language learning and teaching in engineering education. This paper will focus on Content and Language Integrated Learning (CLIL) and Tandem methods which have been tested in BSc engineering education for several years in Finland at VAMK (Vaasa University of Applied Sciences). Results of these teaching experiments have been good and encouraging. Guidelines for new language teaching methods and curriculum development in engineering education will be given in this paper.

Conference Key Areas: Curriculum Development, Engineering Education Research, Engineering Skills

Keywords: language learning, CLIL, engineering education, Tandem method

INTRODUCTION

One critical skill for an engineer operating in today's global environment is the ability to speak several foreign languages. Therefore, it is important to develop and increase different language learning and teaching methods in engineering education and to shift the focus more to the development of communicative speaking skills and natural language learning. Engineering students' possibilities to learn languages in today's tertiary education are no longer limited to the normal basic language courses and the field-specific language courses – usually referred to as LSP (Language for Specific Purposes) offered by the respective institutions. Participating in foreign-language-medium (hence referred to as FL-medium) degree programs can offer an effective

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natural way for language learning if also the linguistic development is kept in mind and supported. Another way to increase the natural language learning and to develop especially the communicative skills is to use the classroom Tandem methodology in the courses or to offer Tandem session possibilities outside the official teaching hours. This works especially well if the university operates in bilingual areas or if there are many foreign students with different mother tongues studying at the university.

This empirical paper describes several *language learning related teaching experiments* conducted in engineering education at VAMK (Vaasa University of Applied Sciences). The aim of the teaching experiments was threefold: first, to develop the language teaching and learning and second, to create new models for natural language learning and third, to improve the engineering students` communicative skills in Swedish which is the other official language in Finland and which language is used very much in the region where the graduating engineers of VAMK will be employed. The local chamber of commerce has supported these teaching experiments and this shows how important engineering students` effective language learning is for the local industry and business life in general.

After presenting the theoretical background in the next chapter, the settings and some findings of the qualitative learning experiments will be presented in chapter 2. Conclusions and new models for language learning and suggestions for the development of the engineering curriculum will be provided in chapter 3.

1 THEORETICAL BACKGROUND

1.1 Learning languages in a natural way – using CLIL

Second language acquisition literature generally divides the nature of language acquisition into two categories related to the learning conditions: Naturalistic (often referred to as *nature*) and instructed (respectively referred to as *nurture*; eg. Mitchell & Myles [1]). Relating to this division we will present the contexts in which the learner in tertiary education faces a foreign language in the following figure 1:

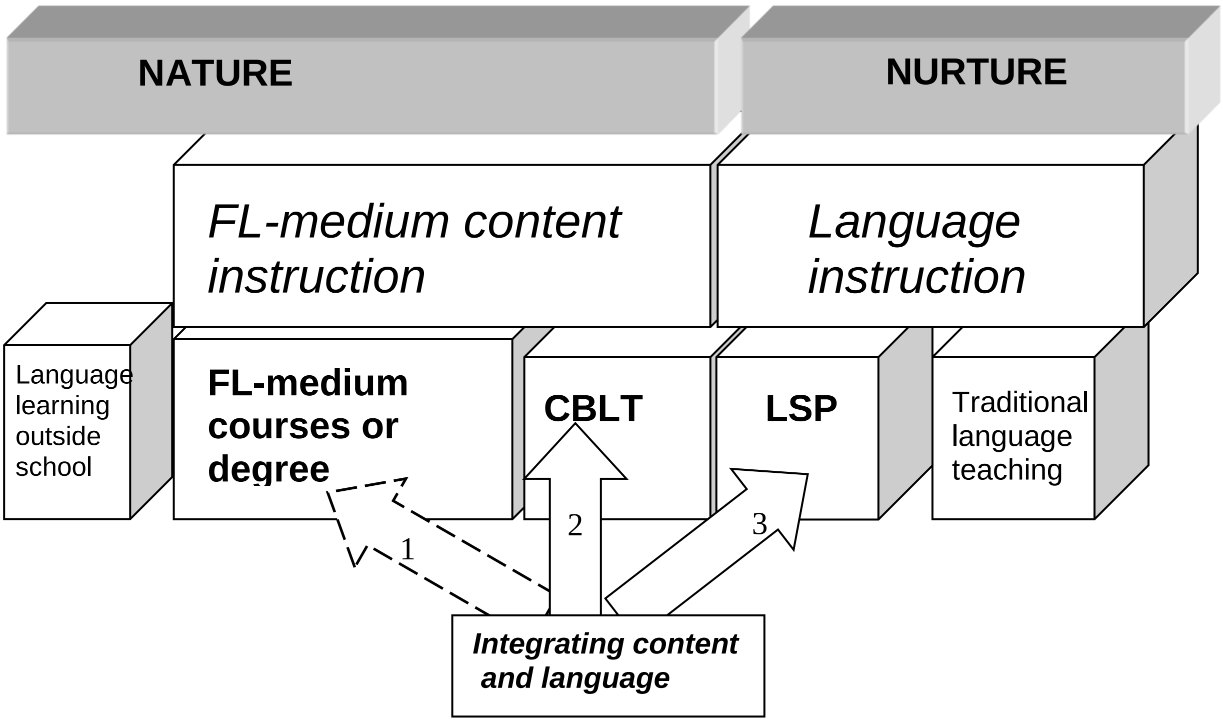

Fig. 1. The spectrum of content and language in tertiary education.

By *FL-medium courses or degree programs* we mean instruction given totally (most typical arrangement) or partially (occasionally) in a foreign language in a professional subject. The starting point in tertiary education when introducing FL-medium courses or degree programs has not usually been primarily to improve the learners' language learning but to boost the international profile of the respective institution, with an aspiration to become part of the international discourse community and to be able to attract more international students. FL-medium instruction could be used as an effective language learning method, too, if used properly and the language learning would be also in the focus of evaluation, even in the subject courses, and not only the subject topic.

CBLT (Content-Based Language Teaching) means typically that a language specialist is also a specialist on a subject-specific topic. The teacher utilizes her expert knowledge (eg. art history) to teach the language – or builds the language course around this expert knowledge. The learners focus on the content and learn the language incidentally, being mainly directed towards learning the content. In higher education the following problem presents itself: a very limited number of language specialists are experts in some other professional content. Perhaps a more realistic option when implementing the CBLT model would be a content teacher who takes a special interest in language development and becomes trained as a specialist in it to some extent. However, the more expertise the knowledge in the chosen subject specific topic requires, the less likely it is that the one and the same person could do both content and language. This is typically the case in higher education.

LSP (language for specific purposes) is a term introduced already in the seventies. It means language classes whose syllabus is closely related to the needs of the learners' future profession – partly intersecting with the concept of CBLT. As an example of this is teaching in English to engineering students using engineering journals, other engineering texts and eg. videos (from the internet) with experts in the field giving presentations. In practice, the use of authentic materials and examples as course materials requires certain co-operation between the content teacher and the language teacher. The element of integrating content with language is thus already built in the structure of LSP courses. The LSP teachers, however, have been faced with the following problem: with the absence of materials and examples from FL-medium content instruction - as not enough such instruction has been available because most content teaching is done in the native language - the language teachers have often had to use simulations and authentic materials from random sources. The idea of integration has been around for the last three decades but surprisingly little seems to be happening even now when more FLM content teaching is provided.

In order to increase natural language learning in engineering education one option is to start integrating content and language. This means introducing the CLIL (Content and Language Integrated Learning) methodology into the engineering curriculum. "*CLIL is a dual-focused educational approach in which an additional language is used for the learning and teaching of both content and language"* [2]. Integrating content and language can be implemented in three different ways (arrows 1,2 and 3 in the figure1). Arrow 1 relates to the possibilities of *integrating language to content* (eg. the language teacher providing vocabulary and other language related help in a FL-medium content course like e.g. Robotics course). An example of this model is given later in this article. Arrow 2 relates to CBLT. This arrangement would be an optimal – although in most cases theoretical – example of content and language integration. Arrow 3 means *integrating content to language* (eg. the lab reports of the physics course would be written in English as part of homework for the English language course).

1.2 Different models of CLIL in tertiary education

As mentioned in the previous chapter, the possibilities of CBLT in tertiary-level context are limited. A more realistic CLIL model in higher education consists of co-operation between the expert in the professional content and the language expert. We present two different models of co-operation possibilities between a content teacher and a language teacher in figure 2:

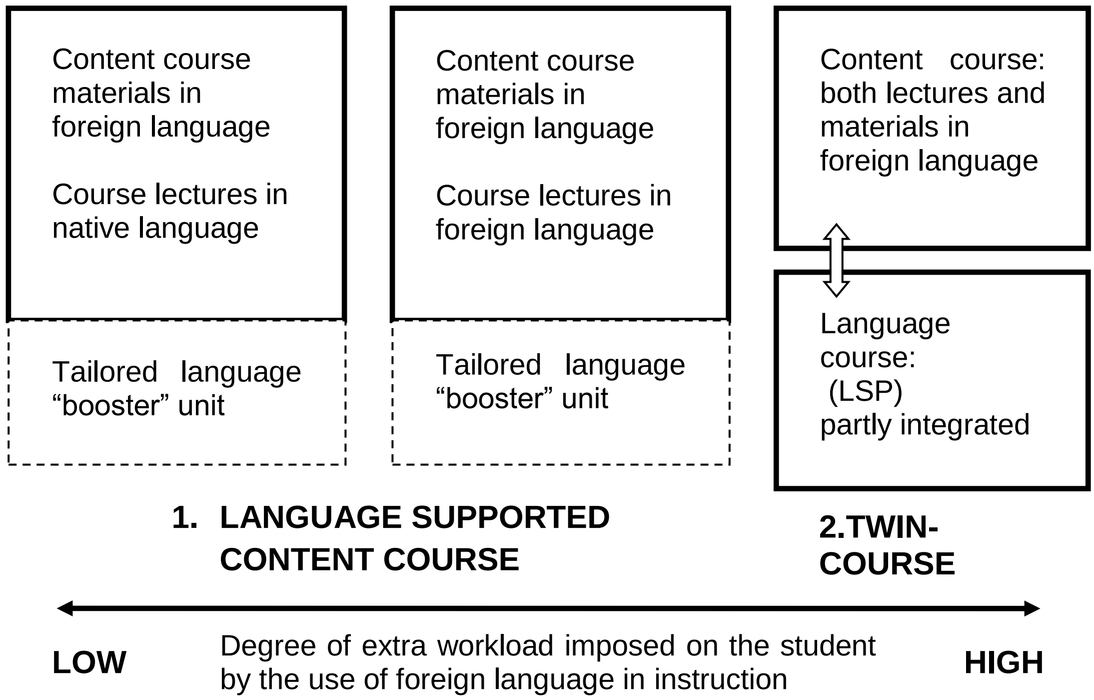

Fig. 2. Different CLIL co-operation models

A twin-course means a content course which is integrated with an LSP course. A language supported content course means that the content course (instructed totally or partially in foreign language) is supported by a separate language "booster module", instructed by a language teacher. A more detailed example, designed and implemented by the current writers, will be presented in the results section.

1.3 Improving communicative skills using the classroom tandem method

Tandem method in language learning means a learning partnership between two persons with different mother tongues. In tandem the learners work in pairs and they both benefit equally from working together. Their language learning is based on communication between them. The two members in each pair have different mother tongues and the aim in tandem sessions is to learn these two different languages (e.g. a Finnish-speaking Finn learns Swedish and a Swedish-speaking Finn learns Finnish). The pairs talk first e.g. one hour in the mother tongue of one of the members and after that they switch into the other person`s mother tongue for another hour. The both learners are experts of their own language and culture and so they can help each other with the linguistic problems occurred in the conversations [3]. Classroom tandem is used in the school context when students coming from different language groups are being taught together and they study together. The tandem teacher must have a new way of thinking and working habits. A new pedagogical mindset is needed. The teacher must set kind of milestones (tasks) on the map and by reaching these milestones the targets of language learning will be acquired. The teacher should help the student pairs to find and accomplish these milestones.

In tandem sessions the pairs can choose to read aloud or they can discuss particular topics of interest. They can also correct mistakes and suggest improvements for each other or just practice conversations and do all kinds of other activities which at the university level in the classroom tandem will be prepared by the language teacher. In classroom tandem the role of the language teacher will change from teacher to more of a facilitator and coach. The tasks must be such that space is left for students`own creativity and thinking. In easy subjects free conversations can be used but in more demanding topics more support is needed from the teacher and the tasks must be more structured [4]. Tandem sessions should be made as interesting as possible for the pairs and the session tasks should deal with topics that are of equal interest to both tandem learners. There are two main principles in tandem: reciprocity and autonomy. Reciprocity means that both tandem partners benefit equally from the cooperation and they should work the same amount for both languages. Autonomy means that both of the tandem partners control their own learning: they define their goals and how to reach them, they decide what kind of support they wish to have from their tandem partner and they also evaluate their own achievement. [5]

2 TEACHING EXPERIMENTS

2.1 Description of the teaching experiments in phase 1 - CLIL

Two different types of teaching experiments were conducted during different academic years at VAMK. In the first phase we developed the English language learning and teaching with the CLIL methodology. We used the language supported content course model. In it a special language module was tailored to the content course – on a very practical level, the description below shows the reader that corresponding models could easily be implemented without complex administrative arrangements. The project included classroom teaching and follow-up research, with learner feedback. In *Table 1*, the setting of these teaching experiments is being described.

Table 1. Description of the CLIL experiments

Course	Corporate Planning 42 classroom hours credit: 3 ECTS points (several courses)	Language Support for Corporate Planning 16 classroom hours credit: 1.5 ECTS points (several courses)
Teachers	Content teacher	Language teacher
Learners	3rd or 4th year mechanical engineering BSc students 40 learners altogether (many groups, during several years)	
Learners' language proficiency level	Heterogeneous groups, proficiency level ranged between A2 to C1	
Responsibility for course materials	Content teacher	
Responsibility for scheduling and assignments	Content teacher	Language teacher
Teaching responsibility	Providing information on theory and practice of Corporate Planning	Providing language support and supervising learners' language production
Language used in teaching	Lectures in Finnish, materials in English	Class room language mainly English, materials in English
Research included in the project	In the beginning of the course: on-line survey and language tests	At the end of the course: on-line survey and language tests

Our follow-up research consisted of an on-line survey where the learners self-rated their language skills and possible changes in these skills and gave feedback on the course. We observed a consequent increase in learner satisfaction, examples of which are given below in table 2, obtained in our survey from our last group.

Table 2. Learners opinions of CLIL

Statement	number of *yes* answers	total number of answers
Reading the materials was useful from the view point of language learning	13	14
My active vocabulary became somewhat larger	14	14
Reading English texts became somewhat faster	13	14
I would recommend this course to next- year students	14	14

2.2 Description of the teaching experiments in phase 2 – classroom tandem

In the second phase we developed the Swedish language learning and teaching with the classroom tandem methodology. As there are two universities of applied sciences operating with different teaching languages in the same city it was easy to start a project using classroom tandem in two language courses because distances were not a problem. As the university buildings situated even beside each other it was very easy to join student groups with different mother tongues (Finnish and Swedish) from both universities into same classrooms at the same time. The other student group learned Finnish and the other Swedish. *Table 3* describes the settings of the experiment.

Table 3. Description of the classroom tandem experiments

Courses	Communicative Swedish course (free choice voluntary course) 36 + 4 contact hours altogether, 3 ECTS Finnish course (obl.course in the BSc eng. curriculum) 3-5 ECTS
Main responsible lecturers and tasks	A team of two Swedish and Finnish language teachers: content and task planning One teacher from each university with different languages of instruction (Finnish/VAMK and Swedish/Novia) Manager: funding and schedule planning and promotion
Learners (different years different groups)	1st year mechanical and electrical engineering BSc students from the Finnish speaking UAS, 14-21 students per year 2nd year BSc industrial engineering and BSc business students from the Swedish speaking UAS , 16-18 students per year In each Tandem session there were ca. 20 students
Learners language level	Heterogeneous group. Proficiency level ranged between A1 to C1
Language used in the teaching and Tandem sessions	Finnish and Swedish , 5-6 Tandem sessions per student pair a´ 2*45 minutes
Student selection	Ranking test was held before the course started. The weakest and the best ones were excluded from the course
Data collection	Open-ended questionnaire in the end of the course

After the courses an open-ended questionnaire was distributed and answers were collected. The main target of the questionnaire was to find out what the students thought about the tandem method and the sessions. Mainly qualitative data was collected. Most of the students (86-88%) had very positive or positive comments about this method. Only a few students (like 1-2 in a group of 20) had neutral comments and none had negative comments about this method.

The free comments about the tandem course were such as : *good thing, helped me much to develop further, a good way to study as one gets courage to speak and use the other language, it was super good to learn to talk, really good idea, it is a pity that we did not have this method already in the gymnasium, this method should be used in all language teaching and learning, very good and educative, best course in Finnish language ever, good course I like it, really effective course, good experience, really nice way to learn, much nicer than the normal teaching, gave me good social competences, much better way than the traditional Swedish teaching, it has gone well and nice it has been, quite good concept, tandem sessions were very educative and nice, good organization, better than the normal way, interesting experience, more of this thanks, good this forces one to learn.* Almost everybody said that they had become more brave in using the language and in the last group 88% thought that they had learned Swedish language better or much better with this method than with the traditional language teaching.

To summarize, the overall student experience was very good. One very interesting outcome of this experiment was the widening of the students` cultural understanding. Both language groups (Finnish and Swedish speakers) said that they had started to better understand the other language group and their culture and habits as they now for the first time ever in their life (most of them) were in contact with an individual from the other language group. So the students not only learned the other language but they developed their intercultural competences. It might sound strange that even in Finland there are cultural differences between Finnish speaking and Swedish speaking Finns but this is the case. So any method to develop intercultural social skills of the engineering students is beneficial as these students in the future will mainly work in bilingual areas and companies where these skills are highly valued and useful in everyday work.

3 SUMMARY AND ACKNOWLEDGMENTS

The paper has presented several pedagogical experiments conducted in BSc engineering education in Finland where engineering students have been exposed to new language teaching and learning methods based more on natural language learning. Based on the qualitative results there is evidence that this type of natural language learning is beneficial and develops especially the students` communicative competences, linguistic self-esteem and also cultural understanding (especially the tandem method) and teamwork skills in general. Therefore it is strongly recommended that the universities should develop their curriculums and teaching schedules in such a way that the curriculums should include courses where students from different universities with different official languages (such as e.g. minority and majority languages in some area) could study together and work on some common tasks and simultaneously learn languages.

Another suggestion is that in the FL-medium instruction more attention should be payed on the development of the foreign language skills of the student. It seems inevitable that the trend in higher education – and all other levels of education – will be towards more FL-medium teaching. The challenge for the institutions is to keep up with this trend to maintain their status. The challenge for the language teacher is to accept the possibility of a structural reform of language teaching towards the integration of a language course to content instruction – and for the content teacher to be ready to co-operate with the language teacher – or ideally adopt an additional role as language model or supervisor. The challenge for the managers and decision-makers in institutions of tertiary education is to optimize the new possibilities for maximal language outcome. This can mean e.g. that in engineering degree programs where teaching is done totally or partly in a foreign language (typically in English) the whole curriculum must be changed in such a way that small language booster units joining the subject courses should be inserted into the curriculum.

In order to realize this type of co-operation the teachers from different disciplines (e.g. a language teachers and a subject teacher) should be encouraged to collaborate and also teachers from different universities with different languages also should be encouraged to conduct courses as teams. This can be initiated by common EU or similar projects where extra resources should be given to the developers in the starting phase. Also the organizational culture at the universities should support cross-functional collaboration and collaboration over the language borders, too. It is an imperative for the universities to further develop themselves and become truly international networked learning organizations from the pedagogical point of view, too.

Finally we want to thank the Ostrobothnia Chamber of Commerce for supporting our classroom tandem teaching experiments for several years. Without this support we could not have conducted these experiments in this scale and developed the new methods to teach and learn languages in engineering education, neither attended this conference. We also thank our partner university Novia`s language teachers for the good co-operation and the anonymous referees of this paper for their comments.

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Examining STEM Learning through memory retention
A research agenda

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ABSTRACT

Ebbinghaus' 1880-1885 study on memorization is considered the seminal research study in the field of memory retention. Observing the increasing number of publications citing this work only proves the constantly rising interest in the field. Right now hundreds of studies on how memory retention works are either based or inspired by the original Ebbinghaus experiments.

While studying STEM Learning, the authors considered examining this topic through the prism of memory retention as well, as memory constitutes the basis for further higher-order learning. Over a period of a year, the authors have carefully reviewed over 200 papers referencing the original work on Ebbinghaus. Findings of the analysis of this review show that, despite the rapidly growing number of publications in the field, practically all of them study memory retention by researching the retention of learning of elements unrelated to sophisticated STEM concepts; such as syllables, series of words, words in a foreign language, personal experiences, number series, and emotional memories.

The number of studies that explored memory retention by studying STEM related content appeared to be extremely few and leave many doors unexplored. In this paper the authors highlight and discuss this research gap and introduce a promising agenda for further research on STEM Learning.

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Conference Key Areas: Engineering Education Research, Engineering Skills, Curriculum Development

Keywords: Memory retention, Learning retention, Engineering Education research

INTRODUCTION

1 HERMANN EBBINGHAUS ON MEMORY RETENTION

1.1 Ebbinghaus' seminal work

Ebbinghaus' 1880-1885 study on memorization "*Über das Gedchtnis"* [1], later on translated into English as "*Memory. A Contribution to Experimental Psychology"* [2], is considered to be the seminal research study in the field of memory retention. For approximately 5 years the German psychologist Hermann Ebbinghaus conducted a series of experiments using himself as the only subject in order to study the speed as well as the retention of learning. Through these experiments Ebbinghaus explored learning of series of syllables or numbers, speed of learning of materials when placed within a meaningful context, retention of learning as a function of time, as well as the effect of repeated learning on retention. The direct result of his studies was the introduction of the learning curve, the forgetting curve and the spaced learning effect.

1.2 The Learning and the Forgetting Curve

The learning curve is a graph that Ebbinghaus used to explain how fast someone learns new or repeated information. As seen in *Fig. 1* learning curves present how learning increases as the attempts to learn also increase.

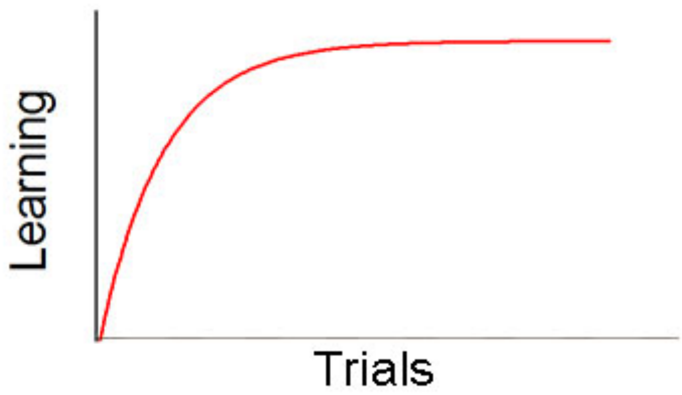

Fig. 1**:** Representation of a Learning Curve

Counter to a learning curve the forgetting curve is the graph that represents the declination of our memory overtime. According to the Ebbinghaus forgetting curve, in the case where there is no attempt to recall this newly acquired information, a typical human tends to forget almost half of what was learned after a day, remembering almost nothing after a matter of weeks. In the case though where the new information gets frequently, consciously or unconsciously, recalled then the forgetting effect starts to decline, as our memory of this particular information grows stronger. In the forgetting curve presented in *Fig. 2* red colour represents the decline of memory in the case where there is no attempt to recall the new information, while green represents the decline of the memory in the case where there is a steady attempt to revisit and recall the new information.

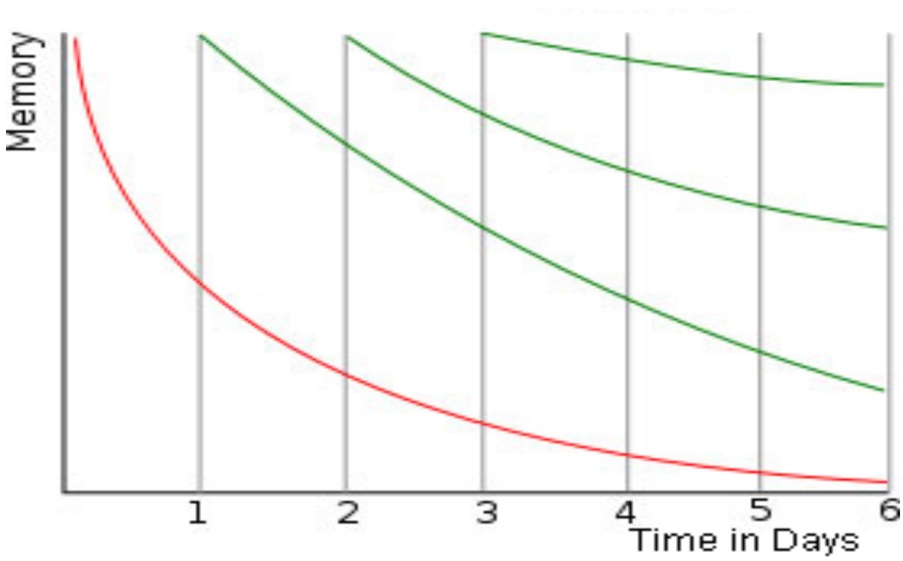

Fig. 2: Representation of a Forgetting Curve

1.3 The rising interest towards the Ebbinghaus work, and how it is positioned within the STEM education literature and on-going research

Although Ebbinghaus conducted his experiments over one hundred years ago his work appears to be the cornerstone of the field. One can easily understand that by taking a look at the rising numbers of the papers that cite his work, and by looking at experiments that are designed according to his seminal work. When looking for relevant information at the Web of Science database, more than 2600+ articles appeared that have cited Ebbinghaus' original work. Out of those approximately 970 papers were then again cited more than 10 times in later studies, gaining more and more popularity with time. Figure 3, as created by the Web of Science, presents the 970 papers referencing Ebbinghaus as they have been published from 1885 until 2016, while *Fig.* 4 presents to rising number of references to the 970 papers throughout the years.

Given the global acknowledgement of the importance of Ebbinghaus' work on memory retention one might expect that this work would also be influencing current work in the field of STEM education, however this does not appear to be the case [3]. Although research and development on STEM education and STEM learning is growing, the personal experience of the authors is that the work of Ebbinghaus is very rarely, if at all, mentioned in this academic community. This personal experience has also been the driving force behind this study, as the authors decided to explore if and how many studies on memory retention were placed within a STEM learning context [3]. At this point the authors would like to clarify that by no means do they imply that learning equals pure memorization, however memory can be considered as the foundation towards further higher-order learning, and therefore deserves particular attention.

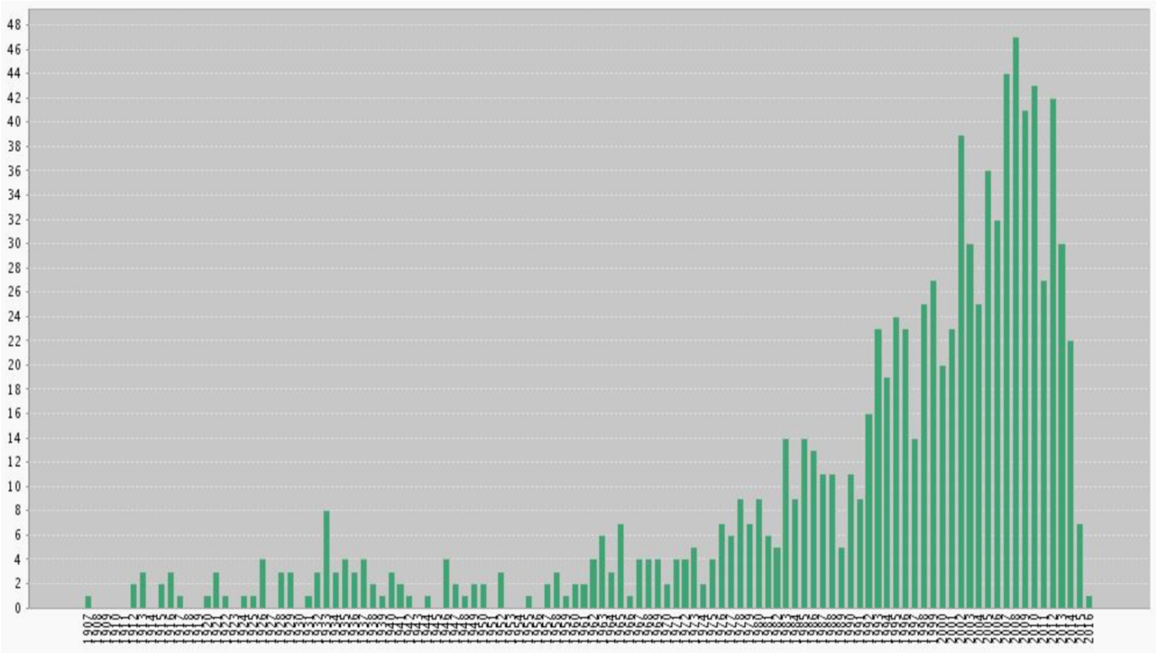

Fig. 3: Number of published papers referencing the work of Ebbinghaus that have been cited more than 10 times from 1907 until 2016

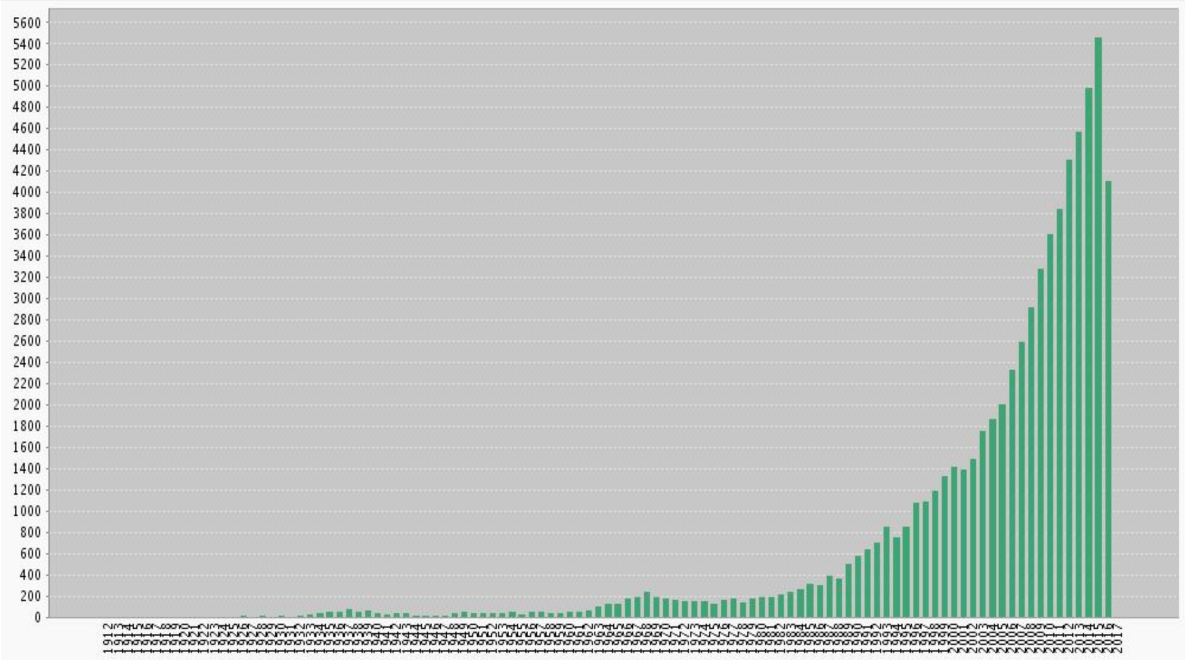

Fig. 4: Numbers of papers citing the publications presented in *Fig.*3 from 1907 until 2016

2 METHODOLOGY

2.1 Data Collection

To obtain the data set researchers performed two searches for papers citing the Ebbinghaus 1885 work; one in Google Scholar and one in the Web of Science [3].

The two resulting lists were sorted into three groups; recent papers published between 2014-2016, papers with high-impact (cited over 100 times), and the long tail including all papers. The papers from the first two groups, including a total number of approximately 200 papers, were then split among two of the authors for further analysis. The choice of a methodology focused on finding papers referencing Ebbinghaus 1885 is based on the assumption that any research relevant to retention of memory would most probably either reference the original Ebbinghaus work or one of the well cited papers that reference Ebbinghaus 1885/1913.

2.2 Data Analysis

Authors started a preliminary analysis by using a general inductive approach through open-coding [4]. Selection of the method was based on the fact that “the primary purpose of the inductive approach is to allow research findings to emerge from the frequent, dominant, or significant themes inherent in raw data, without the restraints imposed by structured methodologies”. After reading the 25% (approximately 50) of the identified papers the two researchers met, re-evaluated the codes they had come up with until that point and agreed to 5 codes representing 5 questions to be answered through this data collection. *Table 1* presents the definitions of the final codes that were then applied to the whole data set in order to complete the data collection

*Table 1.*Codes applied to data during qualitative data analysis

Code	Definition
Title	What is the title of the paper analysed
Interval	What is the maximum time interval between the beginning of the learning process and final memory retention testing? (minutes, hours, days, months)?
Domain	What was the domain in which learning was studied in this research paper (STEM, Language, HASS, non-academic, other)
Techniques	Are there any techniques mentioned in the paper that might lead to delay of memory loss?
Type	What is the type of study presented in this paper (original experiment or a review or prior experiments)?

Once the final coding scheme was created, the abstracts of all papers were reviewed and analyzed. When reading and, if appropriate, referenced papers were also visited and added to the data set. At that point some papers were also excluded from our data sample, as they were referencing the Ebbinghaus work but the actual content of the paper appeared to be irrelevant to memory retention. In the case of data falling under the “Interval’ code, authors further agreed to categorize a study as a long-term study in the case where the testing process would keep taking place more than 2 years (25 months) after the original instance of the learning process, otherwise the study would be categorized as a short-term study. This paper further discusses the findings after the complete analysis of the first 100 papers.

2.3 Study limitations

In the current study Google Scholar and the Web of Science were the two data bases explored during the data collection. Given that, the authors are aware of the fact that there might be other studies referencing Ebbinghaus that might not be included in the aforementioned databases. Furthermore, the authors started the data collection by looking for papers citing the Ebbinghaus' original work, but are aware of the fact that there might be other studies on memory or learning retention that would not appear in the search in the case where the Ebbinghaus work would not be cited in the paper.

3 FINDINGS

After careful review of the first 100 papers, only 8 papers were identified to discuss issues related to retention of memory, the learning and the forgetting curve, or teaching strategies leading to strengthen of memory within a context of a STEM study [3-11]. Five of the 8 papers discuss the topic within the context of Physics and Engineering education, while the remaining 3 are placed within a medical education context but for the purpose of this study we have decided to include them in our findings as the topics discussed have great relevance to Biology education. None of the aforementioned studies were long-term studies.

In greater detail, according to Barrantes [6] about 50% of what is learned in a Mechanics freshman class is lost by the senior year "unless it is re-used, in which case performance may even improve. The research however is inconclusive as to the reasons for such improvement nor gives any hints as to how to increase or measure retention" [3]. Direnga et al [11], studying again a Mechanical Engineering case, showed that students who remain actively engaged in the subject matter "show improvements, which may mean that Ebbinhaus forgetting speed does not applied if not the same but similar concepts are getting reviewed" [3]. Kwam [5] studying traditional lecture vs active cooperative learning in an Engineering Statistics class found that active learning can help to increase retention for students with average or below average scores, but made no difference to good students. Sayre et al [10], when examining a case of Physics showed that "retention and mastery are correlated with practice but again, in a short-term analysis and without any hints for improvement"[3]. Grundmeyer [12] conducting work on retention of STEM education at the high-school level found that "two months and a half after taking tests, A level high-school students score 25% lower on the same tests and B and C students scored 35% lower than their original scores" [3]. Taking a look at the studies coming from the medical field the undergrad students studied by Custers [7] lost about 30% of what the learned in the first year and 50% in two years showing that certain students exhibited longer retention than others – independently of the shape of the forgetting curve. Custers and Ten Cate [8] "suggest that very little knowledge is lost after 1 or 2 years in the case where it gets used, but then it follows a forgetting curve and about 15-20% is retained 25 years later. However, this research has not been replicated" [3] and is examining basic scientific concepts that one would expect they do frequently reappear in the daily life of a medical doctor. Last but not least Fritz [9] tested retention over a 6-month period found that using a simple model to explain a concept is equal to a sophisticated model in terms of retention of medical instruction suggesting that other factors, such as emotional impact, are possibly more important to increase retention [3].

4 DISCUSSION AND SUGGESTIONS FOR FURTHER RESEARCH

Observing the current structure of university curricula one can easily see that many of the subjects taught in STEM schools are almost never used after the final exam, are difficult to master, and are arguably completely unrelated to innate abilities, making the STEM courses ideal test-beds for the Ebbinghaus hypothesis that unused knowledge is forgotten at "Ebbinhaus forgetting speed". However, findings of the analysis of this review show that, despite the rapidly growing number of publications in regards to Ebbinghaus work, the vast majority of them study memory retention by researching the retention of learning of elements unrelated to sophisticated STEM concepts; such as meaningless syllables, series of words, words in a foreign language (many times out of any context), personal experiences, number series, emotional memories [3]. The number of studies that explored memory retention by studying STEM related content appeared to be extremely few, the findings do not appear to align well with strong supporting findings from other fields, the methods do not appear to be rigorous, and in general the STEM related papers identified so far leave far too many doors unexplored.

Furthermore, unrelated to the content to be learnt, when examining the duration of all studies, almost all of them test their subjects starting from immediately after the experiment up to some weeks or months later, but almost never passing the critical 2-year interval.

The fact that there are ongoing efforts to reform STEM learning worldwide only highlights the necessity of understanding in greater depth how memory retention works in the context of STEM learning, as it could possibly be used as the foundation that will guide future content and curriculum development. At this point it would be hard to tell whether the STEM field might be the one to completely challenge the popular Ebbinghaus theories, or whether large scale, long-term studies would eventually prove these theories to be correct once again, however we can say with certainty that there is a big research gap in the area that definitely calls for further investigation.

5 SUMMARY AND ACKNOWLEDGMENTS

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A Teacher? A Mentor? A Friend? – Teacher Mentoring Experience at Tampere University of Technology

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ABSTRACT

In this paper, we research a recently set up engineering students' teacher mentoring programme with special interest on teacher mentors' expectations and experiences from the point of view of self-efficacy and motivation. We aim to have an insight in the teacher mentors' met and non-met expectations and see if this has effect on the teacher mentors' motivation and expectations of the outcomes of the mentoring programme. We also examine how beneficial the teacher mentors consider the programme to be to the students and how this is linked to their motivation.

Conference Key Areas: Engineering Education Research, Engineering Skills, Curriculum Development

Keywords: Teacher Mentoring, Transition to University, Student Teacher relationship, Teacher Role

INTRODUCTION

1 TEACHER MENTORING

1.1 Academic faculty as advisors

Is it true that the faculty is uninterested and unskilled academic advisors? This provocative stereotype, mentioned in many articles [1, 2] is still - at least partly – vivid in many universities. In an engineering education setting, this has been seen even as a bigger challenge. Technical universities and the engineering teachers are aware of the importance of soft skills but still priorities hard skills [3, 4] and similarly they find it less interesting and academically challenging to teach those soft practice skills to students than to teach them technical skills [5]. This problem reflects also on teachers' attitudes towards mentoring, where the focus is not on transmitting students' technical knowledge but rather on everything else.

To find out how the university teachers in a technical university evaluate their skills and attitudes towards mentoring, a survey for all teacher mentors at Tampere University of Technology, was executed in the autumn of 2016. In the spring of 2017, the same questionnaire was re-implemented to discover whether there are any changes in their attitudes or in teachers' skills in advising students after they gained experience from being a mentor. In addition to a survey, teachers' opinions were collected in two meetings where teachers exchanged their experiences. The aim was also to recognize whether there are any certain themes that the mentoring teachers find especially challenging in their role as advisors and mentors.

In Finnish universities, the students' transition from a high school to a university has traditionally been aided by a peer tutoring system where a pair of older students meet regularly with a small group of first year students in an informal setting. However, to help the students' integration to the academic community, Tampere University of Technology started a university-wide teacher mentor program where all first year students were appointed a personal teacher mentor. In the planning phase of the teacher mentoring programme, teachers' personal opinions towards mentoring varied widely. Some teachers considered the mentoring programme irrelevant and did not see any benefits for students or for themselves in the process. They considered the students to be too young to integrate into the academic community and thought that first year students are mainly concentrating on their studies and are not interested in developing skills that mentoring offers. On the other hand, some teachers saw this as a good starting point to plant the seed of professional growth in the minds of students and to increase retention rates.

One element, which strongly affects faculty advisors' motivation towards mentoring young students, is teachers' self-efficacy in advising [6, 7]. To enhance the teachers' competence to advise individual students or small student groups, many universities offer trainings on advising students. Somewhat surprisingly, it has turned out that the majority of teacher advisors feel themselves competent regardless of they have received this training on advising or not [6]. At Tampere University of Technology, teachers were able to participate in a voluntary training, which mainly offered skills on how to guide a small group. Our survey revealed that there was no difference in the beliefs of their competence between teachers who had participated in training and those who had not. What was seen instead was that teachers who didn't have experience in mentoring were more confident about their skills than the ones that had been mentors before. The survey also revealed that mentors who weren't sure about their skills and the purpose of mentoring were the most likely to think that the mentoring is not useful for students. This implies that the role of teacher mentor should have been interpreted better and the aim of the process should have been clarified in more detail.

1.2 The role of teachers in advising and supporting students

In Finnish technical universities, teachers typically have a M.Sc. or a D.Sc. degree in their own field, but little, if any, pedagogical knowledge. Therefore, the idea of a mentoring programme for the first year students raised many questions among teachers when being announced. Many of the teachers felt insecure of their skill to encounter students personally and to communicate with them with topics out of the direct subject discussed during the lectures.

The idea of mentoring itself is not new. Quite the opposite, several articles [8, 9] refer to the idea of mentoring dating back to Homer's Odyssey and it is widely used not only in academic settings but also in business context. The advantages of mentoring, are also well known, including increased motivation, more positive self-image and better retention rates among students [8, 10]. In higher education, the terminology related to mentoring, however, is somewhat ambiguous. The terms "mentor" and "faculty advisor" are often presented as synonyms, however a mentoring relationship is claimed to develop only over a longer period of time (National Academy of Sciences 1997). Researchers [8] present definitions of several researchers, where some of them connect mentoring with emotional intimacy with students while others see it more loosely. Regardless of the level of intimacy, researchers [8] also emphasize the uniqueness of each mentorship and the long-time range of it. Both the uniqueness and the long commitment to the relationship may sound somewhat frightening to a teacher with no previous mentoring experience.

It has been noted that better performance in occupational context is related to high self-regulatory efficacy. According to Bandura, who used this concept at the first time in 1977, self-efficacy means person's beliefs about their competence in certain situations by their own performance. [11]. The origins of self-efficacy are stem from social cognitive theory which sees people as active contributor of their lives, not just passive bystanders [12]. This approach has an emphasis on one's thoughts and emotions concerning certain situation and one's behavioural choices. [7]

Self-efficacy is closely linked to motivational, affective, cognitive and decisional factors. It can be seen as the source of motivation related to learning and has an effect on goal setting and persistence in challenging or arduous situations. If the beliefs are low, people tend to give up more easily. [12] Self-efficacy beliefs can enhance person's performance and have an influence also on well-being. The origins of these beliefs are already in childhood, but also experiences over the lifespan affect person's self-efficacy. [11]

In mentoring, self-efficacy is expected to be significant of teacher mentors' success. However, simultaneously it has been recognised, that "it is difficult for mentor teachers to have a sense of self-efficacy if they do not have a clear sense of their roles and responsibilities." [13]

2 METHODOLOGY

2.1 Data collection

At Tampere University of Technology teacher mentoring programme started in the autumn of 2016. Each first year student was appointed a personal teacher mentor and each teacher mentor was guiding a group of about ten students. As part of this new procedure, a survey was implemented to map out mentors' attitudes towards mentoring. The same survey was conducted also in the spring of 2017 to find out if teacher mentors' attitudes and opinions concerning mentoring were changed.

In the first round, in autumn 2016, 52 teacher mentors out of 117 responded the survey. In spring 2017, 31 teacher mentors responded to the survey. The rate of experienced and non-experienced teacher mentors were at same level in both surveys which means that the results are comparable in the frame of this research. The response rate was higher than expected, especially in the first round, but naturally, lacking responses from half of the mentors needs to be acknowledged in the interpretation of the results.

The survey comprised of 8 multiple choice questions and 6 open questions and was very quick to complete. Multiple choice questions offer comparable information on attitudes and open questions deepen the understanding of the results. In both questionnaires, most of the respondents also answered all open questions even if they were not compulsory.

Data was also collected in two open discussion meetings in which teacher mentors met each other and exchanged their experiences. The first meeting was organised in mid-December and the second at the end of March. In these meetings teacher mentors discussed various topics, also the same matters what were covered in survey but in more detail.

2.2 Background information

As background information, teacher mentors were asked if they had had a role as a teacher mentor before, how many students they had in their mentoring group and if they attended any training concentrating on mentoring previously. In both surveys, the ratio between experienced and non-experienced mentors was nearly the same as seen in figure 1.

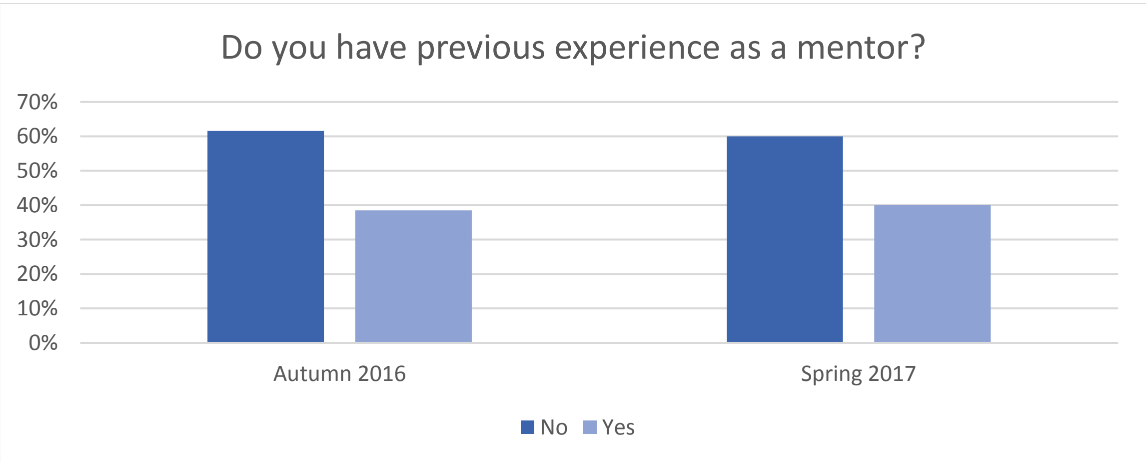

Fig 1. Ratio between experienced and non-experienced mentors.

The ratio between trained teacher mentors and non-trained teacher mentors did not change significantly either between two studies as seen in figure 2.

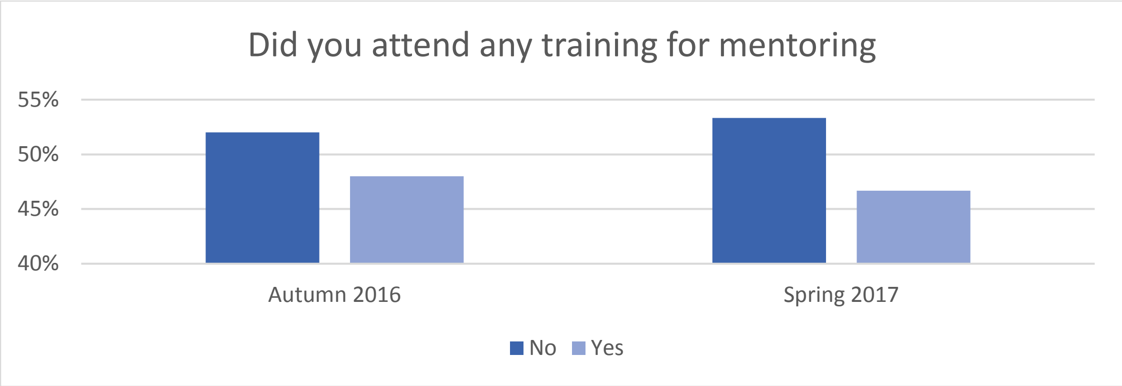

Fig 2. Ratio between trained mentors and non-trained mentors.

As the ratios remain nearly the same in both surveys, it is possible to draw conclusions on the attitude changes of teacher mentors.

3 RESULTS AND CONCLUSIONS

3.1 Teacher mentors' expectations and their experiences

One main aim of the questionnaire was to clarify the expectations and attitudes of teacher mentors to understand better how to support them better in their new role. Teacher mentors were asked to evaluate their self-efficacy, i.e. their skills in interacting with students, guiding studies of the students, supporting professional growth of students, guiding a small group and guiding students to other services. They evaluated their skills on a scale from very poor (1) to very good (4).

In Fig. 3 it is seen that teachers' opinions on how they manage specific skills related to mentoring are not very high, and the opinions do not change significantly after mentoring for one year. In Fig. 4 it is seen that the averages of teachers' self-efficacy towards these skills stayed nearly at the same level when comparing autumn to spring.

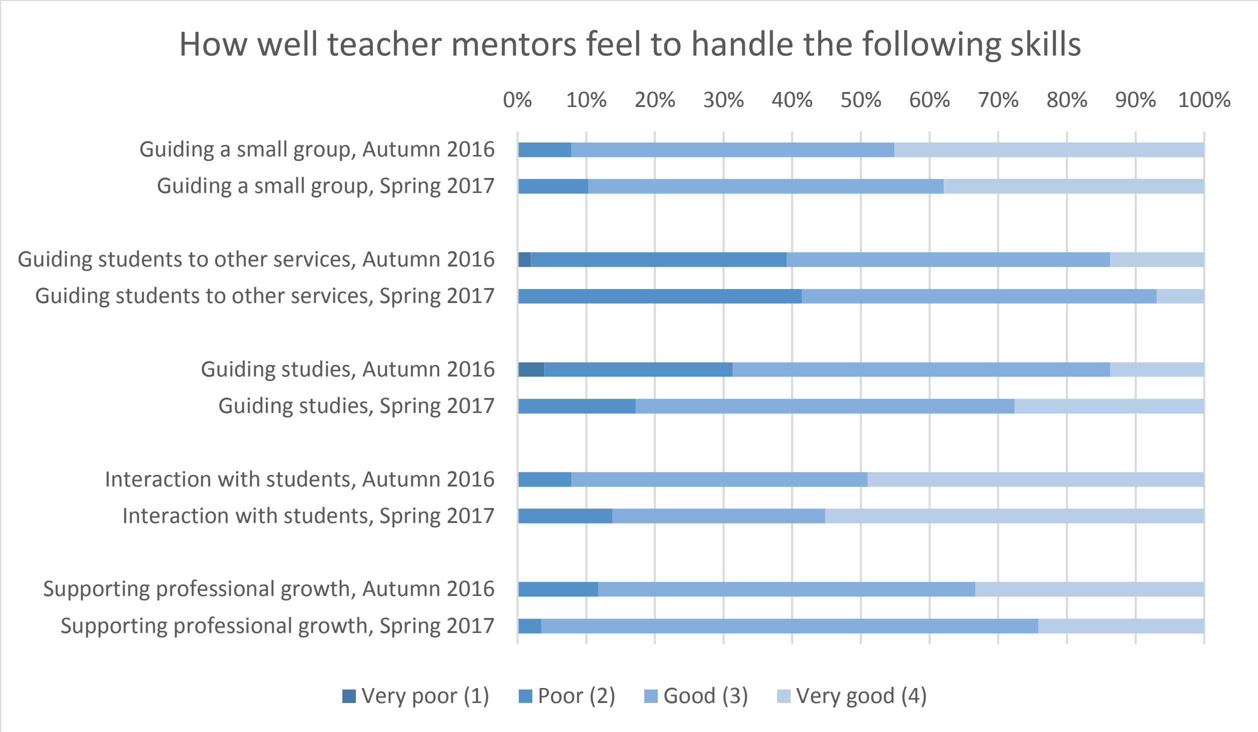

Fig.3 How well teacher mentors manage skills in their own opinion

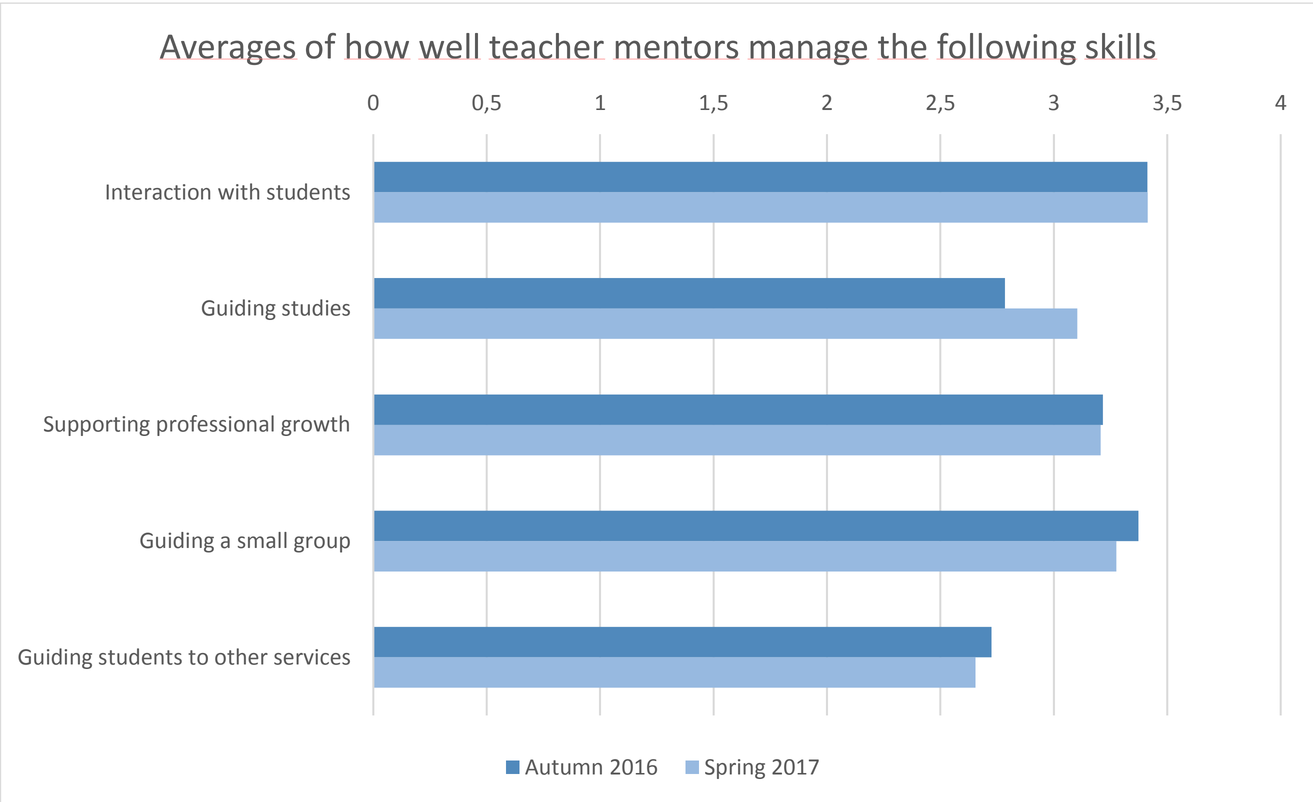

Fig 4. How well teachers' manage the skills in their own opinion

In Fig. 5 it is seen that teachers think very highly of mentoring programme in autumn before the programme was started. They have high expectations towards mentoring and they think that students benefit from the programme. However, after mentoring the students for one academic year, their expectations are lowered and they don't think that students benefit from mentoring that much.

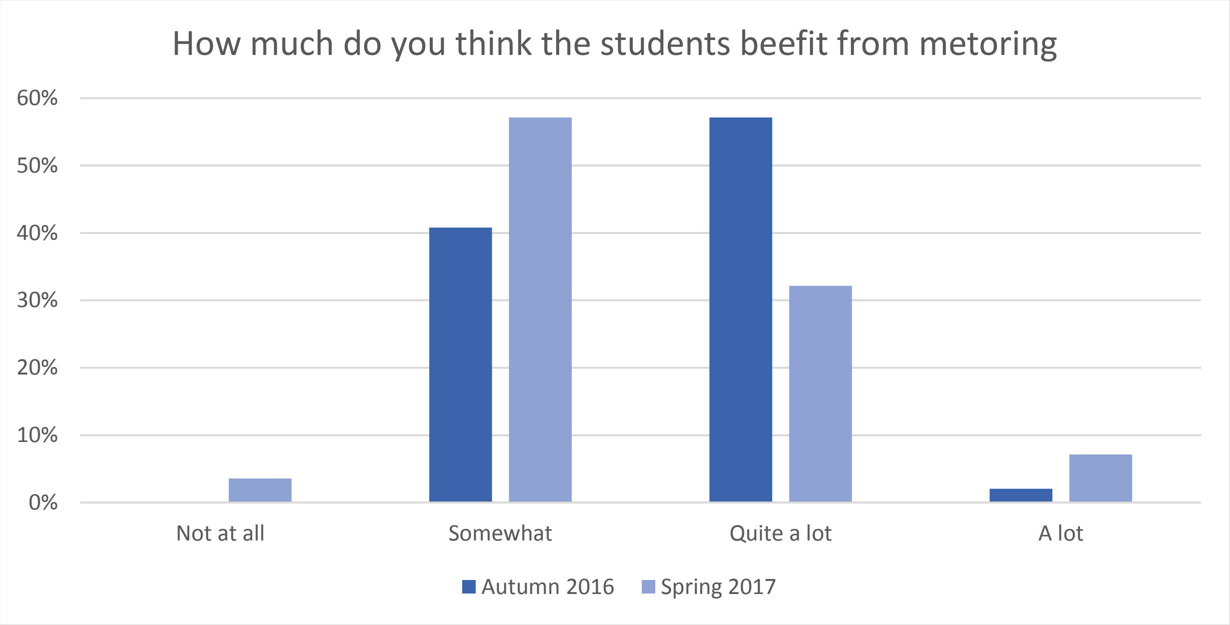

Fig 5. How much do you think students benefit from mentoring

In open answers the same trend was seen. Mentors' though that in general mentoring programme met their expectations but they do not think that students benefit from the programme. Many mentors also had an idea to give students a direction in their professional growth and this expectation was less often met.

In Table 1 the most common expectations, skills that need developing and challenges in mentoring are listed. These were collected from teacher mentors' open answers. In general the expectations were well met and the challenges and improvements of skills did not vary greatly. Lack of time, scheduling meetings and engaging students were seen challenging before and after a year as a mentor.

Expectations towards mentoring

Autumn 2016	**Spring 2017**
Get to know the students and learn to understand their world	Met the expectations well in general
Give help and direction in professional growth	Engaging students from the beginning was more difficult than expected
Create a solid base and a good start to studies and	The time needed in mentoring was more than expected
No big expectations	

Challenges

Autumn 2016	**Spring 2017**
Lack of time	Scheduling
Scheduling	Activate students to participate
Activating the students	Make students to understand the benefits of the mentoring programme
Activate students to participate	
Make students to understand the benefits of the mentoring programme	

Skills that need improving

Autumn 2016	**Spring 2017**
Guiding students in their studies	Guiding a small group
What topics to cover in the meetings	The topics covered in meetings and the role of the mentor
How to help the professional growth	How to get students to participate more actively

Table 1. Expectations, needs of improvement and challenges of mentoring

The most common expectation that was not met, was the help in the professional growth of the students. However, it seems that teacher mentors had quite different ideas on teacher mentors' roles and therefore also expectations on the help in the professional growth they can facilitate. This is most likely linked to the fact that the beliefs of the benefits of mentoring programme have decreased during the academic year.

As previous research has shown, one problem may be due to the vague role of the mentors and unclear distribution of responsibilities with academic advisors [2]. Thus a clearer role as a mentor and more structured forms of mentoring could enhance mentor's beliefs to one's own skills. It can be asked how the organisation can support to build structures and also affect the mentor's motivational factors.

In general, as seen in the previous research and experiences based on this research, the mentoring is beneficial to both students and the teacher mentors. The problem that lies in the lowered expectations of mentoring in this research may rise from the fact that the benefits are not seen immeadiately and in recently started mentoring programme these benefits have not realised yet. Despite the lowered expectations, the mentoring programme is seen as a positive action at Tampere University of Technology.

The teachers' motivation and self-efficacy could be increased by social support and reinforcement. It is already known [6] that if faculty members think that they are adequately prepared to advise students, their levels of self-efficacy increase and the mentors feels more comfortable in their role.

Also previous experience has an influence on person's self-efficational beliefs. The results show that some mentors did not feel secure about their role after the academic year – the experiences, either positive or negative, would be vital to debate and process so that learning could be elicited and the structures for the next year could be seen more explicit from the perspective of single mentor.

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Education of Innovation and creativity thinking on Industry 4.0 course and project

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ABSTRACT

A curriculum was developed to introduce fundamental knowledge of Industry 4.0 to students. It includes lectures of all elements in Industry 4.0, such as Internet of Things (IoT), cyber-physical systems (CPS), big data, cloud computing and so on. In addition, students were required to finish projects associated with CPS. First, students had to watch MOOCs before lectures. For the project based learning, students should use Trello, an on-line project management system, to see messages, submit their assignments, and share their ideas. Students were teamed up at least three people before deciding the project topic. Furthermore, this curriculum integrates with creative thinking strategies, such as six thinking hats and brainstorming. When students conducted their projects, they can use creativity thinking taught in this lecture and ask for help from mentors from industry and lecturers. For instance, they visited a smart factory for mold injection and a motor factory. Students were required to write up proposals for the projects. A competition was held to let students present their CPS project products based on their creativity thinking. This curriculum successfully delivered Industry 4.0 knowledge to students by MOOCs and also applied creativity thinking strategies to students' project based learning.

Conference Key Areas: Curriculum Development, Engineering Education, Physics and Engineering Education

Keywords: creativity thinking learning, Industry 4.0, cyber-physical system, project based learning

INTRODUCTION

Industry 4.0 was proposed by Germany in 2013 for intelligent manufacturing and establishing smart factories. It is the future trend for manufacturing, so engineering students should know the concept of Industry 4.0 and the way to create smart factories in future. This study is mainly concerned with investigation of students' creativity and imagination for undertaking their own projects of Cyber-Physical System (CPS), the key role of Industry 4.0. We design a curriculum including project based learning (PBL) and lectures introducing fundamental knowledge of industry 4.0. Industry 4.0 is integrated with information and communication technology (ICT) data for manufacturing technology. CPS is a term that led to the advancement of Internet of Things implementations and also introduces cooperation among CPS elements, by integrating computational resources [1]. It is also a system that involves a high degree of complexity, temporal scales, and highly networked communications [2]. It has computational and physical components [2]. It is connected with internet and its users. The aim of Industry 4.0 is to utilize CPS to establish a smart factory.

The curriculum we designed has been conducting to promote student interest in the Science, Technology and Mathematics (STEM) fields. STEM education can be seen as a pipeline beginning in early education, extending through college [3]. Today, we have lots of PBL courses applied to CPS. For instance, the future applications of CPS use many elements, such as embedded systems, high speed network, cloud computing and big data technology [4]. This PBL course was motivated and designed by the Urban Information Systems [4].

Since Industry 4.0 is a new concept, there are rare examples to follow or to duplicate. Therefore, students needs to know the way to create various new CPS for a smart factory. In this curriculum, students not only learned fundamental knowledge about industry 4.0, but also needed to implement the project integrated with creative thinking strategy. Moreover, we used the creative thinking strategies, such as "Six Thinking Hat" [5] and "Brainstorming" [6]. We conducted those activities to cultivate their creativity. We had the quizzes for students to know if they understood the units or not in the end of each class.

1 CURRICULUM DEVELOPMENT

1.1 Intra-curricular

MOOCs was adopted to deliver fundamental knowledge of Industry 4.0 to students. Before the class started, students were required to watch MOOCs online videos in advance. Topics of MOOCs includes Internet of Things (IoT), cyber-physical systems (CPS), big data, cloud computing and so on. Lecturers addressed the knowledge what they learned in MOOCs during class. Quizzes were given to students for checking what they have learned and reviewed the contents in MOOCs. The on-line quiz system we used is called “Kahoot”, a platform of mobile learning. It can let students interact with teachers in the lecture room. This curriculum also invited many prestigious mentors from industry to lecture part of topics. Mentors not only shared their experiences, but also taught a lot of professional knowledge of Industry 4.0.

Furthermore, we used two creative thinking strategies that could help students think as they were doing their projects. The strategies used are “Six Thinking Hat” and “Brainstorming”. The reason for choosing two creative thinking strategies is because we can use brainstorming activities to help students work out the new idea for CPS, and use Six Thinking Hat to help students check out whether this idea is good or not. These two strategies might be both used in the activities. They can cultivate students’ creativity and imagination. The activities integrated with game based learning and team cooperation. Students needed to discuss with each other and wrote down their ideas in activities. We designed different topics so that we could train students to use those two strategies in those topics. Since students watched MOOCs videos in advance, they could discuss with one another and shared their thoughts every week in difference topic. When students used “Six Thinking Hat”, they often considered advantages and disadvantages on a topic. Moreover, students would use “Brainstorming” to solve questions. Figures 1 & 2 show the activity during lecture:

Fig. 1. Brainstorming activity.

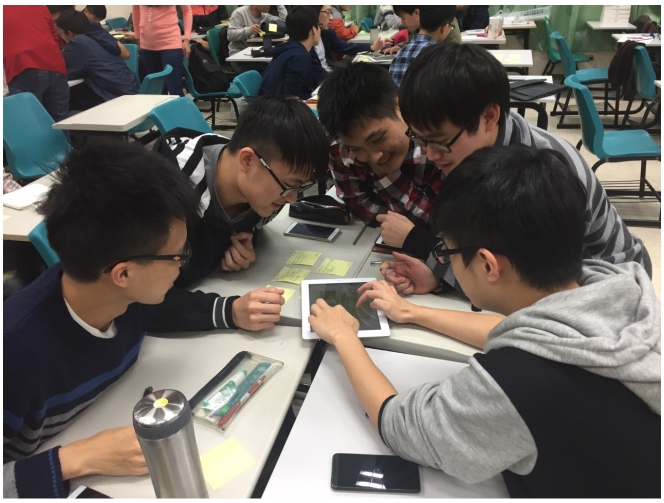

Fig. 2. Brainstorming activity.

The whole schedule of the curriculum is shown as following:

Table 1. Overview of the schedule of the course.

Week	Before class	In class	Project
1		Introduction	

Week	Before class	In class	Project
2			
3			
4		Embedded System & Brainstorming	Team up
5	MOOCs	Sensor & Brainstorming	Choose topics
6	A technical visit in companies		
7	MOOCs	Innovation and applications of IoT & Brainstorming	
8	MOOCs	CPS system & Six thinking hats	
9		Six thinking hats	Presentation of midterm report
10		Discussion	
11		Big data and cloud computing & Six thinking hats	
12		Project implementation	
13		Process automation and special processing	
14		Discussion	
15		Project implementation	
16		Project implementation	
17		Six thinking hats	
18	Presentation of final report		

Besides, we used the project management platform called "Trello" in PBL. Students could get information and post their homework on Trello *(Fig. 3)*. If students had any questions, they could post a message, and a lecturer would answer questions in the system. Trello is just like an interactive bulletin board. It can help students catch information in their group and share every files or pictures they want. It is a convenient platform piling up whole information we have.

Fig. 3. Trello- Industry 4.0.

1.2 Extra-curricular

We also organized industry visits in this curriculum, as shown in Fig. 4. It shows that students had technical tours in a moto company and the Industry 4.0 implementation center of our university and discussed with mentors. Before the visit, each team needed to list several questions they wanted to ask mentors. After arriving at the companies, mentors introduced the company or the center and offered tours around the factory of the company. According to the questions that students proposed, mentors explained one after another, sharing their experiences, so students can learn the details about whole the process through the visit.

Students visited a moto company and attended their lecture

Students visited the Industry 4.0 implementation center in our campus.

Fig. 4. Company visiting.

1.3 PBL

After understanding the knowledge of industry 4.0 and creativity thinking strategies, we expect students could use what we taught in their projects. In this curriculum, we cooperated with three companies. Each group had their topics and they could contact with their mentors from those three companies to report their progress regularly. Students were required to make midterm and final presentations. In the midterm presentation, students needed to write proposals and reported during lecture. The referees would give students a number of comments. The midterm proposal template is defined as following:

- Abstract
- Research Motivation
- Research Objectives
- Programme Design
- Experiment Equipment and Budget Planning
- Difficulty and Solution
- Teamwork
- Evaluation
- References.

Moreover, students finished projects, delivering presentations in final exam (Figs. 5 to 8). Figures 5 to 8 show students' CPS products, which include a smart storage machine, an Automatic Guided Vehicle (AGV), and a game bike. The smart storage machine included the device scanning QR Code and the motor deciding position of every item. The AGV is referred to Arduino as a control panel and uses an infrared sensor to follow the destination. The game bike is integrated with teaching strategy and game scene. According to these projects we just mentioned, they correspond with CPS and creativity thinking strategies.

Students must design the posters showing the characteristics about their CPS projects for oral presentation. In addition to the CPS projects, students also needed to write marketing proposals. It can help students understand how to sell their CPS products and know market requirements. The marketing proposal template is defined as following:

- Abstract
- SWOT Analysis
- Customer
- Product Introduction and Characteristics
- The Marketing Theory of 4Ps
- Conclusion.

Fig. 5. Smart storage machine

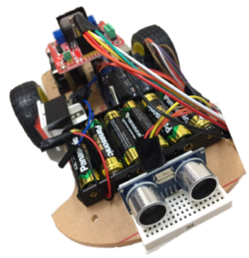

Fig. 6. Automatic Guided Vehicle

Fig. 7. Game bike

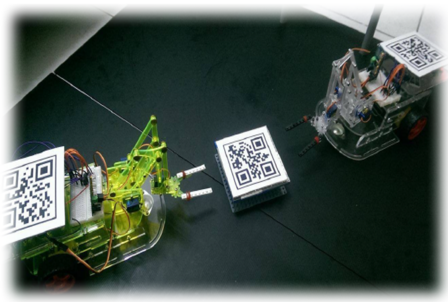

Fig. 8. Automatic Guided Vehicle (AGV)

According to the templates we mentioned, it benefits students for making products by themselves and learn how to use creativity thinking strategies to help them generate ideas.

2 EVALUATION

In this project, in order to know students' background, habits, and interests, pre-test and post-test were undertaken. Both questionnaire and interview were used in the tests. The result of questionnaire shows students' learning outcome, suggestion, and the level of understanding of the creativity thinking strategies in this curriculum.

Regarding the evaluation in this curriculum, we decided the grade criteria in midterm and final presentations. In the midterm presentation, we used five items to evaluate students' proposals. We invited two mentors to judge the proposals. In final exam, peer-evaluation was adopted. It is because students had the same experience and they knew what kind of project would be the best and useful. Furthermore, we gave students four different kinds of color stickers. They could put the stickers to four zones of a poster, which they thought is the best part of the projects. The four zones that are called creativity, presentation, technique, and potential. It is shown on table 2:

Table 2. Evaluation between Midterm and Final Exam

Evaluation in Midterm	Evaluation in Final
Logic	creativity
Technique	presentation
Curiosity	technique
Feasibility	potential
Application of CPS	Development in the future

Figures 9 shows students' final poster presentation. Results and discussion are reported in other papers in this session.

Fig. 9. Poster Presentation

3 CONCLUSIONS

This curriculum includes a variety of learning elements, such as MOOCs, creativity thinking strategies, lectures, project based learning, etc. This paper shows the results of students' projects and various interactive course developments. According to the curriculum we just mentioned, this proposed curriculum can cultivate students' imagination and creativity. Students could learn lots of knowledge about industry 4.0 in this curriculum. We also designed the creativity activity so that it could inspire students' curiosity and imagination. This developed curriculum successfully delivered knowledge of industry 4.0 to students and also opportunities to implement a CPS project based on creativity thinking.

4 ACKNOWLEDGEMENTS

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Engineering curriculum development

Socialization, soft skills and professional identity construction

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ABSTRACT

Since October 2015, CESI's school of engineering has implemented a project-based learning curriculum in its combined work-studies engineering programme. A previous research study, led by CESI's Education Science Laboratory, showed that before this curricular shift, CESI's engineering apprentices developed their professional identity mainly through projects carried out during in-company periods. With this new study, we wished to analyse the impact of the new learning environment on students' professional identity formation. Could the new curriculum enhance their professional identification and sense of becoming during school periods?

We first set up indicators to assess the impact of the curriculum on professional identity development, and conducted both quantitative and qualitative surveys. Our enquiries showed the following results: the key roles of group work, as well as tutors and students themselves in the setting of professional rules in the classroom so that school projects could act as boosters to their self-recognition as novice professionals. The opportunities given to develop self-directedness and metacognitive skills appeared as other key elements in the development of a sense of "becoming" at school. The question of expertise or the prominence of soft skills as pillars to their identity also emerged as a central issue in their development.

Conference Key Areas: Engineering Skills; Curriculum Development; Engineering Education Research

Keywords: Project-based learning; Professional identity formation; engineering skills development; soft skills

INTODUCTION

CESI is a multi-centre French graduate school of engineering, originally created in 1958 as a Continuing Education School of Engineering. It pioneered introducing apprenticeship for higher education, and now about nine hundred freshmen students each year enrol in its combined work-studies engineering programme, in thirteen cities all over France. This three-year combined work and study degree in Engineering, accessible after two years of scientific or technical higher education, leads to the equivalent of a Master in engineering. Since October 2015, and after two years of instructional design by a team of lecturers and course designers, CESI has implemented a project-based learning curriculum in this degree. In the new curriculum, students work in teams of five to six, and carry out multidisciplinary two-to-five week projects, in collaborative learning spaces. Each team has its own space with networked laptops, their own screen and a whiteboard, and five to six teams work in the same room. Lecturers seldom get to lecture anymore and are now labelled *tutors*: they guide the teams, set milestones, and can circulate amongst learning spaces and work with individual students as well as teams. Classrooms are adjacent to *Fablabs*, where students can experiment hands-on learning. This PBL curriculum was designed to be closer to professional practice and prepare future engineers to work in teams and communicate with ease, be adaptive, play a bigger role in their own training. It was intended to reduce the gap between the knowledge they acquire in their engineering school education and their actual in-company role.

1 RESEARCH QUESTION

A previous research study[1], led by CESI's Education Research Laboratory, showed that before this curricular evolution, the professional identity construction of CESI's engineering apprentices occurred mainly during key projects in their companies. Indeed, they were asked to identify turning points in their curriculum that influenced their transition from students to engineers. The 48 students who took part to this previous study pinpointed in-company projects as key moments where they developed project management and teamwork skills, as well as the confidence to label themselves "engineers", thanks to the recognition of their skills by their tutors and peers.

Through this research project, we wish to study the impact of the curricular shift and new learning environment on student's professional identity formation: can the new curriculum, thanks to its teamwork and PBL focus, enhance professional identification and sense of becoming at school? To what extent and through which specific media?

2 SUPPORTING LITERATURE

2.1 Professional identity

Professional identity is an ongoing, iterative, process that is influenced by social interactions, work or training environments, and personal identity [2]. This social "becoming" [3] is related not only to the development of work skills, but also to the development of a sense of belonging, and the recognition, by learners, peers and supervisors, of the learners' abilities and legitimacy. It then implies interactions, and sometimes tensions between a provisional self [3] -a self-projection of one's ideal identity-, one's work representations, and a social, prescribed identity (other people's expectations). Our first mission was thus to determine which indicators could be used to "measure" the professional identity formation of these engineering students and could thus help assess the impact of the new curriculum and learning environment on this process.

2.2 Student dispositions, engineering skills and learning environment

Previous studies show that a training environment that wishes to foster a sense of "becoming" should allow students to experiment with practices and self-images [3] by developing self-reflexivity as well as interpersonal skills like communication. There also seems to have been a shift in industry expectations from expertise in a very specific discipline to more generic and transferable skills for future engineers: their jobs will require adaptive skills. In a professional context that is subjected to technological changes, they will need to be even more creative, innovative and able to deal with new forms of organizations [4]. Expertise, "mastery" as Scanlon calls it [3] is only a "momentary illusion", while soft skills are assets that companies wish our graduate engineers could develop during their studies. Hence learning how to learn, who you are and such concepts as collective thinking seem to be key interpersonal & self-management skills, i.e. "soft skills".

Soft skills are supposedly more developed by active learning than by traditional lectures [5]. However, in the process of professional identity formation, the type of pedagogy used in the programme is not the only element that has an impact on the students. Indeed, the actual interactions between these specific students' dispositions -i.e. their action patterns, their motivation, cognitive capacities, values, expectations- and the curricular environment are key. Indeed, students have their own ideas of how school should prepare them to become their "ideal selves" [6]; i.e. professional engineers, so they will engage in the process according to the experienced "value" of the programme related to their own expectations [7]. As Dahlgren puts it [8], "people impact education" as much as it impacts them.

2.3 Curricular shift and professional identity construction

The new curriculum was designed as a transition between school and company, aiming at integrating disciplinary and professional knowledge. Through team project work, problem-solving loops, and the project leader role to assume in turns, the curriculum designers wished students to practice being engineers at school, to rehearse their provisional selves. The aim of our study is to analyse how the students *actually* experience the curriculum. So does it really boost students' sense of becoming and confidence as future engineers? Does it allow them to practice critical reflection on their development? How does it consider their dispositions?

3 HYPOTHESES

Our first hypothesis is that students probably experience transition levers in this curriculum, but these levers might differ from what curriculum designers had intended, and even differ from one student to another. We want to enquire what these *actual* levers are.

The interrelations between learner dispositions and the curriculum also probably influence the impact of the curriculum on the learners' construction of their professional identities, so we want to enquire potential transitional profiles that may emerge and the main mutual influences between dispositions and curricular tools.

The curriculum should also be questioned as a lever to develop personal identity and learner identity as well as professional identity, as the three seem deeply interconnected, especially through the lens of "soft skills".

4 METHODOLOGY

4.1 Exploratory surveys

A preliminary study was conducted that consisted in an analysis of the curriculum referential, three interviews with the curriculum designers, and test interviews with two students and two tutors from the same CESI centre. This study aimed at four main goals:

- Understanding what the school expectations were in terms of their graduate engineers' skills;
- Understanding what the school expectations were in terms of the impacts of the curriculum on students;
- Starting to define measurement indicators of professional identity development of these engineering students and the impact of the curriculum on this development;
- Testing our interview guides

The data gathered during these different stages allowed us to define the following criteria, to assess the impact of the curriculum on professional identity formation:

- Internal indicators:
  - Student self-expression/identification to a role/position as an engineer;
  - Student self-confidence in engineering missions/ posture ;
  - Conscience of their acquisitions and self-reflexivity;
  - Developed self-directedness.
- External indicators :
  - Acquisition of key engineering skills: problem solving, team and project management, innovation and interpersonal skills (Skills deemed "key" by both students, tutors and designers according to the preliminary study).

4.2 Longitudinal studies

We combined two approaches to gather data to assess our criteria, define the curricular impact, and analyse evolutions and differences between centres, group tutors, specialities, and genders.

A quantitative approach, based on questionnaires to the 900 students in the curriculum, upon their arrival and on years two and three of the curriculum (year three starts in September 2017, so the survey is ongoing). This approach allowed us to gather data on the evolution of their projections as engineers, on their experience in the programme and the evolutions of their "becoming", as well as on the actual levers of development experienced, according to different variables related to environmental factors.

A qualitative approach based on interviews with 30 students and 10 tutors from 6 different learning centres, is used to study the interrelation between student dispositions and curricular impact on the students' transitions.

5 RESULTS

5.1 Key moments

So far, the results analysed take into account the students' experience after a year and a half (out of three) in the learning programme. Students mentioned, both in interviews and in questionnaires[1], the oral evaluations they take at the end of each project as very realistic rehearsals of their skills and postures as future engineers. These evaluations, often organised as role-plays, are reported by students to make them «feel like» engineers, and increase their self-confidence as future engineers. For students interviewed who mention previous difficulties with oral interaction and public speaking, these oral evaluations as well as constant group work in the projects

[1] When specifically asked about « what tools, methods, situations in the school learning programme make you feel like/act like an engineer?"

are qualified as having a positive impact not only on their professional life in the company, but on their personality and overall behaviour towards other people.

Group problem solving stages involving calculations, modelling and prototyping are also mentioned as key elements in the approach, as well as the iterative problem solving method, because students feel these are effective tools they can use in the company, and most of them already use them in their companies. When projects lead to the actual implementation of a solution or to the actual development of a product, students mention the impact on both their motivation and self-confidence. After a year and a half in this active learning environment, most students still consider the company as the main environment to foster their sense of "becoming" and still rate the value of the school programme according to which tools, methods etc. experienced at school they actually use in their companies. However, they are able to pinpoint what activities and tools in the curriculum are key to their development, and when asked about it, they can even mention the generic skills they feel they have developed thanks to this methodology: communication and organizational skills mostly.

5.2 Socialization

Socialization through interpersonal interactions is confirmed as a lever to boost self-confidence, as well as acquire knowledge and project management skills. For example, throughout the first year, students were asked[2] about their confidence in their ability to carry out and succeed in the current project, and their confidence in their group to carry out and succeed in the current project. When only 40% of the students said they felt rather or fully confident they could individually succeed in carrying out the second project, 50% said they were rather or fully confident they would succeed as a group. Then on project 4 -out of 6 each year-, 55% of the respondents mention being rather or fully confident they could individually succeed, and 65.5% being rather or fully confident they could succeed as a group (see *Figure 1*).

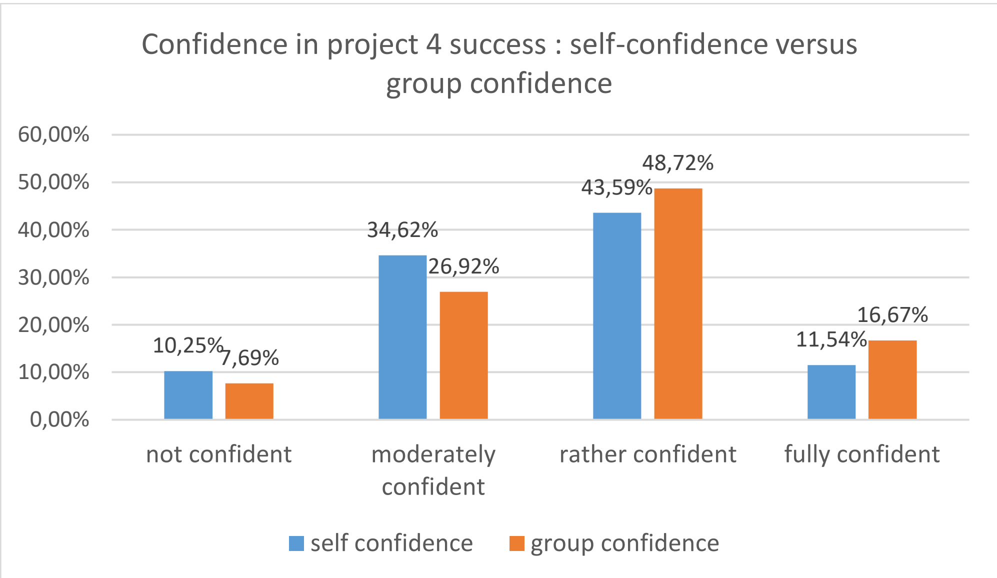

Fig. 1. Role of group work in confidence, example of project 4

[2] Questionnaire based survey sent to students from 6 different centres, on three different projects throughout the year, with an average of a hundred respondents.

This development of overall confidence needs to be compared to data from later projects, to see if the increased confidence is still developing or was only related to the subject of project 4, but what is constant in both surveys is the higher confidence rate as a group rather than as individuals. In interviews, students mention the group as a way to acquire knowledge, as well as a way to feel “secure”, which can explain the data collected in the questionnaire.

However, tensions do arise from group-work as well, and almost 20% of 2nd year students[3] mention “the group” as a difficulty, particularly when conflictual situations arise when not all group members share the same engagement in school projects. Both students and tutors evoke group work as a difficulty during interviews when one or several group members do not “play along” the project simulations. What is striking is that 32% of the second year apprentices who had had previous experience of in-company work did have trouble with group work at school, which is a lot higher than the average score. Students expressed that simulated projects at school were more difficult to engage in than “real” projects and that teamwork at school could be more difficult to handle than teamwork in the company. Working with trainees who are not their supervisors, can make it difficult for them to play along and actually lead a project and organize work. Trainees can judge this lack of actual hierarchy demotivating, or sometimes fear the judgement of their peers.

5.3 Expertise or soft skills?

Students, when they enter the programme, expect more from their company in terms of professional development than they expect from the school (see *Table 1*):

Table 1. Students’ expectations (start of the programme)[4]

Expectations	At school	In company
Develop professional skills	79%	90%
Be guided with professional project	45%	53%
Co-construction of professional identity through interactions	35%	58%
Gain scientific knowledge	72%	44%

What is striking is that the students that have high expectations in terms of scientific acquisitions towards the school are the students who express more dissatisfaction at the end of year 1. Whether they see the engineer as a scientific expert or as a multi-skilled project manager, students will engage accordingly in the curriculum because some think the school projects -that do not aim at scientific expertise- are not adequate to prepare them for their future jobs. Tutors can play a major role here in explaining the value of the soft skills developed, and explaining the learning theories behind the curriculum, and telling students what they can expect in terms of professional development. Results showed that with the guidance of tutors who

[3] 211 respondents, from 6 different centres in France, at the beginning of year two, when asked about their major difficulties at school during year 1. Several answers were possible.
[4] 533 respondents, from 9 different centres in France, at the beginning of year one when asked about their expectations from the school and from their company. Several answers were possible.

practice and encourage such reflexive processes, students are more engaged, and more satisfied with the curriculum.

6 CONCLUSIONS AND PERSPECTIVES

It seems so far that students' attitudes depend considerably on the tutors' roles and not only on the students' dispositions : whether tutors see themselves and position themselves as scientific experts or as guides for the students' professional development and show the links between school projects and students' missions in their companies, tutors can change the impact of the school curriculum. Tutoring and teaching are very different activities, requiring different skills so tutors need to adapt to the new curriculum as well. The key here is whether the value of the soft skills acquired is mentioned or not, whether the tutoring is helping students take a step back from technical and scientific acquisitions or not. Both tutors and students can act on the situation and decide to set professional rules in the classroom, and encourage professional engagement in the projects. Indeed, with the provisional results we gathered so far, we noticed the emergence of one transitional profile: students who are very engaged in the process, and who have more self-reflective abilities, who assign professional goals to the school projects and who use the group to develop their professional identity. These students happen to be older and have had two to five years of work experience as technicians before "going back to school". The majority of other apprentices do not (yet?) view the school periods as opportunities to learn their future job, but rather as a way to build their social network and personal identity. The students who do not have previous work experience, but still perceive what professional skills they can gain from school, are students who set achievement criteria for themselves, monitor their learning and try to relate school projects to company realities. Therefore, students' ability to manage their acquisitions according to their own goals and capacities and the opportunities that the very programme gives students to develop their self-directedness and other metacognitive skills is central. Professional identity formation can be described as the becoming of a self-reflexive individual, and for this to happen, every student's goal, expectations and experience should be made clear, discussed and explained. Our future enquiries will thus focus even more on tutoring and self-directedness development, to try to analyse how the curriculum can help students reflect on what type of professional engineers they wish to be and how school can help them do it.

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The effect of increasing Learner Autonomy in engineering laboratories for Foundation Year students

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ABSTRACT

This paper reports an improvement in depth of understanding and student engagement observed when autonomy in experimental design is introduced in mechanics labs compared with didactic labs. This improvement was seen both quantitatively (from short tests at the beginning and end of each lab) and reported in interviews with both students and teaching staff. This effect was noticed within a single 2-hour lab session for students on a foundation year in engineering. Self-generated identity codes were used to enable longitudinal tracking while preserving anonymity; this approach enabled quantitative data from nearly 100 students to be collected. Semi-structured interviews with 16 students and two lecturers provided qualitative feedback on the lab experience in both autonomous and didactic labs. In addition, we used the results of the quantitative data to study the effect of scheduling labs before or after the relevant theory had been covered in lectures; unsurprisingly, students undertaking the labs after the lecture were found to have a better understanding of the topic.

Conference Key Areas: Engineering Education Research, Curriculum Development, Attractiveness of Engineering Education

Keywords: Learner Autonomy, Laboratory Design, Student Engagement

INTRODUCTION

The educational benefit of enquiry-based experimental laboratories has been reported in many bioscience undergraduate degree programmes, e.g. biochemistry [1], physiology [2], biology [3] and chemistry [4]. This approach to practical laboratories encourages team-working as well giving experience in designing an experiment and understanding the limitations of the experimental approach. Many of the enquiry-based laboratories described in the literature are designed to be planned in one session and then performed and analysed in a few more. This obviously limits the number of experiments that can be undertaken each semester, We wished to see if some of the benefits of this approach could be achieved within a single lab session, through the introduction of limited amounts of autonomy in experimental design, while keeping the range of topics covered as large as possible.

This paper reports the results of a practice-based evaluation of the effect of introducing varying degrees of autonomy in laboratory design in the second semester of a foundation year programme in engineering. Such programmes have been running in the United Kingdom for over 30 years, and offer an opportunity for students with a wide range of non-standard entry qualifications to acquire the necessary level of mathematical and physics knowledge to progress successfully onto an engineering undergraduate degree. They are a key strand of the Widening Participation agenda, and attract students with wide-ranging amounts of prior knowledge and ability. In the foundation year programme reported here, there is an Engineering Investigations module that contains 12 two-hour mechanical engineering laboratories, six undertaken in the first semester of study, and six in the second semester. Students undertake these laboratories working in groups of 2-4 with each lab session having up to 6 different experiments running simultaneously supported by two academics.

A small-scale study in 2015-2016 on the effect of time gap between a topic being introduced in lectures and reinforced in laboratory experiments suggested that the optimum time to schedule the laboratory is two weeks after the relevant lecture. [5]. In that study, a few more able students reported that the traditional lab experience, following very prescriptive instructions, did not encourage them to think deeply about what they were doing.

Accordingly, it was decided to explore the effect of giving some freedom in experimental methodology. The didactic lab sheets in the first semester were retained for two reasons: to enable students to make a comparison between the two approaches, and to reduce the possibility of students becoming overwhelmed by the many changes they experience during the transition to university life and study. In the second semester, varied degrees of autonomy in methodology (given constraints of equipment and time) were incorporated into the experiments.

Autonomy enables students to learn to make their own viable decisions [6] as well as developing graduates with independent mindsets and resilience, two key skills required of professional engineers. As this cohort of students were at the start of their university studies, and taking the findings of Wielenga-Meijer et al [7] into account, only partial autonomy was introduced in the second semester. The intention was that some of the motivational aspects involved with the concept of autonomy, such as the perception of control, competence and confidence in their academic capacity [8] would be experienced by the students.

1 METHODOLOGY

To understand the effect of the introduction of some autonomy on the depth of learning achieved by undertaking the laboratories, quantitative evaluation was used to gain a statistically valid answer. In addition, semi-structured interviews with volunteers (both students and lecturers) were carried out to gain a greater richness of feedback on the project. Each student undertaking the Engineering Investigations module was asked if they would volunteer to participate in the research, and about two thirds did so using self-generated identity (SGID) codes [9] to preserve anonymity and enable longitudinal studies at a later date. For this set of 100 students (49 in semester 1 and 51 in semester 2), four questions generating an 8 character alphanumeric SGID code were found to be sufficient for unique codes to be generated for all participants.

1.1 Quantitative evaluation

For each of the 12 laboratories, six multiple choice questions (MCQ) were devised to test student understanding. Three questions were undertaken at the beginning of the laboratory, and three at the end. Each test was designed to take no more than 5 minutes within the 2 hour laboratory session. Each test was structured to give one easy, one medium and one searching question, and the “before” tests were deliberately made easier than the “after” tests so as not to discourage students before they undertook the laboratory. No students were given the answers to the tests, nor informed how well they had done. Statistical analysis was undertaken only on results when a student had taken both the “before” and the “after” MCQ tests.

1.2 Qualitative evaluation

Semi-structured interviews were held with a total of 16 students after they had completed all 12 laboratories. Both lecturers teaching on the laboratories were also interviewed for their observations on how effectively students engaged with the experiments.

1.3 Introducing autonomy to the semester 2 laboratories

Each laboratory in the second semester was reviewed to identify how to introduce some autonomy without significantly re-designing the experiments and the apparatus. For some experiments, it was difficult to give much freedom in design in a 2 hour laboratory (for example, in an experiment to determine the specific heat capacity of aluminium, copper and lead, the metal specimens were already made, and the only readily variable parameter was the amount of water placed in the calorimeter). For other experiments, students could select apparatus from a range given, decide which (and how many) readings to take, and determine a suitable method of data analysis.

Five of the laboratories each semester were marked in session, and for these, the mark scheme in semester 2 was adjusted to include marks for experimental design. In addition, the students were required to complete an error table listing possible sources of error, the nature of the error (systematic or random) and the effect of the error on the accuracy and/or precision of the result of the experiment.

The other two laboratories are written up as full reports, one each semester. Again, the mark scheme for the report in semester 2 included marks for experimental design and detailed error analysis.

2 RESULTS AND DISCUSSION

2.1 Statistical Analysis

IBM SPSS (statistical package for social sciences) software was used to analyse the results of the MCQ tests using the Linear Mixed Models method. With only three questions in each test, the maximum that a student could score was 3 and the minimum was 0. We defined the Difference in achievement as the “before” score minus the “after” score; thus a greater increase in understanding by the student is represented by a lower Difference value.

The average results of the tests taken in each semester are given in *Table 1*. On average, students scored higher in the "after" tests in semester 2, and showed a greater improvement in understanding of the topic.

Table 1. Average value of test scores in each semester

	Average of "after" scores	Average of Difference score
Semester 1 (labs 1-6)	1.98	0.507
Semester 2 (labs 7-12)	2.21	0.342

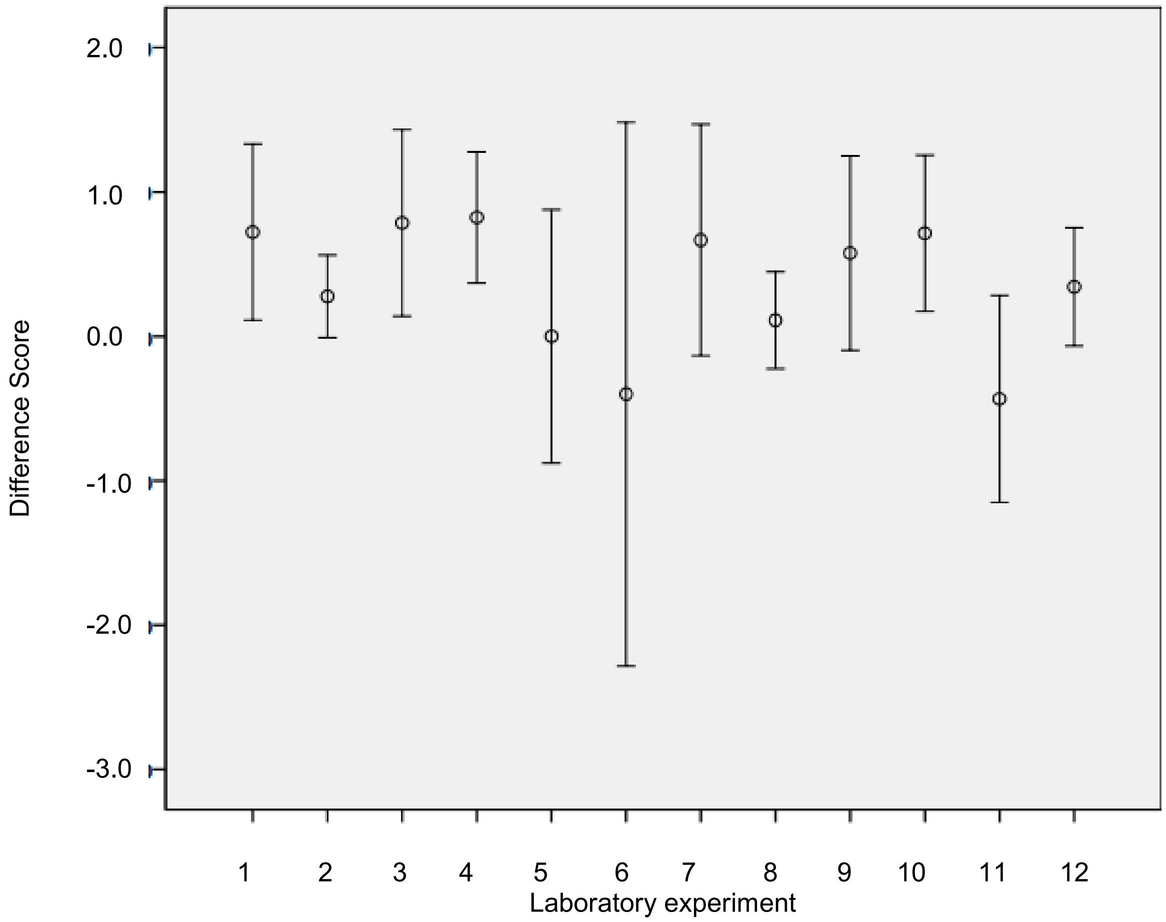

Fig. 1. Graph showing Difference score for each lab. The circle represents the mean score with the 95% confidence interval shown as a bar.

The individual results for each lab are plotted in *Fig.1.* Given that the "after" questions were deliberately more challenging, a Difference score of 0 still represents a greater depth of understanding after the laboratory. Task 6 in semester 1 was the only one undertaken before the relevant theory had been covered in lectures, and the students had little/no understanding of the topic before doing the lab. Therefore it is not surprising that students demonstrated an increase in understanding of the topic, albeit with a large 95% confidence interval. Of the labs undertaken in semester 2, lab 7 had the least degree of autonomy and lab 11 the greatest. The results suggest that increasing the amount of autonomy has increased the depth of student learning during the lab.

To confirm the previous findings of the impact of timing of lab and lecture, the date of each test was recorded and compared to the date the relevant theory was covered in a lecture. In order to obtain significant numbers of tests, the time interval was set either as Lab First (this included data where the lab and the lecture occurred in the same week) or as Lecture First. The results of the linear mixed models analysis confirms that students scored on average 1.06 marks higher in their tests (but not the Difference) for Lecture First.

2.2 Semi-structured Interviews

In total, 16 students completed short semi-structured interviews. Of these, 12 students preferred the style of the semester 2 labs.

I felt more challenged and engaged by semester 2" [student A]

"*I learned from it, rather than just copying it down from the sheet*" [student B]

"... prefer semester 2 more because it makes you think more and makes you learn" [student C]

"*Semester 2 makes you more independent and makes you think more*" [student D]

These responses confirm that the introduction of autonomy enhances students independent thought and their understanding of the theoretical knowledge, as reported by Deci et al. [8]

The design and justification of their experimental methodology in semester 2 required students to read the lab sheet thoroughly before starting the experiment. In semester 1, it was possible to complete the lab with only limited understanding of the underlying theory. This was noticed by some of the students: "*In semester 2 (I) couldn't have started without reading the full lab sheet...in semester 1 no deep understanding was there and made you more prone to mistakes*" [student D] and *"(I) learned to read the lab sheets beforehand"* [student E].

Comments from the 3 students who preferred the didactic labs in semester 1 included:

"You are worrying more about the experiment rather than learning...I prefer to take in the results and theory better after the experiment [student F] and

"You have to think more" [student G].

These comments confirm the findings of Fakayode [4], where the students with a more negative view of increased autonomy did so because of the increased demands on the students' time and intellectual resources.

Students with a positive view of the labs in semester 2 reported increased self-confidence and felt ready to move on to undergraduate study.

When asked about the use of SGID codes, 14 of the 16 students said that they *"felt more comfortable"* attempting the MCQs without revealing their identity. Only two students said they were happy to reveal their identity.

Observations from the teaching staff included:

"Strong students are being pushed to think at a deeper level (in semester 2), which before they didn't really do" and *"Students are having more collaboration with their group members".* However, some of the students managed to stay only minimally engaged throughout the entire module and as one lecturer noted, *"It (autonomy) is not a panacea."*

3 CONCLUSIONS AND FURTHER WORK

The structured introduction of autonomy in engineering labs has been shown to increase depth of learning, with the majority of students rising to the challenge. Students reported feeling more prepared for their undergraduate degree studies. Those students who preferred the didactic lab sheets in semester 1 tended to do so because those labs were perceived as less demanding.

The confirmation that it is beneficial for students to have studied the theoretical basis of the experiment at least one week before the lab has implications for timetabling. For the Engineering Investigations module, it is not possible to achieve this, given constraints on equipment availability, cohort size and the academic calendar.

The results have been sufficiently encouraging that the labs will stay in this format for the next academic year, and the results for the 2017-18 cohort will be compared to the findings from 2016-17.

To fully evaluate the effect of "lab before lecture" versus "lab after lecture", next year we will determine students' understanding of each topic at the end of the semester as well as at the end of the lab. In addition, short videos of relevant theory and self-assessment questions will be developed for two tasks where the majority of the students will not have had the lecture first. These resources will be deployed on the virtual learning environment; engagement with the resources will be monitored and the effect of the additional resource on the efficacy of the labs in developing understanding of the topic will be studied.

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Emphasizing peer learning in a virtually flipped classroom

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ABSTRACT

Peer learning is a powerful learning resource used in many ways in modern education. At Aalborg University it plays an important part of the PBL concept used since 1974, most important in the Problem based Projects solved in groups, but also in courses where lectures is supported by assignments in groups facilitated by teachers.

Aalborg University also offers online part-time master programmes using the PBL principles transformed to online environments where face to interface replaces face to face and courses uses flipped lecture formats instead of transmission based lectures.

Participants in these programmes are often very motivated and they follow the flipped instructions and read the suggested material, but do they also use their study group and experience peer learning?

This question is investigated in this paper using one semester in the 2-year part-time programme: Master in Problem Based Learning in Engineering and Science.

Questions and assignments uploaded by participants is used to analyse the activity from the participants together with recordings from online sessions where teachers answer uploaded questions and calls for discussion with the participants. Questionnaires is used to collect data about how much the study groups are used and if peer learning happens.

Conference Key Areas: Curriculum Development, Open and Online Engineering Education, Engineering Education Research

Keywords: Peer Learning, online education, lifelong learning

INTRODUCTION

Aalborg UNESCO Centre for Problem Based Learning in Engineering Science and Sustainability offers a Master in Problem Based Learning in Engineering and Science programme (MPBL) [1].

It is a 2-year part-time online programme, equivalent to a one-year full-time study (60 ECTS credits), targeting faculty staff at institutions, which want to change to PBL, or faculty staff who are interested in learning more about PBL.

A driving force for the Aalborg Centre is the exemplary practice Aalborg University has for both PBL and integration of sustainability in engineering and science education.

Since 1974, Aalborg University has practiced PBL as the pedagogical learning methodology during the entire study period [2].

The MPBL programme is designed according to the PBL principles used at Aalborg University, being problem based and project organized. The participants work in teams with educational experiments designed to solve real-life educational problems, preferable located within their own teaching practice.

The programme is based on a combination of academic, problem-oriented and interdisciplinary approaches to teaching and learning. Teaching formats include but may not be limited to the following methods [3]:

- On-line lectures
- Web mediated project work
- On-line workshops
- Self-study and readings
- Web mediated exercises (individually and in groups)
- Facilitation feedback
- Self- and group reflection
- Individual portfolio work

This is a new version of the MPBL programme, refined from a previous programme that was running for the very first time more than 10 years ago, with the first batch of participants getting their degree at the SEFI conference in Aalborg 2008.

Starting up the new version in autumn 2014 the teaching staff was more experienced with online education and the courses was planned to use ideas from flipped learning. Both the participants and the teaching staff was very satisfied with the new version of the programme and claimed to have learned very much and gained a lot of knowledge from the discussions and interactions with the other participants and the involved educators.

It is well known that peer learning is an important learning resource in the PBL setting at Aalborg University [4] but it is not yet investigated if learning in the online MPBL programme is mostly individual or to what extent peer learning is used.

This paper investigates this issue, studying the second run of the new MPBL programme, starting in September 2016.

1 MPBL PROGRAMME

This section will explain the outline of the Master of Problem Based Learning programme.

1.1 Overview

The outline of the MPBL programme is shown in *Table 1.*

Table 1. MPBL programme [3]

Master in Problem Based Learning in Engineering and Science (MPBL)				
Course/Project	**Exam form**	**Assessment**	**Grading**	**ECTS**
Semester 1: Development of teaching competences (15 ECTS)				
Project: Teaching portfolio	Written	Internal	7 step scale	5
Course 1: Teaching and learning theories	Oral	Internal	Pass/fail	5
Course 2: Collaborative learning skills and scientific writing	Oral/written	Internal	Pass/fail	5

Semester 2: PBL models and principles (15 ECTS)				
Project: : Design and planning of a PBL semester	Oral	Internal	7 step scale	5
Course 1: PBL models and curriculum development	Written	Internal	7 step scale	5
Course 2: Facilitation skills and teaching methods for active learning	Oral/written	Internal	Pass/fail	5
Semester 3: Management of change and evaluation (15 ECTS)				
Project: Implementation of change	Oral	External	7 step scale	5
Course 1: Management of change to PBL	Written	Internal	7 step scale	5
Course 2: Research methods for educational evaluation	Oral/written	Internal	Pass/fail	5
Semester 4: Master's thesis project (15 ECTS)				
Project: Master's thesis	Oral	External	7 step scale	15
ECTS Total				**60**

The MPBL programme is a problem based learning programme, exemplary for its own contents and delivered as online distance education. A semester in the MPBL programme includes a problem based project and two courses, the main study activity being the project. *Figure 1* depicts the project as a boundary object for all other learning activities. In the project theory meets practice [1, study form].

Figure 1: The project is at the core in the MPBL programme [1, study form].

Learning activities supporting the project are: Facilitation; readings; discussions; peer learning; reflections; courses etc.

Each course have 5 sessions, each with a written instruction with readings and facilitating questions to be discusses in study groups of 2 or 3 persons. The participants can then poste questions and there is an online session where the teacher both answer the posted questions and opens for discussion and experience exchange with and among the participants.

1.2 Focus

Investigating the whole MPBL programme will take more than two years and require substantial resources. At this moment it is possible to look at the ongoing semester 2: PBL models and principles (15 ECTS). The semester consists of two online courses and a project, see *Table 1*. Focus for the investigation is peer learning, both in the teams and amongst the different teams during on-line sessions in the courses.

The project will not be finalised until after deadline of this paper, so it will not be a part of this study, but might be subject for further studies.

Course 1: PBL models and curriculum development, is a theoretical course, and the online sessions are intended for answering the posted questions and inviting for discussions. This can be supplemented by “lecturing” about details in the subject of the session.

Course 2: Facilitation skills and teaching methods for active learning, is a more practical (hands on) course, with focus on sharing of experiences amongst the participants. This is emphasized in the facilitating questions and small assignments for the study groups before the online session. Each session is then used to discuss the different answers to both questions and assignments in order to provide good possibilities for peer learning across the study groups.

2 METHOD

The 2nd semester has 8 participants working in 3 teams as study groups in the courses, discussing literature and facilitating questions and working together on eventual assignments before online sessions. All of the participants are motivated in improving their teaching and have already made several attempts to do that.

Both the answers to assignments, discussions and questions posted for discussion in each session is available on the semester page and is used for analyzing the input from the participants before the online sessions.

All the online sessions is recorded, making it possible to analyze how much the participants are active in discussions and sharing experiences.

Questionnaires, see *Tabel 2,* is used to investigate differences in learning possibilities and outcome in the two courses: how this is perceived by the participants and how they have used peer learning.

Tabel 2. Questions for each session as example

Did you use your study group for: (mark with a X)	No (0)	A Little (1)	Medium (2)	A Lot (3)
Discussing and understanding of the suggested readings				
Discussion of the facilitating questions				
Posting questions for the lecturer				
Doing the assignment				
Did you learn something from each other? (peer learning)				

Comments: ____

How will you assess the on-line session: (mark with a X)	No (0)	A Little(1)	Medium(2)	A Lot (3)
It was about answering the posted questions				
It was a lecture				
It was a discussion forum sharing knowledge and experiences				

What did you like the best of the on-line session:______________________________

____

Why:____

3 RESULTS

The results will be presented separately for each of the courses.

3.1 Course 1: PBL models and curriculum development

This is a theoretical course. The titles of the 5 sessions are:

1. PBL as an educational philosophy / PBL models
2. Curriculum Theories and Models
3. Field research and educational experiments
4. Assessment of learning outcomes within a PBL context
5. Project proposals to trigger the learning process

Analyses of posted questions and assignments

The first session is an introduction to PBL and the participants posted 5 questions that was answered by the teacher at the online session.

For session 2 there were only one question and zero for session 3 and 4. These three sessions was by far the most theoretical sessions and the teachers had to prepare slides for the online sessions based on what they thought would be interesting for the participants as supplement to the readings because there was no questions to answer.

The last session was a hands-on session with an assignment to make a project proposal in the study groups and present it at the online session. Two of the study groups made the assignment and presented it but due to misunderstandings the third group did not collaborate on the assignment and only one of the members uploaded an assignment. No questions was posted.

Analyses of recordings

Looking at the recordings from the online sessions it is clear that the teachers in the first 4 sessions had prepared many slides and used about 1 hour to explain the slides. The teachers was inviting the participants to comment and ask questions and the participants took the opportunity with app. half of them being active in each session. In the last session half an hour was used on presentation from the two groups that had answered the assignment. All of the group members took part in the presentation and other participants and the teacher was commenting and discussing the project proposals. The teacher had prepared a few slides based on the assignments and another half hour was used on presentation and discussion.

Analyses of questionnaires

The answers to the questionnaires reveals differences between the three study groups. The small group with 2 participants didn't use each other at all and didn't answer the questionnaire. The result from the other two groups is shown in *Table 3*.

Table 3. Results from questions about using the study group

Did you use your study group for: (mark with 0-3)	S 1	S 2	S 3	S 4	S 5
Discussing and understanding of the suggested readings	0-1	0-1	0-1	1-3	2-3
Discussion of the facilitating questions	1-2	0-1	0-1	0-1	2-3
Posting questions for the lecturer	1-2	0-1	0-1	0-1	2-3
Doing the assignment (only session 5 had group assignments)	0	0	0	0	2-3
Did you learn something from each other? (peer learning)	1-2	0-2	0-2	1-2	2-3

The results in *Table 3* shows that the activity in the study groups varies in the first 4 sessions and generally is marked at the lower end up to medium (2). In the last session the study groups were asked to collaborate on the assignment raising the level to medium (2) to a lot (3) in all questions.

The answers to the questions concerning the online sessions is shown in *Table 4* that like *Table 3* shows differences in the marking of the first 4 (theoretical) sessions and the last (hands-on) session. The last session is assessed higher than the others regarding answering the posted questions and sharing knowledge and experiences, and lower (No) in being a lecture.

Table 4. Results from questions about assessing the online sessions

How will you assess the on-line session: (mark with 0-3)	S 1	S 2	S 3	S 4	S 5
It was about answering the posted questions	2	0-1	0-1	0-1	3
It was a lecture	1-2	1-2	1-2	1-2	0
It was a discussion forum sharing knowledge and experiences	2	0-2	0-2	0-2	1-2

One of the participants had a general comment to the 2 last questions in *Table 2* for the 3 first sessions. What do you like the best about the online session: “The presentation and discussion forum”, Why: “The experience of the professor”.

I the last session the comments from the same participant was: What do you like the best about the online session: “The presentation of each group”, Why: “I liked the activity”.

These quotes indicates that in the theoretical sessions the experienced professor is important for the presentations and discussions, and when the participants is asked to use their own experience it is also highly valued as a learning resource.

3.1 Course 2: Facilitation skills and teaching methods for active learning

This is a practical (hands on) course. The titles of the 5 sessions are:

1. Reflection on teaching
2. Active learning – small class delivery
3. Active learning - in large and flipped classrooms
4. Facilitation roles
5. Facilitation skills - Maastricht tutoring

Analyses of posted questions and assignments

For the first 3 sessions 4 questions were posted and zero questions for the last 2 sessions. All of the sessions except session 5 used facilitating questions addressing the participant’s experiences as a teacher, to be discussed in the study groups and in session 1 and 2 this was supported by individual assignments on the same subject, and in session 4 there was a group based assignment.

The answers to the assignments was uploaded to the semester page, so everyone could read each other’s experiences. Most of the participants uploaded the assignments.

Analyses of recordings

The online sessions was prepared based on the questions and the answers to the assignments, that were often very usable to identify subjects for discussions. Like in course 1 the teacher used some time presenting the different slides, and called for comments and questions. The last part took up more time than in course 1 and there were more people participating actively.

Listening to the recordings it is very clear that all of the participants are experienced teachers and uses their knowledge and experience in the discussions.

Analyses of questionnaires

The answers to the questionnaires reveals the same differences between the three study groups as in course 1. The small group with 2 participants didn't use each other at all and only one answered the questionnaire. These answers is only used in *Table 6,* so only the result from the other two groups is shown in *Table 5*.

Table 5. Results from questions about using the study group

Did you use your study group for: (mark with 0-3)	S 1	S 2	S 3	S 4	S 5
Discussing and understanding of the suggested readings	2	2	0-1	0-2	0
Discussion of the facilitating questions	2	2	0-1	1-2	0
Posting questions for the lecturer	1-2	1-2	0	0-1	0
Doing the assignment (only session 5 had group assignments)	0	0	0	1-2	0
Did you learn something from each other? (peer learning)	2-3	1-2	0-1	1-2	0

The results in *Table 5* shows that the activity in the study groups is highest in the first 2 sessions. The last session had no readings and facilitating questions, so the study groups had no reason to collaborate. Peer learning was marked highest in session 1, where there was an individual assignment about teaching experiences that was uploaded for sharing with all participants.

The answers to the questions concerning the online sessions is shown in *Table 6* that shows higher marks for answering posted questions in the first 4 sessions than in course 1 (*Table 4*), probably because more questions was posted. The same 4 sessions was also marked lower as a lecture and app. the same as sharing knowledge and experiences. The last session is assessed low like in *Table 5*.

Table 6. Results from questions about assessing the online sessions

How will you assess the on-line session: (mark with 0-3)	S 1	S 2	S 3	S 4	S 5
It was about answering the posted questions	2-3	2-3	1-3	1-3	0-1
It was a lecture	0-1	0-1	0	0-2	0
It was a discussion forum sharing knowledge and experiences	1-2	1-2	1-2	1-2	0

There were similar comments to the first session about liking the activity and presentation done by the participants in the online session, as to the last session in course 1, and similar to session 1 to 3 in course 1 the professor's role was highlighted in session 4.

An interesting quote from session 2: What do you like the best about the online session: "The online session were based on feedback from the previous work done by each of us". This indicates that using the answers to assignments to highlight subject in the online sessions is highly valued.

4 DISCUSSION

The two courses investigated is the second semester of the MPBL education so the participants are familiar with the setup using instructions with facilitating questions and readings.

The results shows that the participants are motivated and experienced teachers that follow the instructions and do the readings. They do not post many questions for the online sessions, but the recordings shows that at least half of them are active in the discussions and participate on a level showing that they have studied the material. The number of both posted questions and active participants in the discussions was generally higher in course 2 (hands-on) than in course 1 (theoretical).

During the first 4 sessions in course 1 the active groups used each other mostly below medium, but the group assignment in session 5 called for more collaboration and improved the peer learning in the study groups.

In course 2 the activity and collaboration was a little higher in the first 4 sessions and very low in the last session being without the usual readings and facilitating questions.

As an average, the participants reported peer learning to happen at a level of 1,5 (between a little and medium) with session 5 in course 1 and session 1 in course 2 being the best rated at 2,5 (between medium and a lot). These two sessions was the most hands-on sessions, using the participants experience as teachers in the facilitating questions and the assignments to promote collaboration, experience exchange and peer learning.

5 CONCLUSION

This paper set out to investigate the use of peer learning in the second semester of a Master in Problem Based Learning Programme. Two courses was the focus, one being theoretical the other more practical (hands-on).

The participants was not very active to discuss the readings and facilitating questions in the beginning, and it took 3 sessions before they realized the potential and started using the study groups more actively. A group based assignment in session 5 of the first course promoted the collaboration and peer learning.

The second and more practical course called for exchanging of teaching experiences, using the facilitating questions and assignments in 4 sessions to set up the best possibilities for that. The outcome was more activity, both in the study groups and the online sessions.

In this investigation, it was possible to develop and use peer learning in online education, but the teachers had to promote it and the participants took a while to adjust to it. Assignments enhanced peer learning and it came easier in hands-on sessions where the participants own experience was used actively.

The Curriculum for the MPBL program is going to be updated during the next year and the results from this investigation will be used to make changes promoting peer learning. Plans for following up research on the coming MPBL educations will be made as a part of the updating procedure.

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Searching for a viable approach to project work in engineering education

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ABSTRACT

Many engineering departments across the world are moving towards implementing project-organised courses. In this paper we make the claim that there is a need for quality criteria for project work, given that research provides a mixed picture of what students can potentially learn in project work. The empirical data in this case study consists of ethnography, video-recordings, video-diaries and interviews, from one project work with four students taking a six weeks long course on machine elements. Our analysis shows that the students spend substantial amounts of time on activities with little or no value to their education, but that this is interspersed with very productive moments. In addition, our analysis showed that two of the students worked considerably less than the other two, but the assessment structure made this more or less invisible to the teacher. The analysis also illustrates the uneven nature of implementations of group work and we argue that as engineering educators we must implement approaches to project work that bring out and utilise the valuable

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parts, while actively suppressing less productive parts, thereby producing a shift towards being more ‘effective’.

Conference Key Areas: Engineering Education, Quality Assurance and Accreditation, Skills and Engineering Education

Keywords: project work, quality criteria

INTRODUCTION

Many engineering departments across the world are moving towards implementing project-organised courses with the aim of improving team-working skills and learning outcomes [1] and to better prepare students for professional practice where engineers generally work in teams [2]. There is broad (but uneven) support for different forms of cooperative learning within engineering education [3]. However, a more detailed understanding of in situ situations in engineering education of how students learn engineering collaboratively is needed. This is particularly pertinent as professional team work differ from project work within education where the main objective (in educational setting) is learning. Indeed, if students take a ‘professional approach’, which is to divide the workload efficiently and have a very strong focus on the end product, this may inhibit learning outcomes [4]. The purpose of this paper is to explore project work in engineering education, in order to contribute to criteria for quality of project work in relation to learning.

1 PROJECT WORK IN ENGINEERING EDUCATION

Project work as well as problem-based learning (PBL) became a part of international educational trends at many engineering institutions during the 1990s [5]. Kolmos points out [5] that *teamwork* is an integrated part of the concept of project work and is characterised by a number of phases: start, problem analysis, delimitation, problem solution, reporting and implementation. These are characteristics that are similar to structures in professional engineering team work. According to Kolmos this organisation of learning is based on the idea of teaching and learning as an *active* process of cognition, in contrast to traditional forms of education where students acquire knowledge. Furthermore, it is assumed that project work will lead to the development of social capabilities, such as team working skills, which are described as essential for the contemporary engineer [6].

Evidence of the effectiveness of active learning is vague, partly because the difficulty of defining what is being studied [3]. Prince’s review [3] of effectiveness of active learning shows the importance of student engagement and that a considerable amount of research support the core elements of active learning such as student activity in traditional lectures while self-directed learning has a slightly negative effect on academic achievement. According to Prince [3], the results of the effectiveness of PBL (as well as project work) may be misleading since the forms of PBL vary significantly. In addition, relevant learning outcomes are simply difficult to measure. A generally accepted finding is that project work and PBL produces positive student attitudes [3]. However, there is no significant improvement on student test scores when implementing long-term project-like learning situation, whereas the introduction of moments of student interactivity in traditional lectures is unambiguously supported by research [3].

So far reports of 'successful' implementations of particular setups of PBL and project work have dominated the field of engineering education research [7]. However, these reports usually have a focus on student attainment on a general level where a detailed understanding of in situ learning situations in the groups is neglected [8]. Kittleson and Southerland's qualitative study [4], which explored knowledge construction in a group of engineers, is an exception. They followed a group of six students taking the course Design of Complex Continuum Systems. A total of 20 lab sessions were video-recorded. The analysis focused on conceptual talk, which is talk that involves the underlying concepts for the task, and procedural talk, which is the mechanics of the task. Using an analytical framework based on Gee [9] they found that social factors such as status became prominent and, more noteworthy, that an *engineering discourse* that promoted efficiency rather than learning gained precedence, which made the group divide the work among them. They also noted, in line with previous research, that students involved in project-based work, even under the best conditions, tend to spend a great deal of time involved in the procedures and administration of the project, rather than the engineering content involved. To sum up, when students work together, a good end product does not necessarily mean that the students have had possibilities to learn [10], due to students' tendency to divide the work among themselves. In this paper we argue that a key to reaping the benefits of project work is to assure that the conditions for time spent on conceptual talk and procedural talk are optimised in order to not be subjugated by the engineering discourse of efficiency.

2 CONTEXT OF THE STUDY AND ANALYTICAL PROCESS

In this paper we present a case study of one project work. The project was part of a six week course within a Swedish three years long Engineering Mechanics Programme which involves the design, production, and operation of machinery. Empirical data was collected through systematic observations of lessons (14 h) and video-recordings (8 h) from this specific project work, complemented with video-diaries with the four participants (3*7 min/student) as well as individual interviews (45 min/student). The empirical material has been collected in accordance with the principles of informed consent and voluntary participation. The project instructions given to the students within this course were very open, focusing on constructing and building a four-bar linkage. Each participant was expected to spend 20 hour on the project although most of the other project teams in the class spent considerably more time. We have focused on a group of four students, Student A, Student B, Student C and Student D and we chose to focus on this particular group because of two reasons. First, since we did not intend to focus on hierarchal relationships in this study, we choose a group that consisted of four men with the same age and ethnicity, and was in that sense typical in its homogeneous construction. Secondly, the students in this group highlighted interesting shortcomings of their project work, and elaborated on how it could have been improved.

The analysis was carried out in three main steps. First, we created a descriptive overview of the ethnographic work and video diaries/interviews, with a focus on who was dis/engaged in which activities. Second, we traced the interviews looking for different narratives on a group-level with a focus on the students' individual attitudes [3] towards their learning process. Third, we made an analysis of our transcribed video-data where all four the students worked collaboratively together. Our analysis of the video-data was based on the premises that social action is always collectively achieved, that not only the person producing an action, but also that the other that are present are part of the accomplishment of a social action [11]. The main feature of video research is its possibility to capture detailed aspects of the students' talk together with small details of bodily conduct, embodied competencies and context [12]. Aware of that we analysed the production of meaning [13] through talk, the bodily behaviour of participants in relation to the material environment. The material environment here became surprisingly dominant in the students' interaction, which we will elaborate on later in our results. We searched for face to face interaction containing conceptual talk and procedural talk [4] as a criteria for quality of project work.

3 RESULTS

Our analysis of the ethnographic data and the video-recordings revealed that a considerable amount of time during the six weeks was spent on relatively mundane tasks. The first week the students were told to form smaller groups and for this particular group it took a several days to do this (in contrast to other groups in the classroom). The group also had problems deciding what to do; they talked about building a damper to a longboard or a clock for a few days, but agreed on that these ideas would be too difficult to implement. In the end of the first week Student A prepared a suggestion that they should build a prototype of a metal cutter and no one disagreed. Typical for the meetings during the first two weeks was that although they decided to meet at a certain time several participants turned up late, sometimes as much as ninety minutes late without notice, which Student A described with some frustration in his video-diary. After that they met and worked with building the prototype at least five times (three of these occasions were video-recorded), but only once during these occasions did all four students participate. The execution of practical work was generally without clear conceptual or practical challenges, disarray of conceptual terms and/or focused on considerations of minor importance from an engineering perspective. Notable in the data was that the Students C and Student D, did not participate or turned up very late on several occasions excusing themselves with sickness, tiredness or simply lack of interest. Student A became the spokesperson for the group, communicating with their teacher. Student B was there all the time and also arranged a meeting with a teacher from another engineering program in order to learn how to operate a laser cutter they needed to use later in the process. Student B also helped other projects in the course, using his expertise in welding.

In the students' video-diaries and their final interviews all four students gave different nuances to the story of this particular project work. Student A described (without specifications) some of the other students in the group as lazy 'with low level of ambition', but overall he found the project enjoyable, especially the moment where the laser cutter caught fire by accident. He also mentioned the moment where they all four got together as 'surprising but sort of fun'. Student B described the project work in even more positive terms: 'it is so fun and you learn a lot'. Student C and Student D were more negative when they talked about the project. Student C only talked positively about the one week he did participate. Still, Student C claimed that they should have divided the work between them even more, having less meetings in person, because that would have been more effective, according to him. Student D said several times in the data set that their project was very simple, and that they should have aimed higher. Something he mentioned as positive was the laser cutter, which was 'user-friendly and nice', although, as far as we know, he did not participate when they used this machine. None of them could be specific about what they learnt in this project, such as a scientific concept or deepened mathematical skills, although they were specifically asked to elaborate on this in the video-diaries and the interviews. When Student A was asked if they had calculated anything during the construction of the metal cutter prototype he answered ‘No, not really. Rather… I guess we have used logical thinking’.

Nevertheless, on a closer look in our video data we found clear examples of episodes where the students engaged in focused valuable interchanges. We present an example here from the one time when they all four worked together, which Student A referred to as ‘sort of fun’. In the video they sit in front of a computer screen working with a draft copy of the prototype of the metal cutter in a computer program:

1 A: The handle cover the knife and this link is on, is on **[*Fig. 1*]**
2 B: this is much easier to see on your mobile or in the workshop hall [Student A holds his mobile phone in front of the screen so they all can see it]
[…*Off-topic talk about if Student A is funny or not…*]
3 C: you can see it much better there, right [Student C refers to the picture on the phone]
4 A: the blades are the same
5 C: I did’nt think of that, more like, on this, how the blade is oriented in comparison **[*Fig. 2*]**,
6 A: OK, I was thinking of this **[*Fig. 3*]** if you start from here, if you start, it becomes, loop-sided. [Student A illustrates with hand gestures that he refers to vertical forces]

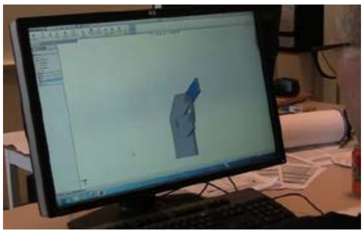

Fig. 1. Student A refers to their draft copy on the screen in in contrast to a real metal cutter.

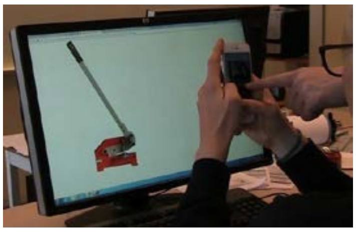

Fig. 2. Student C points at one of differences between their draft copy and the metal cutter in the workshop hall.

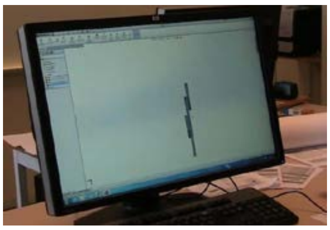

Fig. 3. Student A explains that he is interested in vertical forces by turning the draft copy around.

At a first glance this could be interpreted as that the students plainly pointing at different models without purpose or goal, but when analysing with a focus on how content is presented this transcript contains how Student A points out relevant vertical forces in their draft copy of the prototype in contrast to a real metal cutter (1), and he worries that their draft copy might be skewed (6). In other words, they work with a quite an advanced engineering problem: to use two different models, their own ‘drawing’ and a metal cutter in the workshop hall, and merge them into a prototype that will preferably not be lopsided. In order to do this they use several different pictures: their model which they can turn around, a picture from an ad and their own photographs on Student A’s mobile phone. The conversation continues:

7 C: this part goes down and this goes out, right, and this goes to the other side of the blade, haven’t you seen that. [Student A points at the screen]
8 A: eh… it has two drop arms, the original **[*Fig. 4*]**, because then it is like…
9 C: …that’s not what I meant, either
10 A: but you meant down here **[*Fig. 5*]**, it should only be…
11 C: it has two that have contact with the opening, it works completely

differently, so the forces go, it is fracking two-dimensional
12 A: exactly, it is a fork **[*Fig. 6*]**, it is more like a
13 B: what do you mean with fork?
14 A: that it cuts like scissors between [Student A points at his mobile phone]
15 B: between two like that
16 A: yes, exactly, and the blade goes down in the middle, that is how it is made, here, you can even see here [Student A points at the screen]
17 B: yes, that was what I meant, it goes down from the side like that

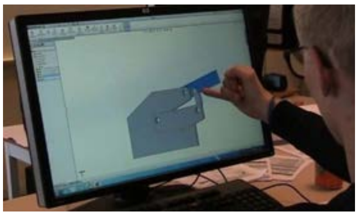

Fig. 4. Student A tries to explain what the real metal cutter looks like by pointing at the draft copy.

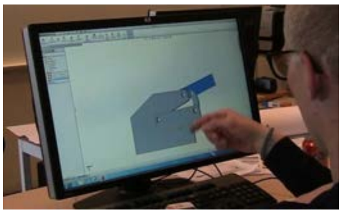

Fig. 5. Student A tries to verify if Student C refereed to the bottom part of the real metal cutter.

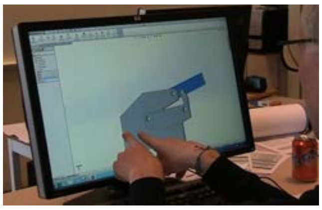

Fig. 6. Student A illustrate what he means with the word 'fork' by making a fork with his fingers.

In the beginning of this transcript Student C points out (again) that one of differences between their draft copy and the metal cutter is that the blade is situated differently in the picture of a real metal cutter (7). Then Student A and Student C start to struggle with understanding each other's description of the real metal cutter, and Student A tries to explain his understanding by pointing at their draft copy from different angels (8-11). When Student A introduce the word 'fork' (12) to describe the differences between the two models they can finally agree on how the forces work in the real metal cutter in order to refine their own draft copy to get the same capacity. Here several content- and task-specific concepts and themes were in play (although not explicitly articulated in words). The students showed tacit knowledge of geometrical understanding as well as skills of handling a problem in two and three dimensions. This discussion continued for one hour and among other things they discussed size and choice of material as they considered function, stability, the process of production, and aesthetics.

In summary, this case study illustrates a diversity that exists within the same project work. Most of the students' time spent in this project work comprised into mundane tasks where two students showed tendencies of skulking. However, as we illustrated above, all four students had a discussion that satisfied our criteria for quality of project work in that the students were using underlying concepts for the task in their conversation [4]. Despite occasional use of swearwords, the students also created an atmosphere where everyone contributed to the discussion where the students showed their capability to draw on their engineering knowledge for disciplinary relevant considerations, and negotiate on what is appropriate and understandable for them, individually and as a group.

4 CONCLUSION AND RECOMMENDATIONS

Although it was easy for us (being there and having access to the video-data) to recognise the physical and cognitive absence of Student C and Student D, this may have been difficult for the teacher – both these students positioned the group as low-achieving and thus gave the impression of themselves as aiming for much more. The video data also revealed other aspects of project work and learning possibilities than the interviews, partly because the students were not capable to articulate their learning processes. A variety of empirical data and a detailed understanding of in situ learning situations is necessary to capture the complexity of project work. In the engineering profession knowledge production balance on the border between the conceptual and practical, and often as in this situation encapsulated in project accomplishments. It is thus something inherently difficult to be articulated about and not necessarily readily recognisable for teachers, students, or researchers.

The conclusion points to the uneven nature of implementations of group work, and thus a mixed picture of what the students may learn. The students illustrated a capability to draw on their engineering knowledge, but their skills in articulating this knowledge was at the same time on a low level. This indicate that they would benefit from more practice in talking about underlying concepts related to the task in an engineering context [14]. There are prominent examples of moments where the group put their knowledge into action and develop their collaborative capabilities, which stretches their repertoire of possible expressions of engineering knowledge. This is consistent with much published research on group work, which often includes insightful moments from group discussions in specific groups [7]. Our results show that quite a lot of the time spent is on activities that are more or less pointless for their education, and that this co-exists with very productive moments. Thus, value of implementing group work has a value in and of itself must be questioned, which is in line with that research on more general implementation of group work seldom shows consistently good results [3]. As engineering educators we must implement approaches to project work that bring out and utilise the valuable parts, while actively suppressing less productive parts, thereby producing a shift towards being more ‘effective’. Thus, it may be argued that the implementation of group work is not a search for the ultimate solution, but a question of systematically being able to identify and enhance the parts that presents a potential for quality learning, while removing or suppressing the parts which does not contribute very much to the students’ learning process.

5 ACKNOWLEDGEMENTS

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How Student Generated Peer-assessment Rubrics use Affective Criteria to Evaluate Teamwork

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ABSTRACT

Student generated rubrics that were designed to peer assess contribution to teamwork mainly use terms that conform to Krathwohl's (1964) affective domain. We have used the affective domain to map the criteria that students use in order to find opportunities to further guide our development and scaffolding of teamwork skills. We are confident that our students are valuing skills within the affective domain as an important contribution to teamwork, but we find that they are making tacit assumptions about the lowest level of the domain – receiving skills. We aim to use this data to support the conscious development of receiving skills, with the aim of promoting team integration.

Conference Key Areas: Engineering Education Research, Engineering Skills, Engineering and Sustainability

Keywords: Professional Skills, Teamwork, Affective domain, Peer-assessment

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1 INTRODUCTION

The Integrated Engineering Programme (IEP) at UCL brings undergraduates together from seven disciplines, largely through problem-based and project-based learning activities (PBL and PjBL). Its main purpose is to provide authentic learning opportunities that support the development of professional and design skills. The programme is just about to enter its fourth year. Like many of the reforms currently in progress in Engineering Education its most distinctive feature is its high proportion of experiential, problem-based learning (PBL), almost all of which requires students to work in teams.

Working in teams provides students with professional (aka: soft) skills as well as conceptual knowledge by giving them the opportunity to apply their technical knowledge to a problem and to enhance their learning experience through collaboration. Numerous studies have described benefits of the cooperative or collaborative experience, which can boost achievement of grades, depth of learning, retention of information as well as enhancing a range of professional skills [2,3].

These benefits are not guaranteed however. In general, PBL learning outcomes are dependent on careful scaffolding and framing of the learning experience. Some authors have pointed out that knowledge learned through PBL may remain unstructured since learning is largely self-regulated and self-directed [4].

Our specific aim is to support the development of a range of professional skills that are sought after by the engineering professions [5]. In order to do so, we need to provide students with a framework to structure their learning and development of teamwork skills as well as their technical knowledge.

In order to achieve this, we have introduced two structuring components to the curriculum of our first year, first term undergraduate PBL module called 'The Challenges', which takes in 660 students and consists of two five-week PBL elements –

i) a workshop providing a conceptual framework aimed at enabling students to structure their teamwork experiences and maximise their successes
ii) a peer-assessment exercise which runs twice at the end of each two five-week problem-based learning activities

Here we present the results of the peer-assessment activity in which members of student-teams assess each other using rubrics that they generated at the beginning of the first of their PBL activities.

One of the issues that students and staff find most troubling when assessing team projects is the potential for team members to avoid contributing their share of the work and taking the grade for free (freeloading) [3]. Yet, team theory tells us that teams need a certain amount of autonomy to set their own rules and manage their own processes in order to function as a team as opposed to a group of individuals [6,7]. In this case, efforts to assess team contribution are better to avoid imposing values or processes on teams because they need to design their own criteria in order to function as a team.

In addition, the criteria by which team members may wish to assess each other are subtle, subjective, interpersonal and hard to define. In these situations, some authors recommend that students define their own evaluation criteria, because what is most important is that they know, understand and agree what the criteria are [8].

The peer-assessment rubrics that were generated present us with an opportunity for evaluation and analysis that we hope will allow us to develop future learning scaffolds to further support teamwork and enable students to develop these skills, without over-managing the teams.

Teamwork skills are ill defined and include such terms as reliability, positive attitude, responsibility, flexibility, motivation, for example. These are the kinds of competencies and attributes that Krathwohl and Bloom (1964) [1] describe in their affective domain. Their taxonomy provides a hierarchical classification of behaviours and attitudes increasing in complexity, which we employ here to aid the design of learning experiences for team function.

Bloom's cognitive taxonomy [9] is widely utilised in curriculum design and evaluation. The affective domain [1] has not yet gained the same traction. It is becoming ever more important to support the development of values, attitudes and behaviours in higher education not only to support professional skills, but also to produce engineering graduates who are capable of sustainable and socially responsible practice fit for the 21st century [5, 10]. Here we report a novel use of Krathwohl's affective domain [1] which we intend to utilise to provide more student learning opportunities for this purpose.

1.1 The Teamwork Curriculum

The conceptual team framework that we give to our students is designed to encourage the independent development of teamwork processes by providing students with a set of tasks, which if accomplished support the functioning of effective teams. We do not monitor or evaluate students' passage through the tasks, but we do set up opportunities for them to do so through teambuilding and reflection.

The framework consists of the following steps, each of which is explored during a teamwork workshop in weeks one or two of the first PBL element:

- Set a vision and performance goals
- Assign task-based roles and team-based roles
- Create and decide on group processes
- Develop trust in interpersonal relationships
- Develop appropriate inter-group relations

The steps are based on research that highlights how team function can be promoted. The aim is to enable our student teams to make their own decisions, devise their own systems, and develop their own relationships in their teams [6,7, 11, 12]. There is no known formula for successfully passing through these teamwork steps and so we support any student teams who get stuck on a case by case basis.

Krathwohl's (1964) [1] classification of affective skills has potential for developing and furthering our understanding of ways to support and scaffold effective teamwork. In order to pass through the teamwork stages, students require affective competencies in the form of particular "interests, attitudes, values, appreciation and adjustment" [1 p24]. Our aim then, is to utilise Krathwohl's rankings to understand the nature of the criteria that the students think is important to assess in their teams.

In 1964 Krathwohl specifies if “affective objectives and goals are to be realised, they must be defined clearly; learning experiences to help the student develop in the desired direction must be provided; and there must be some systematic method for appraising the extent to which students grow in desired ways” [1 p23]. Our only difference from Krathwohl is that although we need to understand whether our students ‘grow in desired ways’, team theory informs us that such appraisal has to come from within the team and is best not imposed from the outside [6,7]

Congruent with this is a body of research that emphasises the need on the part of students for an excellent understanding of the criteria and standards by which they are evaluated. By allowing students to choose their own criteria and standards for peer-assessment, we hope to ensure that teams can understand and agree on what they are will be judged on [8, 13].

In line with this we designed a peer assessment exercise, which students undertake in the first week of their PBL activity. Student teams are asked to design a rubric for use in assessing one another’s contribution to teamwork at the end of the project. Each team chooses their own four criteria on which to evaluate their peers. Then they write rubrics which have three levels of attainment for each of the criteria. Students write a short description of the standards of behaviours and achievement required for each level in each of the four criteria. Every criterion also has a main heading. Here we report on an analysis of the team rubrics from The Challenges 2016. In total, we have examined 110 rubrics.

2 ANALYSIS AND INTERPRETATION

2.1. Coding Methods

Our initial analysis consisted of in vivo coding of 35 rubrics (5 from each of the 7 disciplines represented on the IEP) using an approach based on an inductive ‘grounded’ theory [14]. Using words that appeared in the rubrics we developed 51 codes. We present results here of the detailed coding of these rubrics, which consisted of 4 criteria at 3 levels each but we observed in this analysis that the lowest level of the affective domain (receiving), appeared to be underrepresented in the data. In order to understand this further we analysed a further 65 rubrics only for the verbs that represent the receiving (lowest) level of the affective domain.

2.2 Interpretation

Table 1 shows the frequencies of codes emerging from detailed coding of 35 rubrics. All elements of criteria and descriptions were categorised with 51 different codes. We used a large number of codes in order to ensure that we retained the meaning intended by the students. Clearly, some of our codes are only subtly different in meaning to each other.

The primary observation emerging from the data in *Table 1* is that students have chosen to assess their contribution to teamwork primarily using affective skills. Some of the codes appear to be strongly task based, such as analytic or research skills. Others, such as attendance or punctuality also seem to be task focused, but are in fact professional skills, which represent a choice and a response to the team.

Table 1

Code	Frequency (%)	Frequency Rubrics (%)	Code	Frequency (%)	Frequency Rubrics (%)
Attendance	9.7	97.1	Accepting of ideas	1.2	28.6
Meeting deadlines	8.8	85.7	Progress reporting	1.2	17.1
Quality of work	6.8	68.6	Builds and maintains relationships	1.1	22.9
Completing assigned tasks	5.5	68.6	Cooperative	1.1	22.9
Active participation	5.2	68.6	Shares findings	0.8	14.3
Contributes ideas	4.7	57.1	Encourages discussion	0.5	14.3
Punctuality	4.5	51.4	Problem-solving	0.5	14.3
Effort and commitment	4.3	48.6	Understanding of team objectives	0.5	14.3
Communicates	3.7	74.3	Tact and diplomacy	0.5	11.4
Contributes to team	3.4	48.6	Work-ethic	0.5	11.4
Contributes to discussion	3.2	54.3	Planning and prioritisation	0.5	8.6
Responds to communications	2.8	31.4	Reliability	0.5	11.4
Respects others	2.6	51.4	Shows initiative	0.4	11.4
Research skills	2.3	28.6	Group motivation	0.4	8.6
Listening skills	2.3	34.3	Can request help	0.3	5.7
Helps and supports others	2.1	31.4	Teamwork	0.3	8.6
Contributes to tasks	2.0	37.1	Analytic skills	0.2	2.9
Gives constructive feedback	2.0	34.3	Responds to feedback	0.2	2.9
Task ownership	1.9	31.4	Written communication skills	0.2	5.7
Professional attitude	1.8	40.0	Flexibility	0.2	2.9
Positivity and negativity	1.6	28.6	Manages team / delegates	0.2	5.7
Notification of lateness / absence	1.5	22.9	Leads by example	0.2	5.7
Expression of opinion	1.5	25.7	Efficiency	0.2	2.9
Self-organisaton	1.5	31.4	Gratitude	0.1	2.9
Empathy and understanding	1.3	22.9	Self-awareness	0.1	2.9
Quality of communication	1.3	17.1			

Table 2

Task Based Codes	Frequency in %
Contributes to tasks	2
Quality of work	6.8
Analytic skills	0.2
Research Skills	2.3
Shares Findings	0.8
Task ownership	1.9
Efficiency	0.2
% of Total Codes	**14.20**

Task-based professional skills make up the minority of codes, but have a greater concordance between them. Attendance and punctuality are some of the most popular items. Skills at the more affective end of the range, such as respect, empathy, self-awareness are more scattered between a greater range of codes. Major task-based codes are listed in *Table 2* along with their frequencies.

Given that the total frequency of task-based codes only runs at 14.2%, we can be confident that these students are valuing skills in their teammates that lie within the affective domain.

We were forced to use 51 codes to categorise the rubrics, and nearly 86% of those are easily identifiable as affective behaviours or skills. The wide range of adjectives and verbs that define and describe fully affective criteria goes to show how difficult it is to define and to categorise these skills. The difficulty is likely to be inherent in the exercise of defining affective behaviours and not a feature of these students.

In actual fact, *all* of the task-based codes have some element of affect to them. 'Quality of work', for example, implies judgement of the standard of work. 'Research' and 'analytic skills' include the acts of delineation, differentiation and organisation – all affective skills. So, it was possible, to map all of the rubric codes onto the affective domain. The results of this exercise are shown in *Table 3*, which gives the frequency of the codes as a percentage of total codes and the number of rubrics on which they appear.

The low frequency of criteria falling into the bottom (receiving) level of the domain is what interests us here. At this, the lowest level of the affective domain are behaviours involving receiving information, sensing, observing etc. The most common receiving verb to appear in our data was 'to listen', but others included 'pay attention' and 'open to ideas'.

2.3 Receiving

In general, receiving activities are encompassed in the more complex behaviours described in the domain. It is impossible to respond, for example, if one has not received say, a communication to respond to. It is impossible to be punctual, if one has not received the information that specifies the start date of the event.

Receiving is generally characterised by verbs such as to concentrate, to observe, to listen, hear, respect, ask, identify or locate. It is a vital early step in the formation of a new team, especially in teams that are culturally diverse and whose members may be working in a second language for the first time, as ours are. Yet, listening appeared on 34.3% of rubrics, and the whole class of receiving verbs were only present 57.14% of rubrics. These must have been sparsely utilised on the rubrics that they did appear on, since the receiving verbs represent a small fraction 4.10% of the total codes.

It is quite clear that our students can and do function at this level, since they are capable of functioning at the higher levels of the domain, but the fact that most teams have tacitly assumed that receiving happens without note suggests potential for development or improvement of our scaffolding of team function.

The skill of active listening is now taught across a wide range of professions and some view it as a basic professional skill [15]. Yet, unless it is framed as such, it would seem to students like natural activity that can and should go without comment. Our data suggests that all the behaviours generally associated with affective receiving may be subject to the same assumptions. Should we, as educators, frame these behaviours as skills that can be honed and advanced like any others?

Table 3

Affective Domain Criteria	Rubric Codes		% of codes applied by level	% of rubrics level appears on
RECEIVING -Awareness -Willingness to Receive -Selected Attention	Accepting of ideas Understanding of team objectives Listening skills		**4.10%**	**57.14%**
RESPONDING -Acquiescence in responding -Willingness to Respond -Comfortable in response	Punctuality Attendance Notification of absence/lateness Communicates Shares findings	Responds to feedback Responds to communications Written communication skills Tact or diplomacy Progress reporting	**24.93%**	**100%**
VALUING -Acceptance of a value -Preference for a value -Commitment	Active participation Contributes to team Contributes to discussion Contributes to tasks Quality of work Shows initiative Reliability	Gratitude Professional attitude Meeting deadlines Quality of communication Efficiency Contributes ideas Respects others Encourages discussion	**41.50%**	**100%**
ORGANISATION -Conceptualisation of a value set -Organisation of a value system	Empathy/understanding Helps and supports others Gives constructive feedback Effort and commitment Research skills Positivity or negativity Builds and maintains relationships Problem solving	Task ownership Planning and prioritization Self-organisation Teamwork Can request help Completing assigned tasks Cooperative Analytic skills Expression of opinion Manages team/delegates	**28.14%**	**100%**
INTERNALISATION -Internalisation of value set -Characterisation by own value complex	Flexibility Self-awareness Work ethic	Leads by example Motivates Group	**1.34%**	**22.86%**

Following the detailed coding of rubrics, we searched a further 65 rubrics just for receiving verbs. In the total set of 110 rubrics, each containing 4 criteria at 3 levels (n= 1320 descriptions) we found that 11% of the criteria contained at least one term that fell into the bottom level of the domain.

Each of the four criteria were given headings by the student teams. We found that 60% of rubrics contained one criterion that was headed ‘communication’ and that this was the most frequently used heading. Yet many of the students did not feel it necessary to overtly include any receiving verbs under the heading of communication, despite the fact that this seems like an obvious category within which to include receiving words. Communication was usually described as a response phenomenon, and only a third of communication criteria included 'listening' or other 'receiving' verbs. This confirms our commitment to providing further learning opportunities and exercises in which students can develop, or even become conscious of, receiving skills.

3. SUMMARY

We have used Krathwohl's (1964) affective domain in a novel and effective way in this exercise. We aim to use the findings that have emerged from this research to further scaffold teamwork activities for our students by bringing their attention to the need to consciously receive, absorb and listen to team members if a team is to be effective.

While the most popular of the criteria headings is 'communication' at 60%, it was not matched by an equivalent frequency of 'receiving' verbs. This is incongruous given that half of communicating must be 'receiving' and we intend to work with our students on this aspect of affective learning in the coming academic year to support the development of teamwork skills.

This work is also useful in demonstrating that most of the criteria that students describe on these team assessment rubrics are overtly 'affective'. This is itself is an interesting result and we aim to understand and work with the affective domain further. We hope that it can both inform the way in which we provide teamwork support for students and help us to probe the potential of the affective domain.

We believe that if we are to support our engineering undergraduates to develop work place skills, such as teamwork, then the affective domain may prove to be a very useful tool.

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Case study: Engineering education, Industry 4.0, security, and competencies-based assessment

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ABSTRACT

In recent years we have realized that the higher education teachers' motivation has grown. The research has reached classrooms. We are convinced that engineering undergraduate students could improve their learning by applying new rules and new ways of assessment. This study presents a specific case where the training is updated with techniques and ideas coming from the industry world. On the one hand, we compare the activities in engineering classes with the aspects of industry 4.0, such as the sensors as students receiving knowledge and acquiring competencies, and the tutors as actuators improving the training. On the other hand, we have proposed students from the 3rd year, to be competencies' evaluators. This could be achieved when they develop a team work made by themselves, including some aspects of realistic learning, like activity, reality, principle of levels, interconnection, interactivity, and guiding principle.

Conference Key Areas: Engineering Education Research, Mathematics in Engineering Education, Engineering Skills

Keywords: Engineering education, Industry 4.0, competencies-based assessment

INTRODUCTION

One of the characteristics of today's education is that it focuses on the student. As is well known, we have moved from a teacher-centred teaching (see *Fig*. 1) to one in which the centre is the student, who is responsible for his own learning, like a distributed system (see *Fig*. 2). In this way, a collective teaching in the past, when many were trained, has been individualized and tailored to each one; or rather, each student makes his learning to his measure, without harming the rest. Education has been decentralized to a system of self-organization. In addition to this, the educational system we use tries not to be an additive educational system, since it

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does not seek to add and overlap contents in successive sessions, but the student acquires the competences that he needs to be a competent professional.

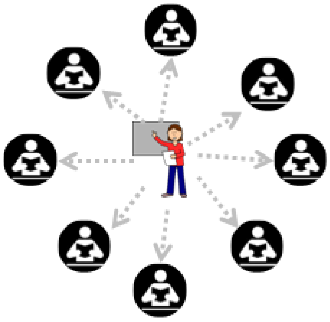

Fig. 1. Centralized system

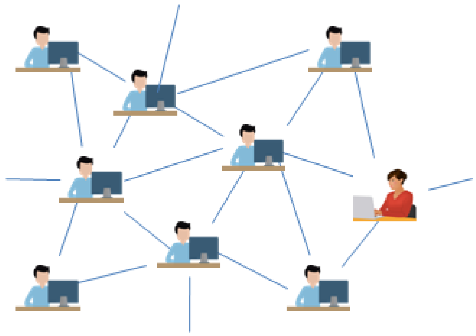

Fig. 2. Distributed system

In recent years, the digitization of factories has led to the concept of Industry 4.0. This term includes technologies such as smart industry and smart products, cyber-physical systems (CPS), Internet of Things (IoT), Internet of everything (IoE), cibersecurity, the cloud, hyperconnectivity, big data, 3D printing or robotics.

Industry 4.0 is the communication within an industrial plant, the processing of production data to improve productivity, effectiveness and quality of the final product or service. It implies the improvement of the relationships within the supply chains. In short, the interrelation between suppliers, manufacturers and final consumers, makes an Industry 4.0.

Our classrooms are no longer a physical space as we also work in cyber-classrooms. Even in cases where an online platform is only used in the most basic way (text files and tasks to be delivered), each trainer is aware of the student's activities and even the time and place from which he or she is connected. The classroom has become a “cyber-physical system” in which we have sensors to record students’ activity and actuators that return feedback, in the form of explanations or marks. That is, we use the sensors to monitor the students and the actuators to change the “parameters” that do not return the proper output.

The progressive implementation of the IoE makes some concepts, such as the computer virus and malware understandable and everyday items. We are all connected. We have proposed our engineering students a Realistic Mathematics Education (RME), related to their engineering knowledge and based on cibersecurity [1], CPS [2], and in general, industry 4.0.

The connection to mobile devices, the IoE, and the invisible information and communication systems embedded in our environment have definitely changed the educational paradigm. All these changes have come very directly to engineering education. In recent years research and innovation has been carried out in engineering, in order to improve the existing system.

This study presents theoretical and empirical aspects that bring changes in which the same ideas of Industry 4.0 have led to an educational system 4.0. In several courses of engineering degrees, in different subjects, a hybrid teaching was carried out, with one traditional part and another with these characteristics. We have analyzed the results at the end of the semester. Some of the grades obtained, when evaluating the competences of the students with rubrics or several tests that include multiple choice questions led us to think that students are not prepared for this type of education, and also that our educational system is not fully adapted to the new evaluation system.

In this experience with undergraduate students, the acquisition of the 8 math competencies was assessed [3]. The results showed that the students who usually obtained better grades were the ones that made worse results in the tests. We will also detail and analyze some of the causes that could lead to these results.

1 ASSESSMENT IN MATHEMATICS

The assessment process has a long history in education and it has attracted increased attention from teachers in mathematics. It has been widely studied. Different tools have defined different approaches to assessment, some examples are the tests, on-demand tasks, the portfolio, performance assessment or what was called authentic assessment, between others [4].

Mogen Niss, in [5], refers to the assessment mode as a vector with the following set of components:

1. Subject of assessment (who is assessed): Individual student or a group of students.
2. Objects of assessment (what is assessed): Mathematical facts, methods and techniques for obtaining mathematical results, or standard mathematical applications, modelling, and problem solving.
3. Items of assessment (what kinds of output are assessed): tasks, and especially questionnaires, exercises, problems, oral presentations, or small programs with specific software, constitute the predominant items of assessment.
4. Occasions of assessment (when does assessment take place): we may distinguish between continuous assessment and discrete assessment using the category of time.
5. Procedures and circumstances of assessment (what happens where and who is expected to do what?): As far as continuous assessment is concerned, students produce the items of assessment, whether material (e.g. written texts) or immaterial (e.g. activity level in class) either directly in the classroom or as homework. Assessment conditions should be just and allow for reliable judgement as well as for objective and easy marking, grading, and comparison of students' performance
6. Judging and recording in assessment (what is emphasized): what is emphasized is students' mastery of the content and ability explicitly or implicitly established in connection with the curriculum. The emphasis on completeness and correctness (reasoning, explanation, exposition, communication, methods, techniques, and procedures involved in arriving at the goals).
7. Reporting of assessment outcomes (what is reported to whom?): What is typically reported is the assessment record in its most aggregate and terse forms (marks and grades, accompanied, perhaps, by general statements). Such additional information can include nuances, explanations, comments, or suggestions which provide a broader and more comprehensive background for decisions and actions.

In the case of the group of teachers that have developed this study, we teach in industrial engineering degrees, specifically in electrical, electronic and automatic, mechanical, and chemical engineering degrees. We have detailed the components of our proposal for the vector defined by Niss in Table 1.

Table 1. Assessment features during our course

Assessment mode	**Our case**
Subject	Group of students and individual students.
Objects	Applications to real life and problem solving.
Items	Oral presentations and a questionnaire.
Occasions	Discrete assessment.
Procedures and circumstances	Immaterial (with an oral interview) by the teachers and by the fellow students, and material (some tests).
Judging and recording	Degree of correctness (reasoning, explanation, exposition, communication, methods, techniques, and procedures) of students.
Reporting	Nuances, explanations, comments, and suggestions by the teacher and by the fellow students.

To make this assessment possible, we have proposed the students the development of a team work in which the following aspects should be included ([6], [7]):

1. Activity: each student is an active participant in his own learning process.
2. Reality: apply the themes and topics of the subjects to the resolution of real problems.
3. Principle of levels: students go through several levels of understanding (in the process of learning) until they are able to see the whole problem. This principle is closely related to mathematical models, which establish a bridge between more purely formal and applied teaching.
4. Interconnection: the topics of the different subjects of the degree are integrated with each other. They are not watertight compartments within the curriculum of the subject.
5. Interactivity: Learning is a social activity and not just an individual task.
6. Guiding principle: it is related to the proactive role of teacher-tutor, as he is the responsible of guiding the teaching-learning trajectory.

Moreover, we asked students to specify the mathematical topic of the work, and they must also develop the 8 competencies in their work, i.e., these competencies will be the common thread of the work.

As final task of the team work, students have to propose a questionnaire in which the 8 competencies are assessed, with at least one multiple-choice question per competence. These questionnaires will be filled by the rest of students' fellows.

During the development of the team work, there are some sessions student vs. tutor to improve the work, the teacher-tutor revises the on-going work and make students to modify some parts, according with the basis of the requested work.

2 COMPETENCIES-BASED ASSESSMENT

During the course, when we study optimization concepts, we have proposed the students a questionnaire, similar to the one that they will implement later on. The questionnaire with multiple choice questions evaluates the competencies.

In detail, the specific proposed problem was to find the point of the band $\overline{AB}$ where it will be easier to score a goal in the *p* goal (considering a football field with the shape and dimensions of the *Fig*. 3) [8].

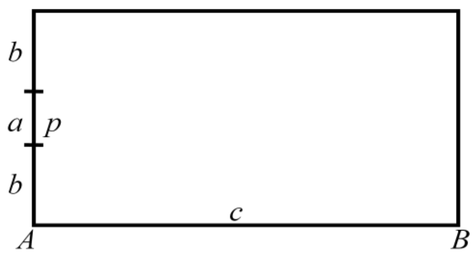

Fig. 3. Football field with the dimensions for the proposed problem

Some of the questions were the following:

1. How would you solve the problem of knowing the point of the band from which to score the goal?
   (a) It is a problem of football strategy.
   (b) It is a problem of probabilities, from the studies of the last parties.
   (c) It is a problem that is solved if you understand football and you like it.
   (d) We can solve it mathematically.
2. What would be the reasoning of the problem?
   (a) We draw a straight line from each point of the band $\overline{AB}$ to the goal to obtain the optimum (although if the shot is angled we should also consider the curves).
   (b) As c≅2b, the point from which it is easier to score goal is the centre of the band.
   (c) The easiest point will be the one with the highest angle, since if we are in *A* it is impossible to get the ball through the goal. As we go towards B it becomes easier.
   (d) None of the above. We are missing data on the problem.
3. Problem statement:
   (a) The higher the angle the goal is seen from the band, the easier it will be to score. We must, therefore, maximize the angle $\varphi = \varphi_1 - \varphi_2$.
   (b) It is necessary to take into account the angle β from which it is thrown to goal and that angle is the one that must be maximum.
   (a) We should use the Thales's theorem (similar triangles) to solve the problem.
   (b) The statement is incomplete and can not be resolved if we do not have more information.

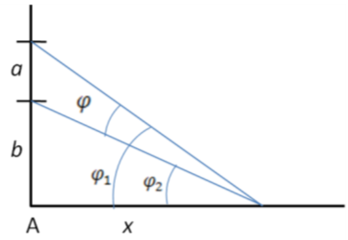

Fig. 2. Graphic from question 3. (a)

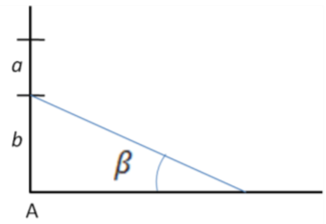

Fig. 3. Graphic from question 3. (b)

4. Solving the problem:
   (a) Since the tangent is a growing function in $[0, \frac{\pi}{2})$, the problem is equivalent to calculating the maximum of φ and of tg φ.
   (b) It is a question of solving an optimization problem, in which the minimum distance from the line $\overline{\mathrm{AB}}$ to the goal p must be calculated.
   (c) Since we have right-angled triangles, we must solve a problem of least squares (that we obtain when using the theorem of Pythagoras).
   (d) We must know the dimensions of the football field to obtain the requested value.
5. Determine which of the following models or methods allows us to solve the problem correctly:
   (a) We must solve a problem of optimization of a variable, which is the distance to the goal.
   (b) We must solve an optimization problem in which the angle with which the goal is seen from the band should be maximum.
   (c) We must solve an optimization problem in which the angle forming the line $\overline{\mathrm{AB}}$ with the ball trajectory must be maximum.
   (d) It can be solved using the relationships between the dimensions of the field, since they are standard and equal in all football fields.
6. Select which of the following expressions gives us the objective function of the problem:
   (a) $\mathrm{tg}\,\varphi = \frac{\mathrm{tg}\,\varphi_1 - \mathrm{tg}\,\varphi_2}{1+\mathrm{tg}\,\varphi_1 \mathrm{tg}\,\varphi_2} = \frac{ax}{x^2+(a+b)b} = f(x)$
   (b) $\mathrm{tg}\,\beta = \frac{\mathrm{sen}\ \beta}{\cos\beta} = \frac{b/x}{x/a} = f(x)$
   (c) $d(\overline{AB}, p) = \sqrt{(x-a)^2 - (x-b)^2} = f(x)$
   (d) $d(\overline{AB}, p) = \sqrt{(x-a)^2 - (y-b)^2} = f(x,y)$

After seeing and solving that questionnaire, students must define a similar one related to their team work. Some of them do not understand the concept of competence, others made questions relate to topics of the work, and others to the curricula of the course. As time passes, students learn from each other, they ask the tutor about how to make the test, and they finally get the questionnaire. The average mark obtained by the students that completed this specific test was 5.71/10. The amount of students that participated was 21 out of 46. These students were more prepared to develop their own questions.

3 DISCUSSION AND CONCLUSIONS

In recent years the assessment process has get more importance, as it establish the difference between different educational systems. We have proposed our students from industrial engineering degrees to assess and be assessed in competencies. The proposed method could be substantially improved, but we tried to start to have the chance to make a better assessment system.

Students from the 3rd year of chemical engineering have participated in this experience. They developed a team work and they proposed a multiple-choice questionnaire to assess the 8 mathematical competencies.

45 students have participated on this course. They were organized in 16 groups. Each group has proposed a multiple-choice questionnaire to be completed by their fellows. The average grade from these competence-based activities was 6.69, but the average in the rest of assessment activities (different problems solved by hand or with a CAS) was 8.22.

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Investigation of a Line-Tracing Auto Guided Vehicle as an Educational Tool for Mechatronics

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ABSTRACT

Department of Mechanical Engineering bears responsibility of automation engineering training, and one related courses is Mechatronics. The author uses the line-tracing auto guided vehicle (LT-AGV) as a Mechatronics course teaching tool for more than ten years. The purpose of this research is to enhance the teaching content of a LT-AGV. The LT-AGV serving as an educational tool is divided into two parts. The first part is the mechanism design of an AGV and the second part is the AGV's control circuit design and implementation. In order to upgrade the LT-AGV's system, plenty engineering designs and manufacturing methods have been developed to improve students' learning outcomes in this research. An experimental analysis method is used to find out the difference of the design parameters through verifing the performance of LT-AGV. After comparing the experimental data of AGV's performance, a more suitable range of design parameters was proposed. Consequently, the investigation of design parameters on the LT-AGV had been accomplished. This new LT-AGV system can serve as an useful tool in teaching.

Conference Key Areas: Curriculum Development; Attractiveness of Engineering Education; Engineering Education Research

Keywords: *line-tracing auto guided vehicle (LT-AGV)*; *educational tool; mechatronics.*

INTRODUCTION

A Line-Tracing Auto Guided Vehicle (LT-AGV) system was developed in a Mechatronics course. This course has been developed for more than a decade. A black curve with 35 mm width is printed on an A0-size white paper (841x1189) to be used as the LT-AGV test track. The test track becomes more and more complex over the past 10 years as shown in Figure 1. The progress of this course in teaching is therefore verified.

The course is constructed by two phases. The first phase is a practice course and the second phase is basic lectures. For the first phase, all the students are asked to make a LT-AGV according to teacher's guidance. Through learning by doing, students can establish the complete concept of an automation system and apply knowledge of basic electrical principle. For the basic lecture

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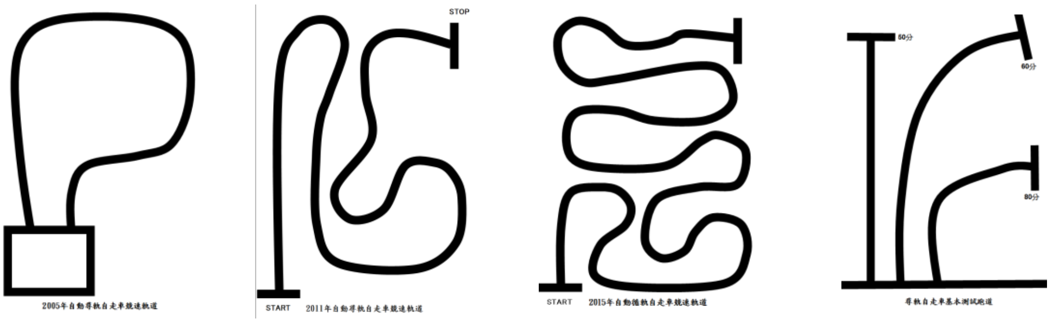
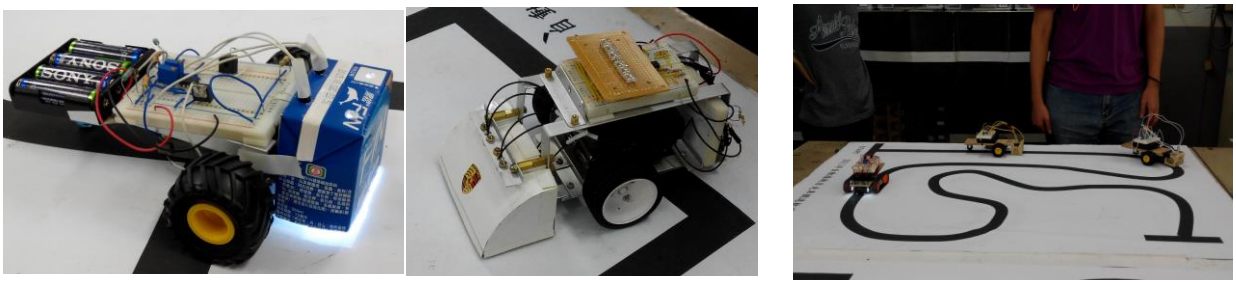


(a) 2005 (b)2011 (c)2015 (d)

Fig. 1. (a)~(c) Test track of 2005, 2011, and 2015. It is printed on A0-size paper. And (d) the easy runway is also prepared for the low performance LT-AGVs.



(a) (b) (c)

Fig. 2. Various AGVs made by students(a, b) and the test scene (c)

in second phase, the lecture material will focus on the automatic system's concept and the introduction of the sensor, the controller, the actuator [1], and the LT-AGV design and manufacture. In the course of this implementation, the study of LT-AGV's performances includes the AGV design, kinetic analysis, the friction force, the wheel, the vehicle speed, and the vehicle turning. Figure 2 shows various LT-AGVs that were made by students and the test scene.

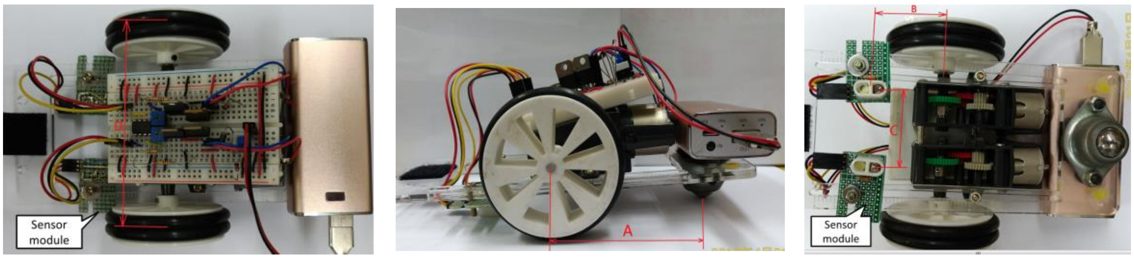
1. The Design Parameters and Related Electrical Circuits of the AGV

1.1 The Structure and Design Parameters of the AGV

In order to explore the influence of geometric parameters on the AGV's line-tracing ability, a prototype of the educational AGV that can flexibly adjust the geometric parameters is constructed and shown in Figure 3. The Illustration of this AGV is shown in Figure 4.

A pair of sensors were used to detect the black track (test runway) which is to be followed. A controller is used to receive signal feed back from the sensors and to submit a command to drive DC motors mounted on both sides of the AGV. When one side of the DC motor stops but the other is running, the AGV will turn. All of these will be properly presented on the basic lecture of this course to teach students to design an AGV with superior performance [2~4].

According to experimental observation, the geometric parameters of the AGV will influence the AGV's ability to turn. Therefore, in order to improve the AGV's line-tracing performance, four kinds of geometric parameters were chosen as shown in Figure 4. Which are：**A:** the distance between the motor's wheel and the universal wheel; **B:** the distance between the motor's wheel and the photo sensor;



(a) Top view (b) Side view (c) bottom view

Fig. 3. The LT-AGV used to experiment and its four kinds of geometric design parameters.

C: the distance between two photo sensors; **D:** the distance between two motor wheels. These parameters must be carefully considered in the design and manufacture process of a LT-AGV. It is easy to understand that the design parameter C depends on the width of the track (black line). Parameter A is a secondary parameter that is less relevant to AGV's motion effects.

1.2 Electrical Circuits of the AGV

The illustration of line-tracing concept is shown in Figure 5. The sensor module can be set over the black track (Run By Black；RBB mode) or beside the black track (Run By White；RBW mode). In the case of RBB mode shown in Figure 5 (a), when the right side sensor module exceeds the black track and senses the white ***background***, the controller should stop the ***left side*** motor to turn AGV left. On the other case of RBW mode shown in Figure 5 (b), when the right side sensor module senses the ***black track*** the controller should stop the

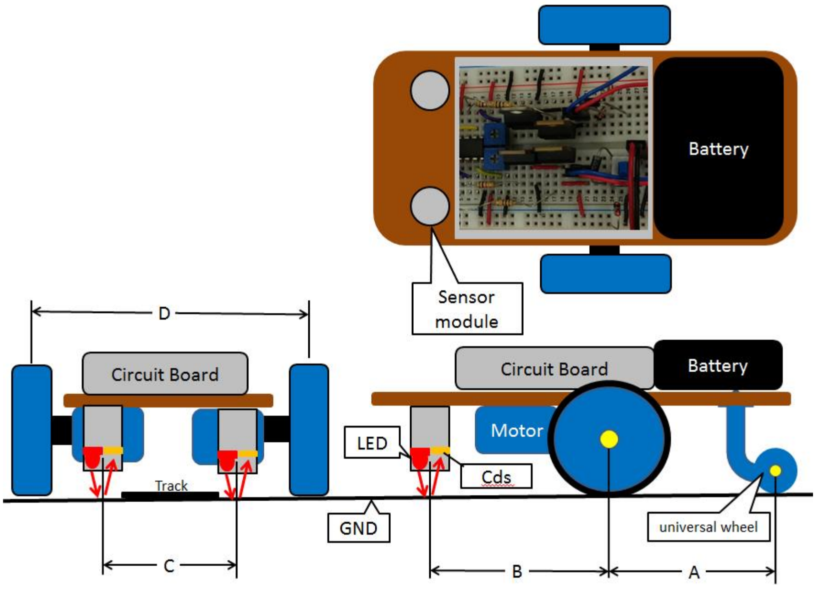
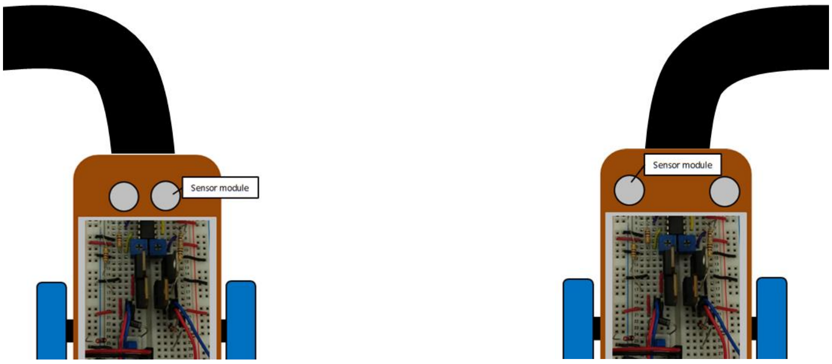


Fig. 4. The illustration of AGV and its four kinds of geometric design parameters.



(a) RBB mode (b) RBW mode

Fig. 5. The illustration of AGV running mode. (Note the location of sensors)

right side motor to turn AGV right.

The photo resistor is adopted as a sensor in the LT-AGV system and is integrated into a sensor module with a LED to avoid the interference of the environment light. The detail is shown in Figure 6.

In addition, both LM358 (operational amplifier) and 2SC1384 (transistor) serve as a controller. The DC motor is the actuator. Subsequently, these components will be the control system that manipulates the AGV's motion. There are two types of control circuit that can be used, as shown in Figure 7. The first one is the RBB mode as shown in Figure 5 (a). In this case, the control circuit is shown in Figure 7 (a). When the photo resistor senses the black track, the weak reflection makes resistance of photo resistor higher and induces voltage Vs higher than Vref. The comparator (LM358) outputs a high voltage to make transistor (2SC1384) switch on. Then the motor runs. Once the photo resistor goes out of the black track and senses the white background, the motor stops. The other case is RBW mode as shown in Figure 7 (b). In this mode, when the photo resistor senses the white background of the black track, the intense reflection makes resistance of photo resistor lower and induces voltage Vs lower than Vref.

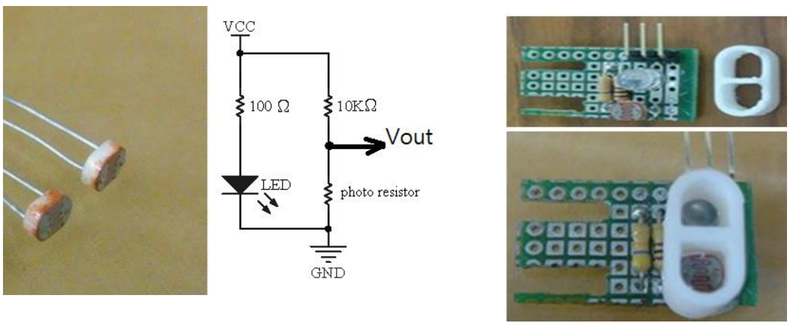
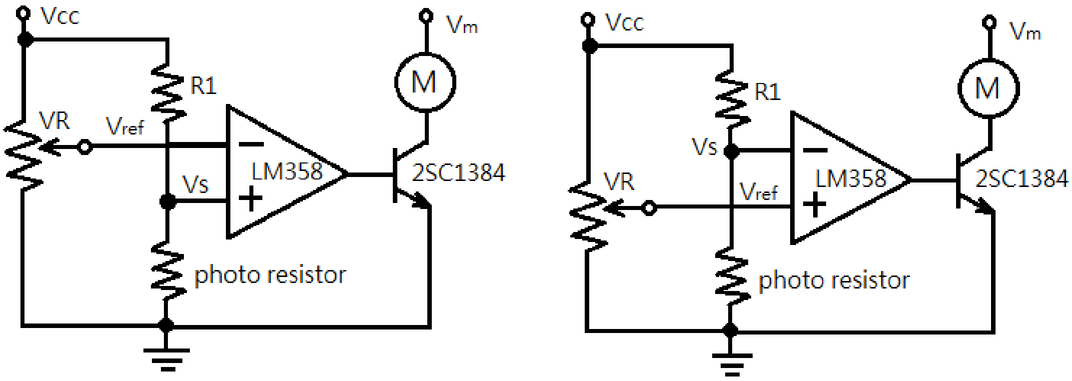


Fig. 6. Photo resistor transfers the light intensity to a voltage output with voltage divider. The sensor module includes the LED and photoresistor are covered by a 3D printed white case.



(a) RBB mode (b) RBW mode

Fig. 7. Two types of control circuit for the LT-AGV. Student can choose one of them to implement.

The comparator (LM358) outputs a high voltage to make transistor (2SC1384) to switch on. Then the motor runs. Once photo resistor senses the black track below it, the motor stops.

2. An Assessment of the Ranges of AGV's Design Parameters

2.1 AGV's Design Parameters

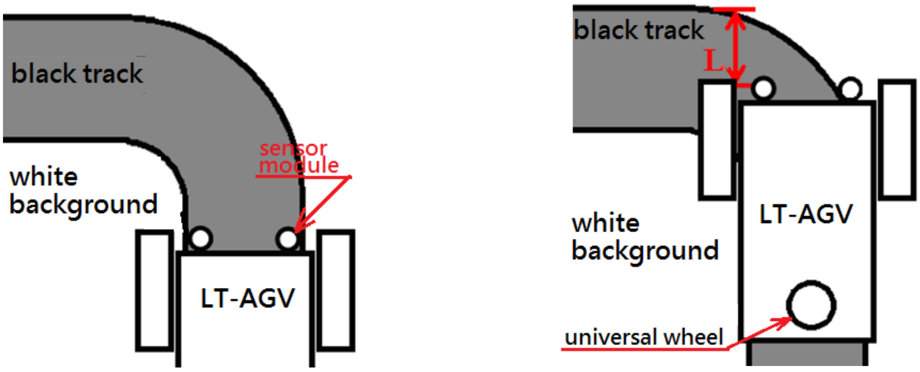
In addition to the geometric design parameters defined in Section 1.1 (***Fig. 4.***), the speed and the stop characteristic of the LT-AGV are also the important factors. It will be consistent with our driving experience, when the speed is too fast the car will not be easy to turn. In addition, when the car's braking force is insufficient, the car will become difficult to drive when turning. To assess the performance of the LT-AGV, the effects of speed and the kinetic parameter (an AGV's moving distance after the motor stops) must be studied at first.

2.2 The Test Track's Dimension and Curve Design

To understand the influence of the AGV's design parameters on it's turning performance, twelve kinds of track turning radii (45 mm, 50 mm, 55 mm, 60 mm, 65 mm, 70 mm, 75 mm, 80 mm, 85 mm, 90 mm, 117.5 mm, and 127.5mm) are selected in the experimental study. The turning angle is preset at 90 degrees.

2.3 The Influence of the Moving Distance (L) on the AGV's Curve-Turning Ability

The kinetic motion of the LT-AGV controlled by the RBB mode is depicted in Fig. 8. As indicated in Fig. 8(b), the right side sensor will exceed the track line when the black track turns left. The signal emitted from the right sensor module will be forwarded to the controller to stop the left motor and the LT-AGV will turn left. However, because of the internal effect of the motor driving system, the motor will keep rotating for a while. This will result in continuous movement for the AGV even though the motor is stop. The continuous movement is called ***the moving distance (L)*** [3].



(a) On the straight track (b) On the turning track

Fig. 8. The kinetic motion of the LT-AGV controlled by the RBB mode.

It is obvious from the figure, the left sensor will also exceed the black track if the L is too long. This will result in the motors stopping at the right and left wheels. Thus, the AGV's track-turning motion will fail. Therefore, to assure a successful tracking on a turning track line, the experimental assessment of an appropriate L at various turning radius of the track line is essential.

In order to measure a longer moving distance (L), a long straight track shown in Fig.9 is constructed. Here, the AGV's velocity depends on the motor's working voltages. Various working voltages can be obtained by connecting various numbers of diodes in a series to the electrical circuit. The related moving distance (L) and available radius of the curved track with respect to various AGV velocities will be obtained by using the experimental tests.

An experimental test of the moving distance (L) with respect to the available radii of curved tracks is performed and the results are shown in Table 1. As indicated in Table 1, the available radius of the curved track will increase if the moving distance (L) increases. A comparison of a maximum reacting distance for the two kinds of AGV's line-tracing control algorithms is inspected and illustrated in ***Fig. 10***. Result in the RBB mode has a smaller reacting distance than that of the RBW. Therefore, the probability of a larger reacting distance to successfully pass through a curved track line is higher than that of the smaller reacting distance.

Table 1. An experimental test of the moving distance (L) with respect to curved radii.

Electrical voltage (V)	L (mm)	R*
2.2	16	50
3.2	38	85
4.2	70	127.5
Note：the R* is the smallest curve track radii that the AGV can successfully pass (mm)		

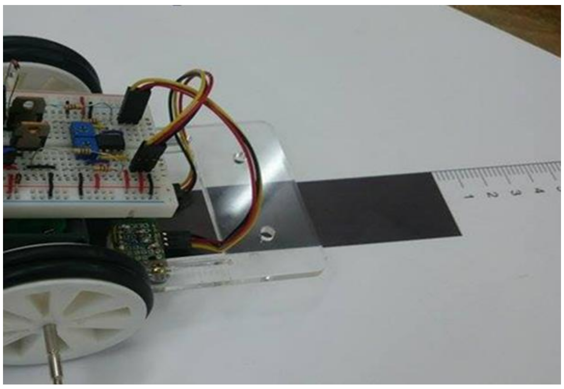
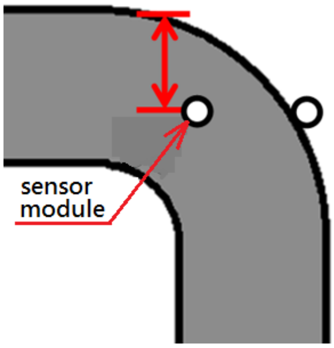
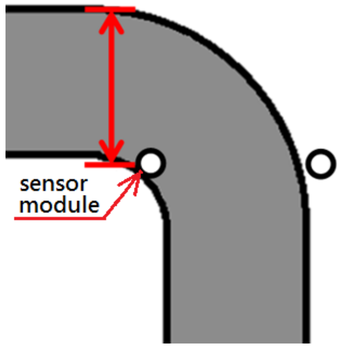


Fig. 9. The experimental testing of the AGV on a straight track.



(a) maximum reacting distance for RBB mode



(b) maximum reacting distance for RBW mode

Fig. 10. The comparison of maximum reacting distance for two kinds of AGV's line-tracing controlling algorithms.

As a geometrical check, both sensors are limited within the black line when using the first algorithm. Conversely, the setting of the sensors' locations will be easily performed with a sufficient space that is away from the black line when using the RBW mode. Hence, in the AGV's educational practice course, the old line-tracing algorithm will be replaced by the ***"run for white line and stop for black line"*** i.e. RBW mode.

2.4 The Influence of Geometric Design Parameters

Experimental tests for the wheel's distance and track turning is performed and shown in Table 2. Both the wheels' distance (D) and the AGV's velocity are selected as the variables. Here, the AGV's velocity will be adjusted by varying the motor's working voltage. As in Section 2.3, the working voltage can be reduced by connecting the diodes in series to the electrical circuit. As indicated in Table 2, the curved track's turning ability will decrease a little when the wheels' distance (D) increases. However, the influence of curved track's turning ability is not obvious if the wheel distance (D) decreases. This is because the wheel distance will be constrained by the motor's gear box. Consequently, the experimental results revealed that an appropriate range of the wheel distance (D) is between **95～115** mm**.**

Because of the space limitations of this article, the experimental data of other parameters on the performance of the LT-AGV are not described here, only the final results. The complete experimental study process and results will be published in a full paper in the future. Here, the experimental results reveal that an appropriate range of parameter B is between 30~50 mm. With this, the line-tracing and curved track-turning in a hairpin track will be successful.

Consequently, based on the experimental results and assessment of the LT-AGV's parameters, four observing aspects that can improve the LT-AGV's line-trace performances are listed below.

(1) The curved track's turning ability will increase when the moving distance (L) decreases. The recommended L is below 4 mm.
(2) The curved track's turning ability will be improved if the wheels' distance (D) decreases.

Table 2. Experimental test for the wheel’s distance (D) and track turning.

case	*MWV*	D	R*	*case*	*MWV*	D	R*	Note 1
1	*A*	95	55	*9*	*C*	115	127.5	D:Wheel’s distance (mm)
2	*B*	95	90	*10*	*A*	125	55	R*:The smallest curved track’s turning radii that AGV can successfully pass (mm)
3	*C*	95	127.5	*11*	*B*	125	85	
4	*A*	105	55	*12*	*C*	125	X	
5	*B*	105	85	*13*	*A*	140	60	X:fail to pass the turning radius of 127.5mm
6	*C*	105	127.5	*14*	*B*	140	90	
7	*A*	115	55	*15*	*C*	140	X	
8	*B*	115	85					

Note 2. MWV (Motor Working Voltage): A (working voltage: 4.3V，higher AGV speed)；B (working voltage: 3.6V)；C (working voltage: 2.9V，lower speed)

(3) The curved track’s turning ability for the hairpin track will be improved if the distance between the sensor and the wheel (B) is between 30～50 mm.

The observation and discussion above can serve as design guidelines in a preliminary Mechatronics course. With this, an advanced electrical circuit design will be further developed in the future.

3. Conclusion

This study proposed that LT-AGV is an effective educational tool for the Mechatronic curriculum and should be the core of teaching. It integrates: (1) the concept of SCAM system chain (Sensor→ Controller→Actuator → Mechanism) for teaching and new course content; (2) Ohm's law and voltage divider circuit applications (3) the knowledge of the transistor in the electronics and its control circuit of the DC motor; (4) the application of the operational amplifier as a comparator in electronics.

Best of all, in the LT-AGV control circuit, because photo resistor is susceptible to ambient light, students are enforced to solve this problem and repeatedly adjust the variable resistor of the control circuit to make their LT-AGV work. In such a process, the students must take the initiative to understand the principles of the control circuit, and then it becomes possible to adjust a good function of the LT-AGV, thus ensuring the effectiveness of teaching.

In addition, LT-AGV on the road test movement characteristics are very complex. In fact, it is difficult to explain very clearly. However, through the implementation and practice, as long as they follow proposed procedures and adjustment guidance, students can complete a good functional LT-AGV. In accordance with the proposed procedure and the adjustment method proposed by this study, students are inspired by the process of ***learning by doing*** in the application of mechanics and kinematics.

The author would like to thank his college for various supports in teaching and research over the past 20 years.

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The effectiveness and predictive value of interventions for bridging students in Engineering Technology

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ABSTRACT

In order to stimulate a flexible lifelong learning system a student with a professional bachelor's degree can sign in to a master's programme provided that the student successfully finishes a bridging programme. Just like first-year students, bridging students experience a feeling of unpreparedness and transition problems, which results in a need for appropriate interventions. Two types of interventions can be defined: 1)focusing on orientation, positioning and preparedness before enrolment; and 2)focusing on support during enrolment. This paper included two support

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interventions: intermediate exams and individual feedback conversations. The results of the intermediate exams (i.e. mathematics and physics) are linked to students' academic achievement of February and resulted in moderate and strong correlations. Analysis did not show a straight-forward effect of the individual feedback conversations, since there are no significant differences in academic achievement between the ones who came and the ones who did not came. This does not mean that this intervention is useless since we believe that the conversations are of great advantage for the bridging students. We want to 1)encourage them to study more (if necessary) or use a different approach, 2)help them if they are facing problems during the semester, or 3)confirm that they are doing great.

Conference Key Areas: Engineering Education Research, Continuing Engineering Education and Lifelong Learning

Keywords: Bridging students, interventions, intermediate exams, feedback conversations

INTRODUCTION

There are two types of bachelor's degrees in Belgium, a professional and an academic one. An academic bachelor's degree is a precursor to a master's degree while a professional bachelor is a straight forward preparation to a professional occupation. In order to stimulate a flexible lifelong learning system a student with a professional bachelor's degree can sign in to a master's programme provided that the student successfully finishes a bridging programme (see *Figure 1*).

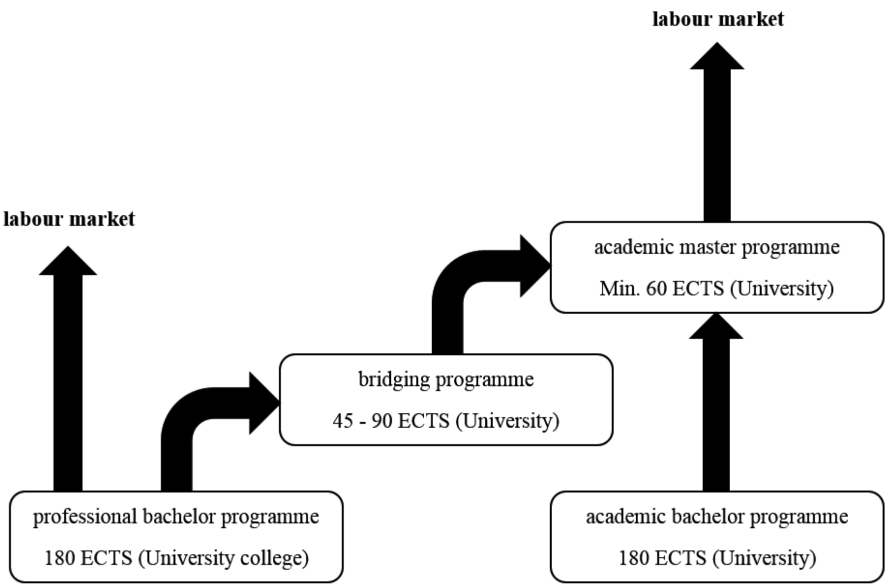

Figure 1. Flemish higher education system

The bridging programme focuses on the acquirement of the missing competences needed to start a master's programme and it is organized by the university offering these master's programmes. The bridging programmes at the multi campus Faculty of Engineering Technology (FET) at KU Leuven have a weight of approximately 60

ECTS, depending on the choice of study programme and the professional bachelor degree. The first semester of the bridging programme has a very general focus with mainly basic science and engineering courses (e.g. mathematics, mechanics, electricity, physics, and chemistry). During the second semester the courses are more aiming at the chosen engineering specialization of the bridging students. Just like first-year students, bridging students enter university for the first time. The FET counts approximately 800 bridging students.

1 PROBLEM

Unfortunately the success rate of the bridging programme is rather low and the dropout rates are high. These rates are comparable to that of the first-year students of FET [1]. Other studies revealed that many new students experience difficulties during the transition from secondary education to university and sometimes they drop out as a consequence [2, 3, 4]. This feeling of unpreparedness and transition problems results in a need for appropriate interventions. This previous research [1] also showed that bridging students feel significantly less well-prepared for university compared to traditional first-year students. The conclusion of this study was that there are definitely similarities between the traditional first-year students and bridging students, therefore interventions developed and organised for first-year students can be used as an inspiration source for interventions for bridging students. Two types of interventions can be defined: 1) the ones that focus on orientation, positioning and preparedness before enrolment (e.g. diagnostic testing [5] and summer courses); and 2) the ones developed for support during enrolment (e.g. Supplemental instruction [6] and assessments and feedback [7]). A time line, that starts in the last phase of the professional bachelor and ends when the bridging programme has finished, with interventions on well considered moments is developed. In this paper two support interventions are discussed: intermediate exams and individual feedback conversations.

2 INTERMEDIATE EXAMS

2.1 Context and sample

Intermediate exams are, by default, organised for the traditional first-year students at FET in the middle of the first semester, normally after five or six weeks of lectures. Thanks to these intermediate exams students get the opportunity to become adapted to the academic approach and, if necessary, they can adjust their study and learning strategies. In general, these intermediate exams account for only a small proportion of the students' final results (e.g. 10%).

The three campuses that are actively involved in this research organised an intermediate mathematics exam during the academic year 2016-2017. Only in campus x (N=99) this intermediate exam is already a real exam. If students pass this exam, they are awarded with the corresponding amount of ECTS credits. If students fail this exam, they have to do it again at the end of the academic year. In campus y (N=78) and De campus z (N=40) this intermediate exam accounts for only 10% of their final Mathematics exam result. The combination of the intermediate and final exam results in a final grade, which determines whether or not the student obtains the corresponding ECTS credits.

We also analysed a Physics intermediate test on one of the three campuses. During the academic year 2015-2016 this intermediate test was voluntary (N=37) and the result did not had an effect on students' academic achievement. In the academic year

2016-2017 (N=47) the physics test was mandatory and accounted for 10% of the total Physics exam result.

In this paper we investigate the predictive value, via regression models, of the intermediate exams and if there are differences between the different types: 1) real exam (100%) vs. limited consequences (10%) and 2) voluntary vs. mandatory.

2.2 Results

2.2.1 Real exam vs. limited consequences

Table 1 shows the regression coefficients of the different models for the intermediate exams of Mathematics. When correlating the intermediate results to the academic achievement in February, strong correlations are found for the three campuses, but the strongest correlation was found for the real exam of campus x (r=.74). For the intermediate exams with limited consequences the correlations are somewhat lower (i.e. campus z: r=.63, campus y: r=.57).

Table 1. Regression coefficients intermediate exam Mathematics

		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
Campus x	(Constant)	18.379	4.371		4.205	.000
	Intermediate exam math	2.402	.394	.571	6.100	.000
Campus y	(Constant)	4.982	3.782		1.317	.191
	Intermediate exam math	3.150	.292	.736	10.778	.000
Campus z	(Constant)	16.267	5.173		3.145	.003
	Intermediate exam math	2.512	.499	.628	5.038	.000

Dependent Variable: Academic achievement February

2.2.2 Voluntary vs. mandatory

Table 2 presents the regression coefficients of the two regression models for the intermediate Physics exams. For both the academic years the test results correlate significantly with academic achievement. For the voluntary test a strong correlation was found (r=.54), while for the mandatory test the correlation was only moderate (r=38).

Table 2. Regression coefficients intermediate exam Physics

		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
AY 2015 – 2016	(Constant)	32.728	4.113		7.957	.000
	Voluntary test	1.598	.420	.541	3.802	.001
AY 2016 – 2017	(Constant)	13.432	9.536		1.409	.166
	Mandatory test	1.660	.600	.381	2.765	.008

Dependent Variable: Academic achievement February

3 INDIVIDUAL FEEDBACK CONVERSATIONS

3.1 Context and sample

Since previous research revealed that bridging students, just like first-year students, are in need of feedback [8], voluntary and individual feedback conversations were organised at one of the three campuses after the intermediate exams. The bridging students were invited via e-mail to select a moment for receiving individual feedback. An independent samples t-test was performed to find out if there are significant differences in academic achievement of February between students who came to the feedback conversations (N=33) and the ones who did not (N=14). Every conversation took about 15 minutes and students were asked the same questions. The responses on these questions were categorised and linked to the students' academic achievement. With the feedback conversations we wanted to find out if students study hard for the intermediate tests and if their results are in line with their expectations. In this research we also examined if students with bad results on the intermediate exams considered this as a wakeup call, and if so, were there some signals they would adapt their study method and/or study attitude? An answer to these questions is given by performing ANOVA analyses or independent samples t-tests. The four questions and the corresponding response categories are the following:

- *"Did you study hard for the intermediate tests?"* resulted in three response categories: 1) Yes, 2) No, and 3) Partially.
- *"Are the results in line with your expectations for Mathematics/Physics?"* resulted in three response categories: 1) Yes, 2) Better than expected, and 3) Worse than expected.
- *"Do you consider these intermediate tests as a wake-up call?"* resulted in three response categories: 1) No, because I started with studying from the beginning, 2) Yes, but I started with studying from the beginning, and 3) Yes.
- *"Are you going to use a different study approach now?"* resulted in two response categories: 1) Yes and 2) No

3.2 Results

Table 3 shows the students' mean academic achievement for the different questions of the feedback conversation.

Table 3. Results of the feedback conversations and the corresponding mean academic achievement.

Individual feedback conversations		Academic achievement February		
		Mean (%)	SD (%)	N
Present for feedback	No	33.53	22.74	14
	Yes	40.77	19.74	33
Study hard	Partially	36.41	21.33	14
	Yes	44.84	18.55	18
	No	83.93	.	1
Expected result mathematics	Better than expected	49.03	22.50	16
	Yes	35.27	19.14	13
	Worse than expected	39.43	15.35	4
Expected result	Better than expected	4.29	.	1

physics	Yes	46.38	17.53	23
	Worse than expected	26.17	16.05	7
Different study approach	No	48.14	17.93	14
	Yes	38.25	22.52	19
Wake-up call	No, started at the beginning	71.52	11.42	5
	Yes, but started at the beginning	41.12	22.13	7
	Yes	36.68	16.33	13

First of all, performing an independent samples t-test revealed no significant differences in academic achievement between the students who came for individual feedback and the ones who did not (t= 1.099; p= n.s.).

On the question "*Did you study hard?"* only one student answered *No.* This student was not included in the analysis. An independent samples t-test showed no significant differences between the students who studied hard and the ones who studied hard for one of the tests (t= 1.195; p= n.s.). Also the questions *"Are the results in line with your expectation for mathematics?"* (F= 1.176; p= n.s.) and *"Are you going to use a different study approach?"* (t= 1.356; p= n.s.) did not result in significant differences.

Since only one student stated that the result on the Physics test was better than expected, this answer was not included in the analysis. Students who stated that their results on the physics test were worse than they thought obtain a significant lower academic achievement in February than the ones that expected the achieved result (t= 2.719; p= .011).

Students who answered *No* on the question *"Do you consider these intermediate tests as a wake-up call"* obtained a significant higher academic achievement that the students of the other response categories (F= 7.486; p= .003). These students mentioned that they started with studying from the beginning of the academic year and do not need a wake-up call. The students who answered *Yes* consider the intermediate tests as a wake-up call, but nevertheless they do not obtain a high academic achievement.

4 DISCUSSION AND CONCLUSION

The predictive value of the real mathematics exam is the highest, which is not odd since the stakes are high. If they not pass the exam they have to do it again during resits at the end of the academic year. The intermediate exams that only accounted for 10% of the final result showed also strong correlations. So both types of intermediate exams are certainly useful. For the Physics tests, the result was not as expected, since the predictive value of the voluntary test is higher than that of the mandatory test. For the mandatory test the correlation was moderate and for the voluntary test a strong correlation was found. A reasonable explanation for this result is the following: The test of 2016-2017 does not differentiate as well as the one of the previous year, since 1) the average result of the test was much higher, 2) the results of the students were rather similar, and 3) there is a ceiling effect. To conclude, there is reason to believe that intermediate mathematics and physics exams, regardless the type, are meaningful predictors for the academic achievement of the bridging students at FET.

Analysis did not show a straight-forward effect of the individual feedback conversations, since there are no significant differences in academic achievement between the ones who came and the ones who did not came. This does not mean that this intervention is useless. Since earlier research showed that students are in need of feedback. The questions asked during the feedback conversation only revealed minor significant results. However, we believe that organising feedback conversations is of great advantage for the bridging students. During this conversation we want to 1) encourage them to study more (if necessary) or use a different approach, 2) help them if they are facing problems during the semester, or 3) confirm that they are doing great.

5 RECOMMENDATIONS FOR FURTHER WORK

By providing interventions, the ultimate goal of this research is to reduce the dropout rate and increase the success rate. To make this possible, it will be of great importance to analyse all the developed and implemented interventions. Therefore we also need to focus on the interventions that take place before enrolment and other support interventions. The interventions that take place before enrolment aim to prepare the students better for the bridging programme and/or encourage them to make a well thought-out study choice. Analysing, adapt and or develop other interventions will be the scope for future work.

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Cross-Disciplinary Creative Engineering Education with Internet of Things Technologies

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ABSTRACT

Due to the developments of sensor networks, RFID and information processing technologies, remarkable breakthroughs have been made for the Internet of Things (IoT) applications. In order to successfully implement the IoT applications, effective solutions linked to the cross-cutting issues will be an important subject in future engineering education. Therefore, instead of applying a traditional single-discipline lecturing approach, this project aims to conduct project-oriented learning and use the application development training as a concrete embodiment of the interdisciplinary engineering education, which makes the transition from being a student to establishing a creative design. For achieving cultivation of creative thinking and the realization of interdisciplinary engineering education, two representative trainings are conducted: (A) Proposing human-centric application proposals with Internet of Things techniques and (B) Implementing the proposed projects with embedded systems. Essentially there are four major steps involved in this one-year project: (1) Integrating creative and design thinking with social care infrastructures and local services (e.g., visiting a nursing home, a special education school for the deaf, or a fire station), (2) Developing applications of Internet of Things (proposing a specific problem statement), (3) Embedded system implementations, and (4) Validating the system design via user feedback. On the topic of education training, we plan to arrange cross-presentation of creative thinking techniques and experience sharing in the field, which may allow the students to leverage IoT techniques and describe general issues of people-oriented problems through observation and discussion. This paper will present the preliminary results of this project, which emphasizes on human-centric design process and aims to develop an architecture model for problem solving and application service.

Conference Key Areas: interdisciplinary engineering education,

Keywords: internet of things, interdisciplinary engineering education, creative thinking, embedded system implementations.

1. INTRODUCTION

Due to the developments of sensor networks, RFID and information processing technologies, remarkable breakthroughs have been made for the Internet of Things (IoT) applications. In order to successfully implement the IoT applications, effective solutions linked to the cross-cutting issues will be an important subject in future engineering education. Therefore, instead of applying a traditional single-discipline lecturing approach, this project aims to conduct project-oriented learning and use the application development training as a concrete embodiment of the interdisciplinary engineering education, which makes the transition from being a student to establishing a creative design. For achieving cultivation of creative thinking and the realization of interdisciplinary engineering education, two representative trainings are conducted: (A) Proposing human-centric application proposals with Internet of Things techniques and (B) Implementing the proposed projects with embedded systems.

At present, there are many creative competitions (for example: MediaTek Technology Networking Development Contest-2016 communication contest), but before the creative reality, how to cultivate the students to possess the concept of design thinking, so that students can use social care activities to translate their observations into insights into the products and applications that can improve human life, but a very important training experience. The notebook program will try to break through the traditional engineering education only focusing on single-domain phenomena, applications such as: Problem-based Learning, Project-based Learning teaching mode, and concludes other sub-plan themes, with the IoT platform and application as a specific cross-domain engineering education Implementation example. From the discovery of the problem, with the creative thinking of the notebook plan training and the design of the Internet, cultivate students with creative and complex problems to solve the logical thinking and technical knowledge, so that the general learners can be transformed into the training of creative people through the course of the realization.

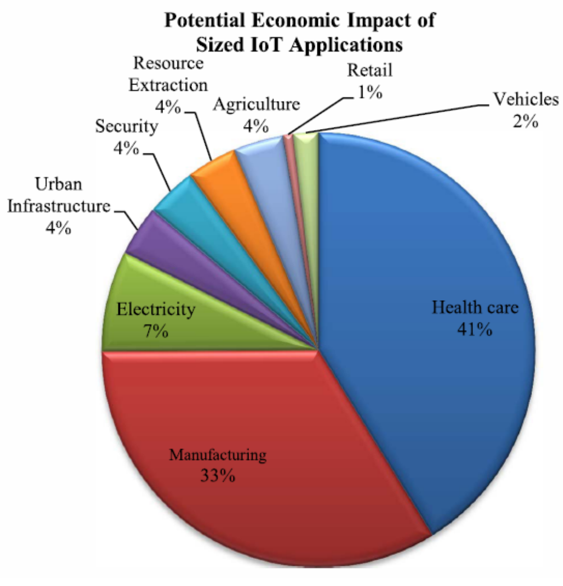
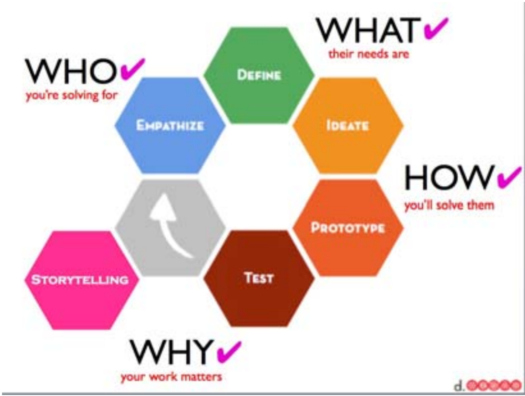


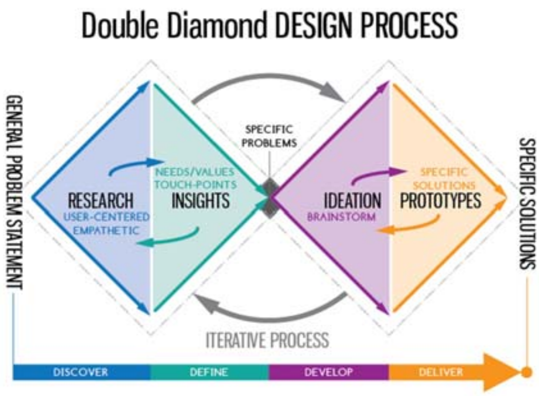
Fig. 1. Emerging application domains: opportunities for IoT technologies [1]

Essentially there are four major steps involved in this one-year project: (1) Integrating creative and design thinking with social care infrastructures and local services (e.g., visiting a nursing home, a special education school for the deaf, or a fire station), (2) Developing applications of Internet of Things (proposing a specific problem statement), (3) Embedded system implementations, and (4) Validating the system design via user feedback. On the topic of education training, we plan to arrange cross-presentation of creative thinking techniques and experience sharing in the field, which may allow the students to leverage IoT techniques and describe general issues of people-oriented problems through observation and discussion. This paper will present the preliminary results of this project, which emphasizes on human-centric design processes and aims to develop an architecture model for problem solving and application service.

2. Human-Centric Design Process

This project explores the learning experience by integrating creative and design thinking with social care infrastructures and local services. Using the process of design thinking presented by Stanford (Fig. 2 (left)), learners can translate their observations into insights, products and applications that can improve human life. Note that although the thinking process is human-centred, it is a system design viewpoint. Furthermore, the industrial mentor may be consulted to guide the learners from discovering problems, defining issues, proposing possible solutions, and finally finding the best solution by using the Double-Diamond Thinking mode (Fig. 2 (right)). It is to be hoped that through the idea of the concept of creativity training, students can gain experience and skills for proposing general issues, which may provide a basis for defining specific problems (Empathy and Define). Then, through the combination of creative thinking training and engineering education, an appropriate solution may be explored to solve the problem (Ideate, Prototype, and test).





(a) (b)

Fig. 2. (a) Design thinking process [2] and (b) Double-diamond thinking model [3].

2.1 Phase I: Cross-Domain Perspectives

On the theme of creativity and design thinking workshops, several lectures and experience-sharing group discussions will be arranged. Related Topics cover: the technology and concept of creativity and design thinking, training procedures, tools, and the need and importance of creative thinking in engineering education. Hope that through this workshop activities and thoughts training, students can cultivate the ability to think creatively in engineering education. For instance, guide students to think about the improvement of health-related quality of life and well-being by visiting the nursing house or the center for the mentally handicapped (Fig. 3), which leads the students to consider the design issue from cross-domain perspectives and may further provide a better solution for the caring of our society.

Fig. 3. The issues of caring for an aging society and handicapped people [4]

2.2 Phase II: Idea Proposal

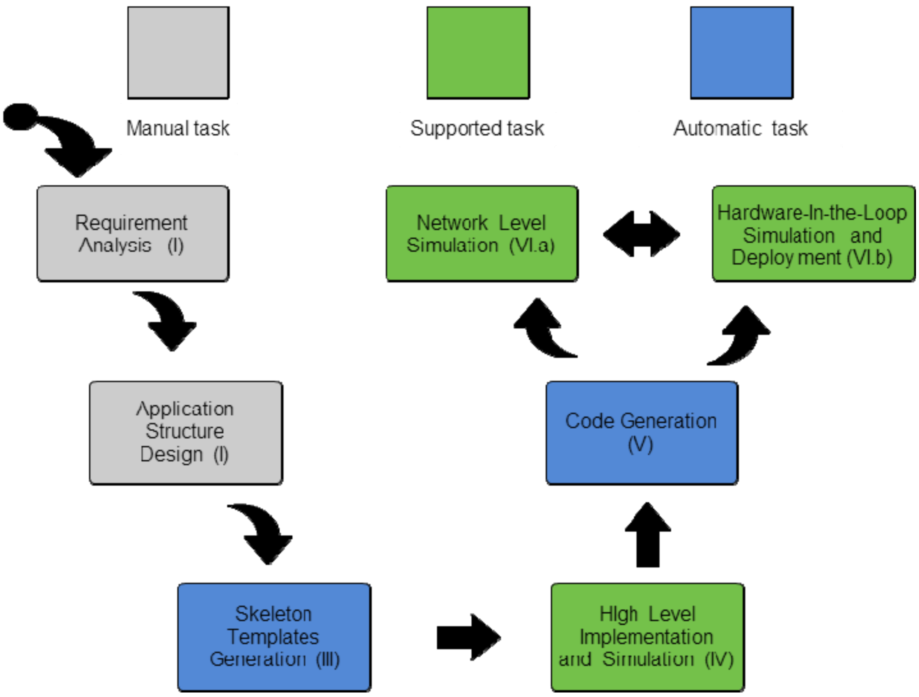


Fig. 4. Key procedures in the design of application tasks [5]

As shown in Fig. 4, three types of tasks are considered in a design work: (1) manual task, (2) supported task, and (3) automatic task [5]. In a research and design process, the manual task includes the requirement analysis and application architecture design for the core application, such as listing the features required for application and supported properties. The analysis results provide the application designers to deconstruct the foundation of application architecture, dividing the main development concepts into several abstract design modules. Through the interaction of these abstract design modules and the exchange of service messages, the operation logic of the foundation and core application of network operation is established (Automatic Task). Afterwards, simulations of the application design and system implementation may be performed to verify the system behaviours, and then realize the optimum design of the core application (Supported Task). In order to render the conceptual design architecture diagram of the system, this project will illustrate the key technologies and hardware and software elements involved in the system design.

2.3 Phase III: Embedded system implementations

To conduct embedded system implementation, students usually need fundamental understanding on embedded system design. Since embedded system is by nature cross-discipline, from the perspective of lecturing a course, it can be a preliminary of advanced courses and focus on giving an overview of system design. For example, a traditional bachelor course on "embedded system" in EECS will introduce fundamentals of embedded hardware components and firmware. Labs are usually given to concrete the abstract concepts. On the other hand, it can also be an integration of core and fundamental courses (e.g., circuit design, VLSI, SOC) and can be further arranged as a senior course or a first year graduate course.

Nowadays, to accomplish a real world application with embedded systems, a variety of knowledge are required. For example, many applications require the ability to interact with outside world so that the network protocol stack should be included to access the Internet. For ease of implementation, many state-of-the-art embedded design platforms with OS ported are chosen, which implies that knowledge on system software, client-server programming, distributed and parallel architecture are thus required. Furthermore, to endow applications with intelligence, preliminary knowledge on data mining or machine learning may be needed. As can be seen that embedded system implementation involves many traditionally disjoint engineering disciplines, (e.g., OSs, MCs, programming languages, networks, applications, data analysis), a comprehensive education program on embedded system is essential to provide appropriate foundations for the embedded system design. Therefore, it is not easy to convey comprehensive knowledge in one or two curricula so that students can complete their projects to a certain level.

A more efficient arrangement of a course on embedded system implementation is to adopt problem-based learning (PBL), which is a pedagogy where groups of students work together and apply practical techniques to solve a problem. The problem is an incentive that keeps students thinking and proposing a probable solution. It is also the motivation for students to learn the fundamental knowledge of embedded systems in order to complete their proposal. From the PBL aspects, we can detail only on embedded system components that are demanded to solve students' problems and convey other topics briefly. For example, to equip an application with automatic decision ability, classification techniques like regression or neural network may be lectured on, instead of a complete introduction to all data mining techniques. Besides, as the technology advances, more embedded hardware or software components are wrapped layeredly. For example, many circuits and chips of variety function are wrapped into SOC. This trend can be obviously seen as software components are also wrapped layer by layer into a high level module or API. Therefore, detailing the knowledge of all components for embedded system is even more difficult and may not be necessary for embed system implementation. However, applying PBL is not an easy task because defining a proper problem to arouse resonance and inspire discussion is difficult especially when students' preliminary knowledge is not sufficient or not consistently. A real problem given by cross-discipline experts is hard to solve expectedly while unrestrained imagination from students themselves are generally impractical.

Therefore, different from a traditional PBL course, we arrange a two-course program of IoT and embedded system to solve cross-discipline problems. In the first and 2nd stages, we stimulate the critical and creative thinking of students by 1) vising real fields where IoT technology can be adequately applied, 2) lecturing IoT related knowledge, and 3) encouraging students to consider the design issue from cross-discipline perspectives and propose an IoT-based solution for the caring of our society. In the third stage, we encourage and guide students to apply embedded system technology to realize their ideas and proposals. To provide an incentive for the student to learn embedded systems, we continue the main theme of the IoT course and convey knowledge of embedded system under the framework of an IoT system. The course is arranged as a part of our master program for the students are more ready for PBL. We also encourage the senior students of our bachelor programs to go on the course strongly. In the course, students are grouped and collaborate to accomplish their project.

Specifically, with the goal of realizing students' proposal of an IoT application, we first give the fundamentals of embedded system. The main topics include an overview of embedded system, embedded system design flow, and major hardware and software components. We are prone to guide the students to implement a prototype of their idea by applying the existing embedded system platform with OS as well as IoT sensors and IoT networks. Thus, although the embedded operation system plays as an important role of an embedded system, many components of OS, such as cache replacement mechanism, CPU scheduling, disk management, won't be detailed. Similarly, nor do we detail the theoretic perspective of how a microcontroller is designed, the MCU architecture, or the assembly language.

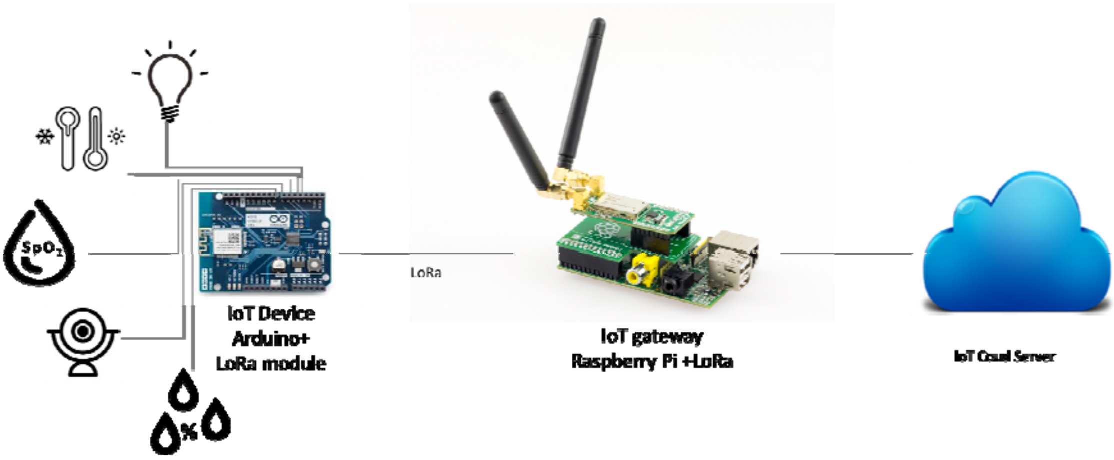


Fig. 5. An architecture of IoT Applications

Under the architecture of an IoT application as shown in Fig. 5, we will detail on I/O interface, interrupts and control mechanism, process operation w/wo OS, and data flow and storage. In addition to setting up a development environment, students will conduct the labs on building a basic IoT device to sensing data, integrating multiple sensors and performing a complex sensing task, interacting IoT device with IoT gateway, processing data among IoT device, IoT gateway, and the sever end. By the approach, we can avoid to integrate too much materials in a single course and can still promote student to complete their proposal to a certain degree.

2.4 Phase IV: Validating the system design

To validating the system design, we conduct opinion survey on both students as well as the users. Specifically, at the end of the second stage, the users as well as domain experts are invited to give suggestions on the ideas and the proposals based on student's demonstration. Students can grasp the chance to review their idea and proposals. In the third stage, students are encouraged to team up to participate in some contests like [6-7]. This is another chance for students to rethink the pros and cons. Finally, a creativity test on students will be conducted to evaluate the effect of the pedagogy on the student's creativity thinking at the fourth stage. The suggestion of the users, the degree of accomplishment, the feedbacks from the student, and even the contest results are feedbacks to revise the content of the program.

3. Case Study

A course project may be applied to develop a practical application using IoT technologies. The students are grouped into teams to discuss application architectures from cross-disciplinary perspectives and propose their problem statements, project deliverables, system descriptions, project setups, prototype implementation, test and feedback. Accordingly, each team will deliver the full architecture of the system and the important pieces of implementation details. Here, we use an activity monitoring system as an example to describe the design issues. A team project example is depicted in Fig. 6, where students may design an IoT application from cross-disciplinary perspectives for rescue and environmental monitoring by visiting a working fire station.

Fig.6. Developing a practical application with creative thinking and IoT technologies.

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The Development of Engineering Creativity Scale

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ABSTRACT

The purpose of this study was to develop an instrument to measure the quality and pattern of engineering creativity in university students in Taiwan and to investigate its reliability and validity. A scale named the “Engineering Creativity scale” was developed with two sub-tests: Design in Generating Sound and Design a Car. The items and framework of the scale were derived and revised from Charyton’s [1] and Yeh’s [8] studies with minor changes according to the Mandarin usage and local culture.

One hundred eighty-eight undergraduate students from a university in Taiwan were recruited as participants in April, 2017. The results indicated that the test-retest stability, internal consistency and content validity are satisfactory. The implications of this study for further research to establish the Engineering Creativity Scale and engineering creativity teaching and learning are discussed.

Conference Key Areas: Engineering Educational Research, Attractiveness of Engineering Education, Skills and Engineering Education
Keywords: Engineering creativity, Scale, University students

INTRODUCTION

In recent years, creativity has become one of the most important issues in engineering education in Taiwan. Many trans-disciplinary programs in Taiwan have focused on the subject and hundreds of web pages display information on how to be more creative and achieve innovation in engineering. To understand and evaluate the quality and pattern of engineering creativity in university students in Taiwan, a trustworthy, reliable and valid creativity instrument is needed to meet the needs of practice and research purposes. The purpose of this study was to develop the Engineering Creativity Scale for measuring university students’ engineering creativity and to analyze the psychometric properties of the scale.

THE DEVELOPMENT OF THE TEST

One of the most common frameworks for creative thinking processes, described by Torrance [6], consists of four aspects: fluency, flexibility, originality, and elaboration. Fluency refers to the production of a great number of ideas or alternate solutions to a problem. Flexibility refers to the production of ideas that show a variety of possibilities or realms of thought. Originality involves the production of ideas that are unique or unusual. Elaboration is the process of enhancing ideas by providing more detail.

Recently, engineers not only need to address esthetics like artists, but they also need to solve problems, prevent potential problems, and address utility within the constraints and parameters that have been designated[1]. These aspects of creativity have been described as ‘‘functional creativity’’ [4]. Functional creativity means that products designed by engineers typically serve a functional and useful purpose. Building on this, problem-finding offers another avenue for increasing creative production [5]. Problem-finding and problem-solving are skills often found in and commonly associated with art, yet are also necessary in science and engineering. However, these attributes have not been specifically measured traditionally and, more recently, in engineering creativity. Such attributes need to be assessed and further developed by appropriate educational intervention activities [4]. Torrance’s four dimensions (fluency, flexibility, originality, and elaboration) and their usefulness were adapted in this study as central to the development of the theoretical framework of a scale, namely, the Engineering Creativity Scale.

The “Engineering Creativity Scale” consists of two sub-tests: “Design of generating sound” and “Design a car” which were derived and revised from Charyton’s [1] and Yeh’s [8] studies with minor changes according to the Mandarin usage and local culture. The “Design in Generating Sound” was designated to ask subjects to draw two designs based on two 3D images. The subjects were also asked to describe their designs by answering the following questions: “what is your design?”, “what are the materials of your designs?”, “what are the problems solved with your designs?”, and “who will be users of your designs?”. The second sub-test, “Design a Car”, was designated to ask subjects to draw a car using their imagination and design. Then the subjects were asked to describe the features and specifies of the car they designed. The Engineering Creativity Scale” is shown in Appendix 1.

The test was designed for group administration. The test time limit is 30 minutes (10 minutes for Design in Generating Sound; 20 minutes for Design a Car). The draft version of the test was given to 6 university students (3 males and 3 females) to measure the face validity of the scale. In order to estimate the psychometrics of the scale, a sample of 188 university students in a local university were recruited as participants. Among these participants, 22 of them were administered a two-week test/re-test process for examining the stability of the scale, and 28 participants’ Engineering Creativity Scales were scored by 4 trained scorer(one educational doctoral candidate and three electrical engineering graduate students) for examining the inter-rater reliability of the scale.

SCORING PROCEDURE

In this study, the answers of participants’ Engineering Creativity Scales were scored by one educational doctoral candidate and three electrical engineering master graduate students, and they had been trained by this paper's authors to learn how to score the engineering creativity scale within the previous two months. The following procedure steps were used to score each subject's answer. The Design in Generating Sound consisted of four dimensions: fluency, flexibility, originality, and usefulness. Fluency was computed by the number of ideas on the sketch, description, materials, problems solved, and users. Flexibility was counted by the number of different categories, types, or classifications of responses. Originality was scored by an 11-point scale. The Usefulness is scored by a 5-point scale. At first, D1 and D2 were scored separately, and then sum of D1 and D2 was computed for each dimension, separately.

The Design a Car" included four dimensions: fluency, flexibility, originality, and elaboration. The fluency score was given simply by counting all of the valid responses given by the subjects. The flexibility score was given by counting the numbers of category of students' answers on the car features. The originality score was developed from a tabulation of the frequency of all of the responses obtained. Frequencies and percentages of each response were computed. Among all answers, 2 points were given to a special answer for the originality score when the probability of this answer was smaller than 5%. One point was given to an answer of which the probability is between 5% and 10%. The elaboration is obtained by counting the numbers of car specifies given by subjects.

Finally, the total score of "Design of Generating Sound" for each subject was computed by summing of his/ her T scores of fluency, flexibility, originality, and usefulness. The total score of "Design a Car" was computed by summing the T scores of fluency, flexibility, originality, and elaboration. The total scores of engineering creativity for each subject are computed by averaging scores of these two subtests' scores.

RELIABILITY AND VALIDITY ANALYSES.

1 Reliability

1.1 Internal consistency reliability

The Pearson product-moment correlation coefficients among dimensions (fluency, flexibility, originality, elaboration, and usefulness) and total score were calculated. The results are shown in Table 1. The correlation coefficients between dimensions and total score vary from 0.23 to 0.94, which are relatively high. Most of the correlations coefficients are significant at the 0.001 level except the correlation between usefulness and elaboration

.

Table 1. The internal consistency reliability of ECS (*n*=188)

Variable	Fluency	Flexibility	Originality	Elaboration	Usefulness	Total Score
Fluency	1					
Flexibility	.88***	1				
Originality	.79***	.72***	1			
Elaboration	.68***	.58***	.64***	1		
Usefulness	.50***	.46***	.61***	.23***	1	
Total Score	.94***	.90***	.91***	.74***	.65***	1

****p*<.01

1.2 Test/re-test reliability

The results of the test/re-test reliability are shown in Table 2. The correlations coefficients between the first test and retest are significant among fluency, flexibility, originality, and total scores (r (22) =.44 - .56, p<.05). The results of this study indicated that the engineer creativity scales developed in this study has a good stability.

Table 2. The test-retest reliability of the ECS (*n* = 22)

Variable		Re-test					
		Fluency	Flexibility	Originality	Elaboration	Usefulness	Total Score
Test	Fluency	.50*					
	Flexibility		.44*				
	Originality			.56**			
	Elaboration				.38		
	Usefulness					.21	
	Total Score						.51*

**p*<.05 ***p*<.01

1.3 Inter-rater reliability

The results of the inter-rater reliability are shown in Table3. The Kendall's W coefficients of fluency, flexibility, originality, elaboration and total scores are between .47 and .97, which are significant at the .01 and .001 level. The results of this study indicated that the scoring criteria of the engineering creativity scale between different scorers are consistent.

Table 3. The inter-rater reliability of the ECS

	Fluency	Flexibility	Originality	Elaboration	Usefulness	Total Score
Kendall's W	.97***	.91***	.75***	.93***	.47**	.92***
Chi-Square	105.04***	97.85***	81.17***	100.45***	50.78**	99.46***
df	27	27	27	27	27	27

Note: Scorer=4; *n*=28 ***p*<.01 ****p*<.001

2 Content validity

Content validity refers to the extent to which a measure represents all facets of a given construct. Content validity requires the use of recognized subject matter experts to evaluate whether test items assess defined content and more rigorous statistical tests than does the assessment of face validity. An initial pool of 4 subtests were written to reflect the logical and semantic content of the concept of creativity based on relevant past sources and engineering creativity research and on dictionary definition. Nine experts or university professors in engineering, education, or psychology were asked to determine content validity of the four initial subtests. The content of the Engineering Creativity Scale has been modified based on the experts' suggestions and comments. From the initial 4 subtests, two of them were chosen for use in this study.

SUMMARY AND FURTHER WORK

The purpose of this study was to develop the Engineering Creativity Scale for university students in Taiwan and to investigate its reliability and validity. Based on the creativity structure model and related theory, the Engineering Creativity Scale was developed to consist of two subtests: "Design in Generating Sound" and "Design a Car". These two subtests were designed to measure five aspects: fluency, flexibility, originality, elaboration, and usefulness. The internal consistency, test-retest reliability, interrater reliability and content validity are found to be satisfactory.

This study proposes some suggestions for engineering learning and teaching, and further research. First, a parallel form of the current scale should be developed in order to estimate the alternate-forms of reliability. Second, the criterion-related validity with existing tests, such as the Torrance Test of Creative Thinking [6] needs to be estimated in order to confirm the criterion-related validity of the engineering creativity scale for assessing creativity of university students in Taiwan. Third, further research should explore the relationships between different university students' backgrounds and engineering creativity using the Engineer Creativity Scale that was developed in this study. Matters that could be explored might include: the relationships between grade, school type, the field of study, family background and engineering creativity.

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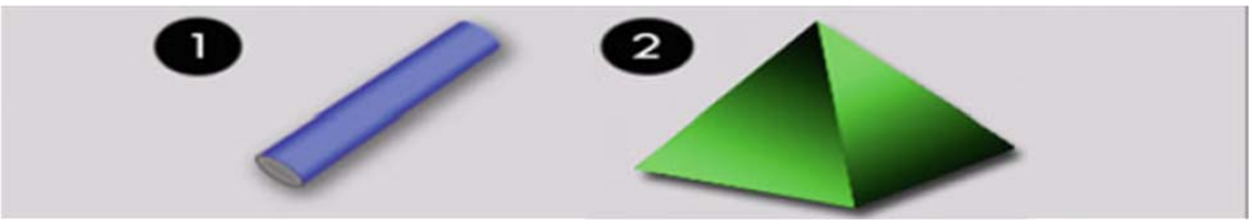
Appendix 1

I. Design of Generating Sound（10 minutes max）

Below you find 2 shapes. At seeing these two shapes, you might have some ideas popping up. Be creative, use your imagination and see if you can come up with “a design that generates sound.” These 2 shapes can be of any material and size of your choice, and can be either solid or hollow. However, <u>each shape</u> can be used <u>only once</u>. Please make sure that you include the drawing of the design, description of the design, the materials used (the texture), problems with which the design may be solved and people who may find the design handy.



Your design	1	2

Description of your design		
Materials used / texture		
Problem with which design can be solved		
Potential users / why they may find the design handy		

II、Design a Car （1）Drawing a car（10 minutes max）

What would you do if invited to design a car? You are encouraged to incorporate as many different ideas as possible. Draw your design below and <u>name</u> the overall outlook and every feature included. Lastly, give the whole design/model a <u>creative name</u> as well.

Name of the model of the car：

____

II、Design a Car（2） Special features of the car（10 minutes max）

Please write down special features the car may have on the left, and on the right, specify with what <u>objects</u> or <u>facilities</u> you may make the special features possible. If you missed anything in the previous section, you may include them here. You may check back on your design but do not add anything else on the done design. The more you list here, the better.

Features（ex: … may allow; … can）	**Specify（what may be needed，ex：it needs..）**
ex：fire missiles	Need missiles、launcher
1.	
2	
3	

4	
5	

Active Learning in Practice
Implementation of the principles of Active Learning in an engineering course

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ABSTRACT

The most common form of teaching is still the form where a teacher presents the subject of the lecture to a listening audience. During teaching history this has proved to be an effective way of teaching, however the probability of students being inactive is high and the learning outcome may be small for these students.

An alternative teaching method is "Active Learning" and in the autumn 2015 we implemented this method to a 5 ects. course of "Material Science". What we wanted to examine was:

- How can Active Learning be implemented in the Material Science course
- Is it possible to get through the same curriculum as usual during a term?
- Will Active Learning reduce failure rate?
- Will Active Learning give a higher learning outcome than traditional teaching?

This paper deals with the results of this experiment, answers the mentioned questions and presents a way to implement Active Learning.

INTRODUCTION

In the spring 2015 the subject of the biannual teaching and learning seminar which The Technical University of Denmark (DTU) arranged had the subject "Active Learning".

The main speaker at the seminar was Mark Decker[1)] who gave an excellent presentation of the principles of Active Learning under the title "The One Who Does the Work Does the Learning".

We decided to implement the ideas of Active Learning in my course; a 1st semester course for diploma engineering students with the subject: Materials Science.

The subjects of my study were:

- How can we implement the model of Active Learning in the Materials Science course?
- Is it possible to get through the same curriculum as usual during a term?
- Will our implementation of Active Learning reduce failure rate?
- Will our implementation of Active Learning give a higher learning outcome than traditional teaching?

The project of implementing the Active Learning principles in the course was succeeded in the autumn 2015, and after this semester Active Learning has been conducted three times.

1 ACTIVE LEARNING AND TEACHER CONTROLLED TEACHING

1.1 The One Who Does the Work Does the Learning

The basic idea behind Active Learning is that the outcome of learning is higher for a student who reads the text, works with the exercises and tries to find solutions to the problems rather than a student who gets the curriculum told by a teacher and sees the solutions to exercises on a screen before having worked with them.

That is what is behind the words: 'The One Who Does the Work Does the Learning'. When one reads the lecture material and then works with the problems given in the text or as an appendix to the text and try to understand difficult parts by working with them instead of just asking an expert, the learning outcome will be high.

So the basic principle behind Active Learning, as a structure in the lessons, is that the teacher does not speak or present the curriculum, instead the students use the time to make self-studying. This can be in groups or individually, but in most cases group work is used.

1.2 Mark Decker's structure of a lesson based on Active Learning

One of the basic principles in Mark Decker's[1)] implementation of Active Learning is group work and here it is important that the facilities of the tuition room(s), support group work. Actually a sub title to the teaching and learning seminar at DTU in the spring 2015 was "Creating Effective Active Learning Environments" and here a room with small tables and many whiteboards was suggested.

The structure of the lesson is an alternation between group work with problems given by the teacher and group presentations of the results from the group work.

Mark Decker divides the curriculum of the day into the levels of Bloom's Taxonomy. The part of the curriculum of the day which belongs to the lower levels of Bloom's Taxonomy is not discussed in the lecture. It is taken for granted that the students have made themselves acquainted with this part, which can be read from a text book or from other sources. "The students always meet up well prepared" Mark Decker claims and if they do not, they will soon learn that if they are to perform in the group, they have to be well prepared.

The questions, which are discussed and later presented by the groups, start from or just above level 2 and during the lesson climb higher and higher and sometimes, reach top level.

The students are active throughout the lesson either by working with the problems, by presenting their results or by evaluating other groups' work. The groups that are to present their results are chosen from a random number generator, so the groups have the same probability for being selected for presentations and therefore they quickly learn to utilize the group working time efficiently. A point system ensures that the students actually do the group work and don't let the person who seems to be the most clever answers the questions.

The active work in the class room and the active acquisition of the basic stuff at home ensures the Active Learning.

1.3 The Traditional Teaching method and the Active Learning

It is often mentioned that Active Learning (and many other teaching methods) gives a higher learning outcome than the widely used method where a person tells and presents subjects to students. However, when alternative teaching methods such as 'Problem Based Learning', 'Learning by Inquiry', Spiral learning', 'Learning with Cases' are presented, it is often where the amount of "subjects" or the complexity isn't high. In many courses with higher complexity or where the amount of details to be acquainted with is high, the teacher often selects the teaching method where he or she presents the stuff to the students.

In situations where textbooks and other sources are not in good agreement with the content of the course, the teacher also often selects teacher controlled teaching.

Teacher controlled teaching still has some advantages and there may also be students who learn more from an expert than from self-studies and group discussions.

The course Material Science is a course with high complexity and a high amount of details. Therefore this course was selected as test course.

2 IMPLEMENTATION OF ACTIVE LEARNING IN THE MATERIAL SCIENCE COURSE.

2.1 The planned structure

The following lesson structure was decided as a practical bridge between the recommendations of Mark Decker[1)] and what seemed feasible.

0:00 - 0:30 Class discussions of questions which the students have asked me to go through after the previous lesson. Questions can be given after the previous lesson or during the week.

0:30 – 0:45 Presentation of the subject of the day and presentation of the questions they have to work with in groups.

0:45 – 1:45 The students work in groups with the questions

1:45 – 2:00 The groups present their work and their answers to the questions

2:00 – 2:10 Collection of questions to be highlighted next time.

2:10 – 4:00 Half of the groups work with exercises (standard home exercises) which are to be handed in 7 or 14 days later. The other half of the groups work with practical exercises in a material test laboratory. Over each of these exercises the groups shall deliver a journal. The groups alternate such that next week the group working with the home exercises will make the practical exercises and vice versa.

As can be seen each lecture covers four hours, where the final two consist of some kind of exercise.

The material the students have to read before the lecture is certain pages in the text book and the power points I would have used during a normal lesson.

Before the experiment started in the autumn 2015, the final two hours of the 4 hour lesson were also reserved for exercises and one can claim that in this period the students did a kind of Active Learning, however it is not in accordance with the definition of Active Learning.

When comparing with the Active Learning as presented by Mark Decker, it is seen that the full model of Active Learning is not implemented. *First* each lesson starts with half an hour of teacher treated content, however this part of the stuff is an enquiry from some students and it is assumed that the students are motivated to actively follow the teacher's explanations. *Second* the questions given are based on the textbook and the notes which the students have been able to download from our information board at least a week in advance. So the questions and discussion deals with the lowest level of Bloom's taxonomy.

There were three reasons for this model.

- The students are newly enrolled in the university and have no experience in studying. For many of the students the jump from being guided through the material to be an active student is high.
- Although being an experiment the demand; that the experiment must not result in lower exam grades or in lower learning outcome has not been reduced, thus I did not dare to make too large a step.
- The experiment should reveal the above mentioned effects from Active Learning. Therefore I did not dare to change to many parameters at a time. The job was to investigate the effects of exchanging the speaking teacher with self-studying groups.

2.2 The structure as it developed

Active Learning was introduced in the first lecture in order to make it start from lecture no. 2. And the model from above was introduced.

1. It **s**oon became clear that the session with groups presenting the results they had achieved during group work did not work. I had not implemented the random number generator or the point system, which might have helped. Some groups declined presenting their results, and soon it was the same two groups that presented their results each time.

Often they had some difficulties answering the questions which gave me an opportunity to address these questions to the auditory and thereby start a class discussion over a subject which assumable all groups had had problems with. However this does not violate the principles in Active Learning, so I did not make any efforts in changing this.

Another problem was the time schedule. Only 15 minutes were reserved for the presentation/discussion part of the lecture and this was not enough. Often we finished the theoretical part of the lesson after 2½ hours giving only 1½ hour for exercises.

These problems caused that group presentations over a period of about two months stopped and were fully replaced with class discussions.

2. A problem, which quickly rose, was that the students felt uncertain whether they learned what they had to. Many people have the feeling that what they learn through self-study is not as good as what a professional teacher can teach them. It makes Active Learning an insecure experience.

In the course description 8 to 12 learning objectives are given, this is sufficient for a student to select or deselect the course or for a board to get an impression of the course content. But for a student, who follows the course, these learnings objectives are insufficient to use as indicators for how well their learning complies with what is expected.

So in order to give the students indicators they can use to evaluate how well they follow the course, I made a list of learning objectives for each lesson. The number of learning objectives for each lesson was between 8 and 12 and the complete list ended with about 100 learning objectives. This list proved to be a great help giving the students a feedback of how well they followed the expected learning outcome.

I named the list '*Core Elements*', ignoring that this concept is often used for other subjects in the teaching environment.

3. After a while the students stopped making question to be treated the following lesson. The reason was not that they had a good understanding of all the questions and felt secure regarding that. The reason was partly that some lost their overview over weak subjects, some were not able to express their questions and others were not so worried over what they did not understand that they formulated it as a problem to go through.

Therefore I got the idea to start each lesson with the list of core elements from the previous lesson and use this as a check list. For each core element I asked the auditorium whether they felt that they had an adequate understanding of the subject, or if they knew how to achieve this understanding. This helped a lot for revealing soft spots.

The planned half hour was often insufficient for teaching these subjects; however it also turned out that it was unnecessary with 15 minutes for presenting the subject of the day, so some time was taken from this activity.

At the end of the course the daily plan had changed to:

0:00 - 0:40 Showing and discussing the core elements from the previous lesson on the video projector screen. Making a short teaching/updating of the subjects where the students wants a deeper understanding, however in order not to start to much ordinary teaching, the discussion is made without PowerPoint support. Mostly oral explanations and some strokes on the whiteboard

0:40 – 0:45 Presentation of the subject of the day and presentation of the questions they have to work with in groups.

0:45 – 1:45 The students work in groups with the questions.

1:45 – 2:20 Class discussion of the answers to the mentioned questions.

2:25 – 4:00 Half of the groups work with exercises (standard home exercises) to be handed in 7 or 14 days later. The other half of the groups work with practical exercises in a material test laboratory. Over each of these exercises the groups must write a journal.

Despite changing the ideal lesson plan it is still Active Learning, because the achievement and treatment of the new learning subjects are done by themselves, I only help when they need help.

3 DID THE IMPLEMENTATION OF ACTIVE LEARNING GIVE AN ANSWER ON THE MENTIONED SUBJECTS?

3.1 How can Active Learning be implemented in the material science course?

In part 2.1 and 2.2 above a course structure utilising the ideas of Active Learning is described. The plan follow the suggestions of Mark Decker[1)] with the following exceptions:

- In the first 30 to 40 minutes of the lectures the core elements from the previous lesson are discussed. Partly as repetition but mostly as a check for the student to clarify, whether their knowledge of the stuff is adequate or need further treatment.
- The questions in the self-study time belong to the lowest level of Bloom's Taxonomy, where Mark Decker recommends that they deal with the higher levels.
- There were no score systems for the students and the presentation session was replaced with an open class discussion.

3.2 Is it possible to get through the same curriculum as usual during a term?

Yes, we came through the same amount of material as in the previous semesters. The distribution of the curriculum over the lessons was exactly the same. In a way it was easier, because the students got the whole curriculum for the day to read and to get acquainted with and there was no expectation that the questions they worked with did cover the entire curriculum, but they should still adopt the stuff.

In a normal lesson it is expected that the teacher gets through all the stuff that has been given in the curriculum of the day.

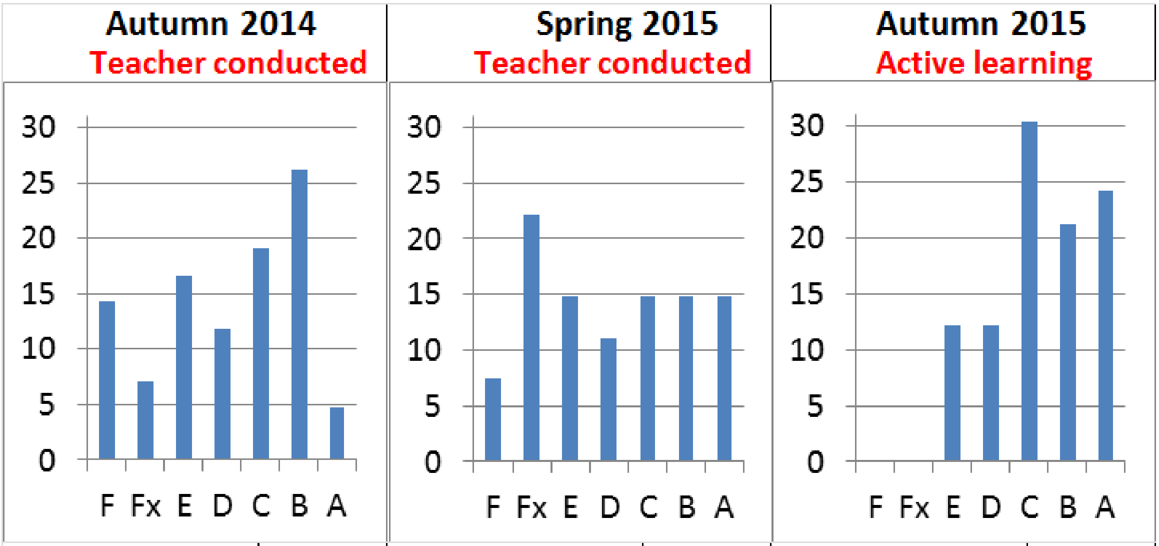
3.3 Will our implementation of Active Learning reduce the failure rate?

Figure 1. The Danish ECTS grade levels.

ECTS Grade	Description
A	Excellent
B	Very good
C	Good
D	Average
E	Sufficient
Fx	Insufficient
F	Poor

The course ends with a 4 hours' written exam, and the above mentioned question is best answered through a study of the examination results which are sorted into the levels shown in figure 1.

Figures 2A and 2B show the examination scores and only students who participate in the exams for the first time are included.



Fraction F and Fx	0,21	Fraction F and Fx	0,30	Fraction F and Fx	0,00
Fraction D and E	0,29	Fraction D and E	0,26	Fraction D and E	0,24
Fraction A, B and C	0,50	Fraction A, B and C	0,44	Fraction A, B and C	0,76
Fraction A and B	0,31	Fraction A and B	0,30	Fraction A and B	0,45
N. of candidates	42	N. of candidates	27	N. of candidates	33

Figure 2A. Scores for the 3 first semesters

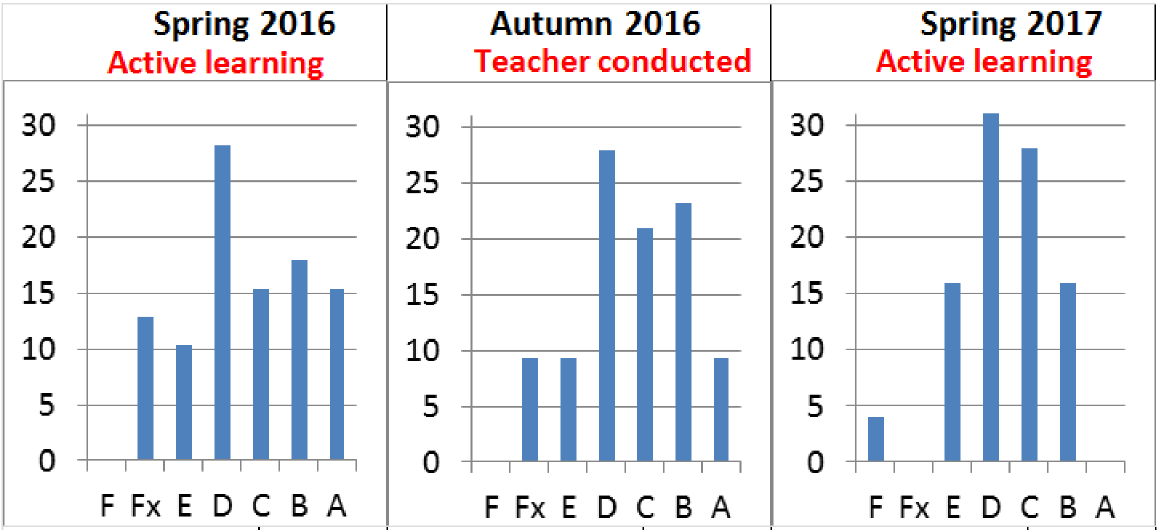
The semesters with teacher conducted teaching gave the following failure rates: 0.21, 0.30 and 0.09 giving a mean of 0.20 and a standard deviation of 0.102

The semesters with Active Learning gave the following failure rates: 0.0, 0.13 and 0.04 giving a mean of 0.06 and a standard deviation of 0.066

The failure rates and the calculated mean values are shown in figure 3.A

A mean failure rate of just 0.06 contra 0.2 indicates that Active Learning gives a lower failure rate but it is interesting to calculate how significant this deviation is.

Due to the poor statistical material it is supposed that the mean values follow a Student-T distribution which is shown in figure 3.B.



Fraction F and Fx	0,13	Fraction F and Fx	0,09	Fraction F and Fx	0,04
Fraction D and E	0,38	Fraction D and E	0,37	Fraction D and E	0,52
Fraction A, B and C	0,49	Fraction A, B and C	0,53	Fraction A, B and C	0,44
Fraction A and B	0,33	Fraction A and B	0,33	Fraction A and B	0,16
N. of candidates	39	N. of candidates	43	N. of candidates	25

Figure 2B. Scores for the 3 last semesters

The true mean failure rate for teacher conducted teaching is called μ_C and the mean failure rate for Active Learning is called μ_A. The question to be answered is: <u>Based on the given data, on which confidence level is μ_A is lower than μ_C</u>?

By utilizing the student-T test it can be calculated that $\mu C > 0.11$ on an 85 % confidence level.

$$\mu_{C,lower\ bound} = 0.20 + T.INV(1-0.85,2) \cdot 0.102/\sqrt{3} > 0.11$$

And it can be calculated that $\mu A < 0.11$ on a 85% confidence level:

$$\mu_{A,upper\ bound} = 0.06 + T.INV(0.85,2) \cdot 0.066/\sqrt{3} < 0.11$$

where T.INV(α,β) is the invers cumulated Student T distribution with probability α and degree of freedom β.

I.e. the data shows a significantly lower mean failure rate for Active Learning on a confidence level 85 %. ($\mu_{C,\text{ lower bound}} > \mu_{A,\text{ upper bound}}$).

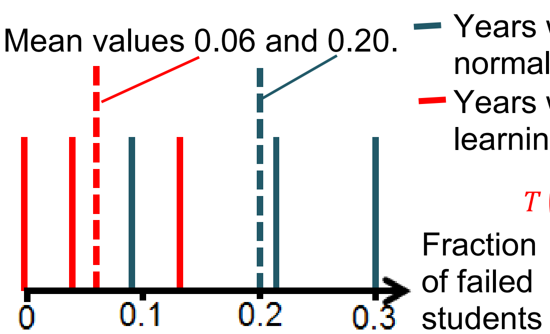


Figure 3A. Measured failure rates and calculated mean values

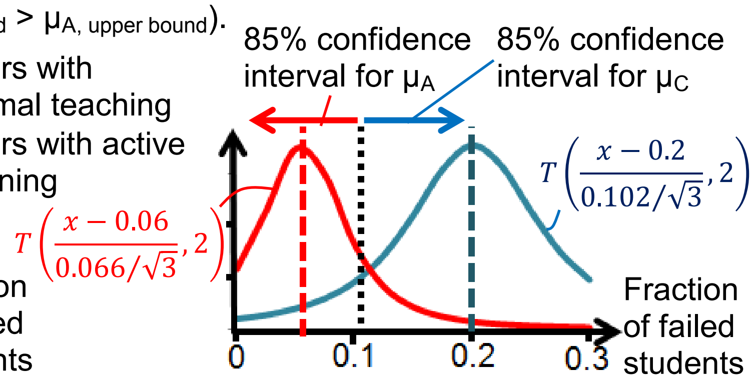


Figure 3B. Mean failure rates follow a T-distribution

3.4 Will our implementation of Active Learning give a higher learning outcome than traditional teaching?

With the concept "Learning Outcome", I mean the deep understanding or the academic insight that lies well beyond “just passing the exam”, where one can understand why the elements are designed and why they have the properties they have or in other words; the knowledge where one gets to the top three levels of Bloom’s taxonomy.

A good question is whether there are measurements that can reveal whether the proportion of students, who have achieved this goal, has risen?

One could suggest that the fraction of passed students who achieve a C, B or A, or perhaps just the fraction of students who has obtained a B or A, indicates the fraction of students who have reached a level of deep understanding. An increase in these fractions in the Active Learning semesters could indicate that Active Learning gives deeper learning outcome.

The fraction of students having passed the examination and obtained a C, B or A score can be calculated as:

$$\mathrm{F_{ABC}} = \frac{\mathrm{F_A + F_B + F_C}}{\mathrm{F_A + F_B + F_C + F_D + F_E}} = \frac{\text{Fraction A, B and C}}{(\text{Fraction A, B and C}) + (\text{Fraction D and E})}$$

where F_A is the fraction of students in the class who obtained an A, F_B is the fraction of students in the class who obtained a B, and so on. (Fraction A, B and C) and (Fraction D and E) can be read from tables below figure 2A and 2B.

Similarly, the fraction of students having passed the examination and obtained an B or A score can be calculated as:

$$\mathrm{F_{AB}} = \frac{\mathrm{F_A + F_B}}{\mathrm{F_A + F_B + F_C + F_D + F_E}} = \frac{\text{Fraction A and B}}{(\text{Fraction A, B and C}) + (\text{Fraction D and E})}$$

The mean value for F_{ABC} in the years with traditional teaching is: 0.62
The mean value for F_{ABC} in the years with Active Learning is: 0.59
Which must be interpreted as; “no difference” compared with the scattering of the results.

The mean value for F_{AB} in the years with traditional teaching is: 0.39
The mean value for F_{AB} in the years with Active Learning is: 0.33
Which again must be interpreted as; “no difference” compared with the scattering of the results.

So the test does not indicate that Active Learning gives an achievement of deep understanding, nor the opposite. (The two numbers are a bit lower for the years with Active Learning, but due to the scattering of the results this must be interpreted as random deviations).

4 CONCLUSION

A pedagogical experiment of using Active Learning as replacement of the traditional teaching was conducted with the purpose of answering the following questions:

- How can we implement the model of Active Learning in the Materials Science course? *The study showed that this was possible.*
- Is it possible to get through the same curriculum as usual during a term? *Yes*
- Will our implementation of Active Learning reduce the failure rate? *Yes. Data shows that Active Learning gives lower failure rates on a confidence level of 85 %*
- Will our implementation of Active Learning give a higher learning outcome than traditional teaching? *No it is unaltered.*

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Introducing Process Simulation in Junior Level Chemical Engineering Courses Using a Problem Based Approach

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Abstract

Problem-based Learning (PBL) is an approach that challenges students to "learn how to learn," working in groups to seek solutions to real world problems. The process replicates the commonly used systemic approach to resolving problems or meeting challenges that are encountered in practice, and will help prepare students for their careers. In this respect, the intent is to begin the development of students toward expert level. Cognitive psychology [1] and naturalistic decision making communities have developed an extensive amount of literature documenting the differences between novice and expert performance. It is now an established notion that individuals learn by building on what they know. However, chemical engineering students often enter their junior year with various misconceptions, some with minimal knowledge of the domain and a minimum understanding of how the discipline is organized. Therefore, developing learning events, for these students (novices) require us to understand what the differences are between students and experts, which will enable the selection of appropriate instructional strategy [2]. In order to design training that will support this learning process, it is essential to define the two levels of proficiency and understand the differences between them.

Conference Key Areas: Classroom delivery, engineering domain knowledge, summative assessment, formative assessment, curriculum development

Keywords: Concept Inventory, engineering problem solving, conceptual learning, process simulation

INTRODUCTION

Leading organizations [3],[4] such as the American Society for Engineering Education; National Academy of Engineering [5], and President's Council of Advisors on Science and Technology [6] have made a national pitch in favor of improvement in undergraduate science, technology, engineering, and math (STEM) education. The envisioned improvements would be a vehicle to increase quality, and diversity of STEM graduates. However, such an outcome is unachievable without keen attention to the instructional practices of STEM faculty. Currently, as public institutions struggle with budgetary issues, and in many cases, underperformance based on metrics such as graduation rates, growing attention toward instructional practices of STEM faculty is encouraging the adoption of research-based teaching.

Problem Solving

It is an accepted notion in the engineering community that problem solving is central to engineering practice activities and is a key component of engineering training. In the spring 2016 semester a section of the chemical engineering junior-level separation process course was piloted to deliver new information in a workshop format in the first part of a week, then conduct process simulations in the second part of each week to validate results or explain discrepancies obtained through graphical or hand calculations. Each significant example calculation that accompanies a new topic area such as using the McCabe-Thiele Method to determine the number of theoretical stages in a given distillation process were subjected to this modified course delivery approach. In addition, students worked in groups of three or four on the simulations and were required to document their results in a structured report format, and submitted for grading as a mini-project. Formative assessment using Students Assessment of their Learning Gains (SALG) [7], resulted in 100% response rates with at least 67% of the class reporting moderate–great gain in understanding content, impact on their attitude, increase in their skills, integration of their learning and helpfulness of their class activities along with the benefit of citing their experience on their resumes. These formative assessments were conducted to ensure that the change in delivery from previous practices was not a source of distraction and will be continued as part of the course but not as the focus of the work being proposed here.

Instructor Reflection

Observation along with feedback from colleagues who have been teaching the course revealed that students have entered the process separations course with a substantial deficit in domain knowledge and an alarming amount of misconceptions about transport processes. In addition, it appears that students armed with current computational-able technology are deciding to abandon traditional problem solving techniques such as developing a process diagram, an abstract representation, containing all given information prior to attempting to delve into deriving solutions. This approach usually lead to poor results and frustration. It is well established in the literature [1], that the quality of a problem representation influences the ease with which such a problem can be solved. Others have observed that physics experts organize their problem representations around abstract physics principles while novices tend to organize their representations and approaches around the problem surface features [8], [9]. According to some [10], concepts function as organizers, that is, they help us to differentiate between plants and animals or velocity and mass and momentum. Concepts allow us to categorize our physical surroundings and does have an impact on what we do with our categorized information. This means that understanding conceptual knowledge is a critical factor in the development of competence in engineering students and in practicing professionals [11], [12]. Indeed, the inability to recognize changes in process variables such as flowrates, temperature or pressure will ultimately lead to poor designs and sizing of operating equipment for use in processes involving energy exchanges, the consequence of which can be extremely costly in both economics and human lives.

AIM

In this work, we seek to use the process simulator as a means to refocus students on the concepts relevant to process separation. Process simulators by design contain several combinations of thermodynamic systems (packages) that capture the conceptual characteristics of real operating thermal and transport systems. For example, in a distillation process one (or students) must select a package that can predict the behavior of a given combination of chemical species under a specified set of operating conditions of temperature and pressure. The product distribution and accuracy of such a simulation forms the basis for the design and construction of industrial operating separation process systems. The thermal and transport concepts built into the thermodynamic packages are taught in prerequisite thermodynamic courses, however, course delivery time constraints substantially limit the amount of application-related practice in such prerequisite courses. Here, we seek to identify and repair conceptual weaknesses as they pertain to process separation. We plan to focus on those concepts exposed in thermodynamics relating to heat transfer, mass transfer, phase equilibria, and molecular diffusion all of which are considered difficult to understand. Misconceptions in these emergent processes could arise very early in science education, for example, in the study of blood circulatory system in an 8th grade biology class where a causal mechanism between the constituent components and the pattern in a non-direct process were underemphasized [13]. Indeed, if the identified misconceptions are longstanding, a corrective process employing a process simulator may prove to be an effective strategy given students' penchant for current computation-able technology, given that such misconceptions are still operational.

In a study conducted on undergraduate students' beliefs about engineering problem solving, five major categories were uncovered that are influential [14]: 1) The problem solving process, 2) The role of classroom problems, 3) The role of workplace problems, 4) Personal characteristics that affect problem solving and 5) The resources that assist problem solving. It has also been reported that students who preferred a classroom setting tended to conceptualize learning engineering as "testing" and "calculating and practicing" while students who preferred a laboratory setting conceptualize learning engineering as "increasing one's knowledge," "applying," "understanding," and "seeing in a new way" [15]. Further, the conceptions of learning for science can be represented by seven categories [16]: "memorizing," "testing," "calculating," "increasing knowledge," 'applying," "understanding," and "seeing in a new way," can be further subdivided into two views of learning; a lower-level view and a high-level view. The conceptions consisting of "memorizing," "testing," and "calculating and practicing" are reproductive learning strategies and reflect a lower-level view of learning; while "applying," "understanding, and" "seeing in a new way" are considered constructive learning strategies and reflect a high-level view of learning [16], [17].

Strategy

Recognizing that one approach to facilitating the capability to allow expertise to develop is to improve the level of domain knowledge and repair misconceptions of the incoming junior-level chemical engineering students entering the process separation course. Therefore, we are targeting their problem solving process to incorporate the strategies and techniques that practicing engineers are likely to use in their daily practice. Our approach will include categories 1, 2 and 5 as reported in [14] with the understanding that practicing (or real) engineers require a much broader problem-solving repertoire than any 4-year academic program can provide [18]. Indeed, real engineering experience will be acquired over the course of time following graduation, notwithstanding limited hands-on approaches that have been interjected through internships where available prior to graduation. We also seek to achieve the high-level view of learning: "applying," "understanding, and" "seeing in a new way" [16], and [17] in our graduates as this skill will provide them a head start toward becoming an expert engineer.

METHODS

It is a widely studied notion that, people tend to retain overly favorable views of their abilities in intellectual and social domains [19]. This overestimation of ones abilities seem to be rooted in the lack of the metacognitive ability to realize ones' own deficit. Apparently, the very skills that are required to evaluate competence in a domain are the exact ones lacking in the evaluator of others in that domain. There are established testing formats reported in the literature that can be adapted to determine which quartile display this metacognitive deficit [19], [20], and such instruments will be considered as an adjunct whose results may be useful in addressing longstanding misconceptions.

In addition, we will adopt results from past studies in chemical engineering education, for example [21], whose efforts focused on identifying important concepts in thermal and transport science that are difficult for engineering students to learn. In addition, we will consider and adapt approaches and results from others, such as in [22] that have already identified related thermodynamic and heat transfer concept areas along with accompanying common misconceptions with a different perspective.

Following the identification of the affected concepts in both thermodynamics and transport processes as they pertain to process separation, we plan to follow published works such as in [23] to seek confirmation of the reported effectiveness of differentiated overt learning activities in our study. Specifically, we anticipate creating an environment that supports interactive and constructive activities.

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Secret Agents at Campus

Mystery shopping feedback at a technical university

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ABSTRACT

At xxx University constant feedback is collected regularly through several different channels. This feedback is the core of the improvement of teaching and services offered to students. Even if the feedback is collected regularly it is somewhat difficult to create a big picture, what is it like to study at xxx University. To tackle this challenge, and gain more insightful information on the matter, Teaching and Learning Services together with the Student Union conducted a mystery shopping exercise. The mystery shopper method has not been used in any other university before and has been

criticised not to be suitable for university setting. At xxx University the mystery shopper exercise was seen as very insightful and valuable and despite its weak points, eg. personal opinions and narrow data collection, it was seen as a great way to give more detailed but also integrated information on what is it like to study at xxx university.

Conference Key Areas: Engineering Education Research, Quality Assurance and Accreditation, Curriculum Development

Keywords: Mystery shopping, student feedback

INTRODUCTION

Students, teachers and other personnel at xxx University share the goal of improving the quality of teaching and learning. University's quality assurance system ensures that the quality and standards of degrees are consistently maintained. The system is based on the Plan-Do-Check-Act (PDCA) model known as the Quality Cycle that supports a systematic and continuous cycle of improvement. University undergoes an external audit of its quality assurance system every six years. The purpose of the audit is to identify the university's strengths and challenges. Despite the fact that feedback is collected regularly, more comprehensible point of view was needed. For this, it was decided to implement a research by using mystery shopper method.

1 BACKGROUND

1.1 Feedback in a university context

Regular feedback is collected from students to develop the quality of teaching and learning. Students are encouraged to provide feedback by answering queries through course feedback system and completing other surveys concerning the quality of education, supervision or student services. For example, all students who graduate with a master's degree complete a survey that explores their career expectations and learning experiences.

Student feedback is regularly reviewed by department-specific committees that also include student representatives. Feedback helps the departments determine specific areas for improvement. Student feedback is very much appreciated and helps the university continuously improve and assess the quality of education.

xxx University has implemented a range of long-term plans to maintain and enhance the quality of education. Students have the opportunity to get involved in quality assurance by providing feedback and serving on various governing bodies and committees. There is also an email-address for open feedback where students and personnel can send feedback concerning all actions at xxx University. New initiatives can be made by sending email to another email address.

2 DATA COLLECTION AND METHODS

2.1 Mystery shopper method

Mystery shopping is a well-known and widely used method to test customer service processes. It can be used in any industry but it is mostly used in retail stores, hotels, movie theaters etc. The methods can vary widely but the main idea is to use trained individuals to act as a customer and report on their experiences in an objective way

[3]. In a mystery shopping method it is possible to use professionals who act as a customer or to use actual customers who then report their experience [2]. Douglas et al. explored the appropriateness of using mystery shopping in higher education institutes and concluded that would be a long way off [1]. Especially in engineering education, where most of the faculty are engineers themselves, a method of mystery shopping is not straight forward. It raises many questions on the reliability of the data and methods of collecting it.

2.2 Data collection

The key feature of the successful project was functional and direct communication between the university and the Student Union. After the reports were completed, they were openly available in the university intranet for all staff member and students.

During an appointed six weeks period, a chosen group of students kept a diary on all services they used and classes they attended and wrote down their feelings and opinions. The main aim was to collect supplement information to complement other surveys that are ran regularly. This kind of research method has not been used in any university and it gives a new insight into the world of engineering students. It compiles students' daily activities together with the lessons, software they use in the computer classes and methods that teachers use in their teaching.

Mystery shopper students were asked to observe their daily life but also to assess the quality of teaching and learning, highlight good practices in different faculties and degree programmes and assess the pedagogical competence and culture of teaching. The data offered an insight into the world of an engineering student. For example, what the students expect of teaching and how the teachers respond to this. Students also commented on instructions and guidance on courses they were taking, as well as on the course arrangements. Diaries also offered a source of information on the culture of learning, services for students and what xxx Univeristy is like as a campus and learning environment.

After the data collection phase, the students handed in their report diaries to Student Union that put together six extensive reports, one for each faculty. In these reports, a single mystery shopper student was not recognisable. The reports offered a big picture of students' daily life but also included valuable information on details that has not been visible before. Most of the qualitative research is focusing on multidisciplinary students and universities. This research exclusively offers insights in the world of a student in a technical university

2.3 Data collection process

The mystery shopping assessment method is widely used for example to evaluate the functionality of the customer service and improving the quality of various companies. Yet, the universities have not taken advantage of this method while evaluating the services they provide or the user experience the students receive. In the method, the subjects are not aware of the assessment process; therefore they are not aware that they are being evaluated. The goal is to generate objective and independent, although randomly collected, feedback. During the pilot project, feedback was collected only during the observation period, not during the surveyor's whole studentship.

The mystery shopper students were not given detailed instructions on how to collect the information. This was a deliberate decision in order to leave room for students' own ideas and impressions. Instead, students were only advised to write down their experiences and feelings about all services they use and courses they attend, but were asked to leave out the burden of history and unpleasant experiences they may have had in the past. Students were given “a fish-bone-model” of the quality of teaching and learning at xxx University which is seen in Figure 1 and were asked to write their diaries based on this model.

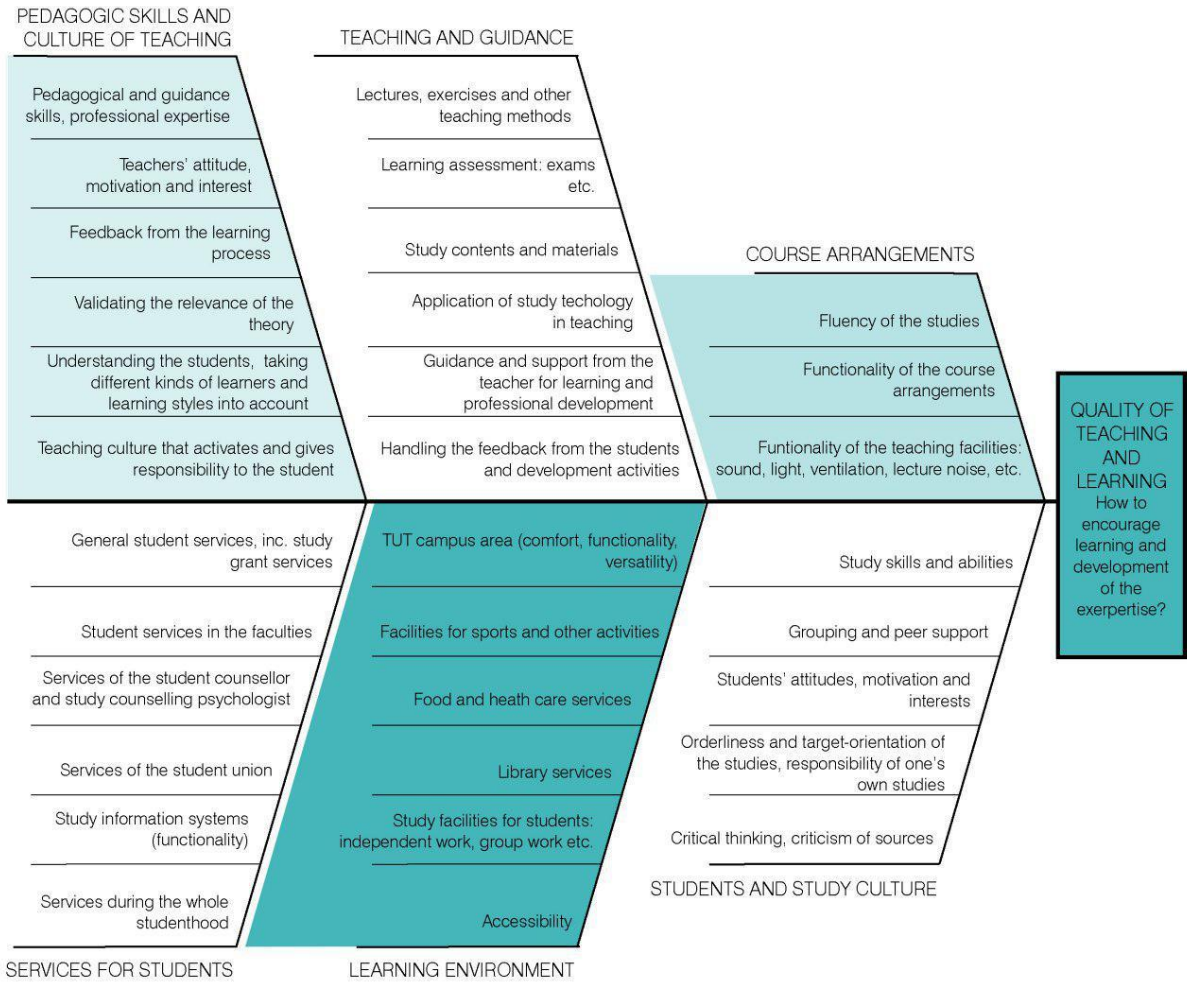

Figure 1. Fish-bone-model of quality of teaching and learning at xxx University.

2.4 The collection of the assessment group

The Student Union called for students to participate in a pilot group to assess the quality of the education and learning at xxx University. In total 46 students from years 1 to 7 applied to the group. The assessment group selected according to their degree programme and the composition of the group is seen is Figure 2.

ARCHITECTURE	6 females, 1 male years 1-4
CIVIL ENGINEERING	3 females, 3 males years 1-4
NATURAL SCIENCES	9 females, 3 males years 1-7
INDUSTRIAL AND INFORMATION MANAGEMENT	3 females, 3 males years 1-5
ENGINEERING SCIENCES	4 females, 2 males years 2-5
COMPUTING AND ELECTRICAL ENGINEERING	4 females, 4 males years 1-6

Figure 2. The composition of the pilot mystery shopper student group

The assessment group had a joint training session where the quality of education and learning process was approached with the help of "the fish bone model" as seen in Figure 1. The fish bone model was given to mystery shopper students to support reflection and the collection of the observations. The mystery shopper students were given a nominal fee of 100€ for their participation to ensure the retention and the quality of the reports.

2.5 Data collection period and reporting

The observation time for mystery shopping exercise was between 9th of February and 3rd of April 2015. This was chosen so that the observation period lasted slightly over one teaching period and it contained also an examination week.

After the mystery shopper time period, the students handed in their individual reports to Student Union. Eventually, Student Union compiled final reports, one for each faculty, from the individual reports. The reports were generated based on the following structure:

1. Teaching staff and teaching
2. Students and the study culture
3. Services for student
4. Learning environment

Individual observation reports illustrated a subjective experience of studying and learning of a student during a randomly selected period and courses at given time.

To validate the findings of the reports, the Student Union facilitated a meeting for each degree programme, where observing students from the degree programme in question collected all vital observations together. In addition to this, the groups ranked to most relevant observations in the reports and agreed on the feedback that will be in the final report. This validated the data, and the observations can be seen as common feedback and not only as individual opinions.

The final reports of the faculty-based groups were about 15 to 25 pages long and contained also observations from individual courses in addition of “the fish bone model”. These course-related comments were found at the end of the reports. The themes that were covered in the reports varied somewhat according the services and teaching methods the faculties provide and that the students need.

3 RESULTS AND FINDINGS

3.1 Main Findings

The mystery shopper students gave feedback from all the subareas mentioned in the fish bone model. Most of the feedback naturally concerned the quality of teaching. Students feel that teaching faculty at xxx University are experts in their own field, but that there is a wide variety of pedagogic skills and implementations of the courses.

Even if the students want to take responsibility of their own studies, they require clear information on the requirements to complete the courses and information on course arrangements. Altogether, the students wanted to be better informed.

There were also comments on individual courses and proposals for improvement. The quality of teaching and learning has a strong impact in the progress of the studies and the development of expertise. The utilization of technology was pronounced crucial.

Lecture recordings were considered a positive trend, partly because the traditional lectures were not considered that useful and students wanted to have more flexibility in their studies. However, there were concerns over the capability of the teaching staff to use new teaching technologies.

Observations about motivations were versatile. There were comments about the motivation of the teaching staff, but mainly the students commented on their own motivation to study. The key factors that determine students’ motivation seem to be related to the processing of the feedback during the course and the interaction with the teaching staff.

Facilities at xxx university were often brought up in the observation reports. The students felt that facilities influence greatly the fluency of the studies. New learning spaces were warmly welcomed. The university studies include more and more independent work and group work that are carried outside of the lecture halls, so diverse learning spaces are important. At xxx University, the students also spent a lot of their free time at campus, so functional social and sport facilities were experienced to be important.

At xxx University, the Student Union and the guilds have a major impact on the grouping the first-year students. The tutoring is organised together with the university and the Student Union and it is highly valued. Strong grouping among students in the same degree programme was experienced to be helpful later in the studies and also helped the integration into the academic society.

The attitudes towards gaining social skills and soft skills during studies have changed due to the needs of the working life. According to the observation reports, priority of social skills learn during studies seem to be related in social activities that are not directly related to the studies or courses. The solidarity of the student community was recognised to be very important.

3.2 Exploitation of the findings

Observations mentioned in the reports had various responses depending on the department: some found the comments from the reports familiar and had heard the same things through other feedback channels, for others the feedback was more surprising.

The attitudes towards the feedback collecting method were not unambiguously positive or negative: some felt that collecting feedback “in secret” to be strange, others thought the mystery shopping method was too unscientific, subjective and poorly comparable to be used to collect student feedback. Some departments thought that the feedback reflected the feedback received from other channels and highlighted noteworthy details. Altogether, the project brought out differences between departments when dealing with feedback. Despite the doubts, it was received positively.

Development actions in relation to the functions of the departments, faculties, support services and whole university were discussed during the autumn in 2015 in various administrative organs such as Education Council and Academic Board.

The Student Union’s board members responsible for educational affairs, the vice president for education and the Head of Education visited the departments and discussed the department-related reports and actions the departments are planning to take regarding the reports. Especially in the department meetings, the co-operation between the Student Union’s board members, Vice president for education and Head of education had a significant influence to transforming the observations into practical corrective actions.

in general the departments and faculties were using the results of the project to implement developments in their own teaching and services. However, the findings could have been exploited more widely at the university, especially in the serviced offered to student centrally.

4 SUMMARY

In general, the mystery shopper method was seen very positive. It gave new insight and overall picture of the university and what it is like to study there. Even if some people were worried about pointing out persons or bringing up some student frustrations in the reports, this was not the case. Students are very experienced in giving feedback and can do it in very constructive way. Also positive feedback was given a lot. We found the mystery shopper method eye-opening and will be re-implementing the research again but this time for students who start their studies to reinforce the first year student experience and retention of students.

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The praxis of gender-inclusive science education in engineering

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ABSTRACT

Many feminist science philosophers claim that gender-inclusive science education benefits women and men. However, most of these claims are theoretical propositions and lacking in empirical evidence. Therefore, this study attempts to examine these claims by exploring the learning experiences of male and female students in engineering project-based learning (PBL), a type of instruction found in gender-inclusive science education. This study was conducted in a PBL course offered by a power mechanical engineering department in a Taiwanese university. The project involved designing a mechanical equipment to accomplish a specific mission. This study involved 10 PBL groups of undergraduate freshmen with different gender compositions. Data collection involved recording videos of the whole processes of these 10 groups, related documents about the process such as their paper reports and project blueprints, and group interviews. There are three main findings. (a)The contextualized ontology, socially constructed epistemology, and multiple methodologies of this pedagogy have responded to recent developments in engineering. Therefore, this pedagogy expands and enriches the professional vision of both male and female students. (b)Traditional gender socialization and the male-dominated engineering culture are the main obstacles to gender-inclusive education. (c)Gender equality education is indispensable for rendering engineering education more gender inclusive

Conference Key Areas: Attractiveness of Engineering Education; Engineering Education Research; Gender and Diversity

Keywords: engineering education; gender-inclusive science education; PBL

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Development of Project-based Learning (PBL) for Internet of Things

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ABSTRACT

An increasing number of physical objects are being connected to the Internet realizing the idea of the so-called Internet of Things (IoT). A basic example is the idea of smart homes. There are also other domains in which the IoT can play an important role and improve the quality of our lives. These applications include transportation, healthcare, industrial automation, and emergency response. Since project-based learning (PBL) provides contextualized and authentic learning, which has been demonstrated to foster higher order thinking while promoting acquisition of content-area knowledge, this project applies PBL for learning of IoT application development. A PBL curriculum was designed to emphasize a real-world problem (specifically, designing a smart watch for monitoring the state of pressure and the quality of the sleep) while enhancing learning motivation, learning emotion and performance, and fostering the creativity and problem-solving skills necessary for innovation and excellence in the learners' future professional careers as IoT application developers. The study will adopt a pretest and posttest quasi-experimental design. Over an 16-week intervention, the control group will receive traditional instructions while the experimental group will receive PBL instructions. Analysis of covariance (ANCOVA) will be used to compare the learning outcomes of the two research groups. This study will explore how different teaching strategies affect students' creativity and problem-solving skills and, at the same time, acquiring engineering knowledge for developing IoT applications.

- Conference Key Areas: Sustainability and Engineering Education, Curriculum Development, Engineering Education Research

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Keywords: Internet of things (IoT), project-based learning, creativity, problem-solving

INTRODUCTION

As an emerging technology, the Internet of Things (IoT) is expected to offer promising solutions TO transform the operation and role of many existing industrial systems such as transportation systems and manufacturing systems. For example, when IoT is used for creating intelligent transportation systems, the transportation authority will be able to track each vehicle's existing location, monitor its movement, and predict its future location and possible road traffic. The term IoT was initially proposed to refer to uniquely identifiable interoperable connected objects with radio-frequency identification (RFID) technology [1]. Later on, researchers relate IoT with more technologies such as sensors, actuators, GPS devices, and mobile devices. Today, a commonly accepted definition for IoT is a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual 'Things', with intelligent interfaces, have identities, physical attributes, virtual personalities, and are seamlessly integrated into the information network [2].

The IoT enables physical objects to see, hear, think and perform jobs by having them "talk" together, to share information and to coordinate decisions. The IoT transforms these objects from being traditional to smart by exploiting its underlying technologies such as ubiquitous and pervasive computing, embedded devices, communication technologies, sensor networks, Internet protocols and applications. Smart objects along with their supposed tasks constitute domain specific applications (vertical markets) while ubiquitous computing and analytical services form application domain independent services (horizontal markets). Conceptually speaking, every domain specific application is interacting with domain independent services, whereas in each domain sensors and actuators communicate directly with each other. Over time, the IoT is expected to have significant home and business applications, to contribute to the quality of life and to grow the world's economy. For example, smart-homes will enable their residents to automatically open their garage when reaching home, prepare their coffee, control climate control systems, TVs and other appliances. In order to realize this potential growth, emerging technologies and innovations, and service applications need to grow proportionally to match market demands and customer needs. Furthermore, devices need to be developed to fit customer requirements in terms of availability anywhere and anytime. Also, new protocols are required for communication compatibility between heterogeneous things (living things, vehicles, phones, appliances, goods, etc.).

Since project-based learning (PBL) provides contextualized and authentic learning, which has been demonstrated to foster higher order thinking while promoting acquisition of content-area knowledge, this study applies PBL to learning of Internet of Things (IoT). A PBL curriculum was designed to expose students to real-world problems, deepen their academic knowledge while exploring, and further enhance students' learning motivation, learning emotion and performance, and creativity skills [3]. For college education, courses that require great amounts of hands-on experience extensively adopt PBL to cement students' practical use of knowledge. However, to better prepare students for the future challenges, traditional PBL can be enhanced by specifically integrating creativity skills. To serve this purpose, this study adopted Creativity-enhanced PBL, emphasizing the training and development of creative thinking, and using a real world issue －Design and implementation of IoT devices for different domain-specific applications－to foster problem solving (PS) skills [4]. The goal of fostering creativity in instructions is to promote divergent thinking [5] and to guide students to develop the ability and intention to develop innovative solutions to problems.

THE DESIGN OF RESEARCH EXPERIEMNTS

This study adopted a pretest and posttest quasi-experimental design. The experiment design is illustrated in *Figure 1*. The independent variable was the instructional strategy, either Creativity-Enhanced PBL (the experimental group) or traditional PBL instruction (the control group). The dependent variables were students' engineering knowledge for IoT design, problem solving skill, creative thinking capability, and learning motivation.

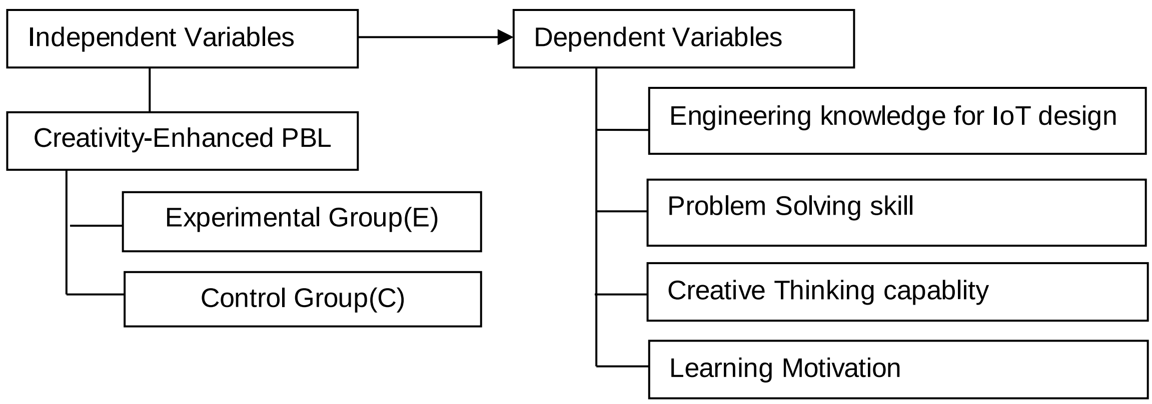

Figure 1. Experiment Design

1 SUBJECT RECRUITMENT

Subjects for this study were recruited from an undergrduate course offered at a large university in Taiwan. Forty-eight students registering for the course "Design and implementation of IoT applications" were randomly assigned to one of these two groups.

2. EXPERIMENT PROCEDURES

The duration of the experiment was twenty-four weeks, over the course of two semesters (i.e. twelve weeks for each semester) . The students enrolled in the first semester were assigned to the control group (C) while the students enrolled in the second semester were assigned to the experimental group (E). The number of students in the control group and experimental group are 23 and 25 respectively. The age of students range from 21 to 23 years old. The percentages of female students in the control group and experimental group are 24% and 25% respectively. Four tests were given as pretests, including a test about the knowledge related to IoT (e.g. understanding of sensors, network protocols and embedded systems, etc), the Abbreviated Torrance Test for Adults (ATTA), Creative Problem Solving Test (CPST), and Motivated Strategies for Learning Questionnaire (MSLQ).

The course was designed to emphasize the real-world IoT problems in design and implementation using the production of an IoT system for healthcare as a case study through in-class lectures, user studies, and laboratory experiments. In-class lectures included topics such as working principles of the sensors, network protocols, data management and the use of various open-source software and hardware such as Arduino, Android, Hadoop, etc., covering professional knowledge required for making a real-world IoT application and system. User studies were designed for the students to understand practical issues by interacting with real ordinary users, while laboratory experiments were aimed at evaluating the mechanisms of any of the design strategies, e.g. issues related to user-friendliness and energy saving .

In the first weeks of the course, each group attended the class to take the pretests and receive an introduction to the curriculum. Beginning at the second week, the course proceeded with lectures covering basic knowledge of designing and implementing IoT systems, such as sensor selection, UI design, and network protocols. For the fifth and sixth week, the problem context was introduced to both groups: How to design and implement an IoT system for sleep-stage monitoring with an accuracy greater than 85 percent.

At this point the instructional strategies for the two groups diverged. For the control group (C), the lecturer adopted traditional PBL by leading group discussion sessions about power saving, physiological signals processing, user interface design, database management, etc.; for the experimental group (E), creativity-enhanced PBL was augmented with a group brainstorming activity—card exchange. In a group of three, one student, based on the problem the lecturer gave, noted down his/her idea on a card with a blue pen, then passed the card to the other group members and continued to add more thoughts on the card. If the member has any idea similar to the previous ones, he/she could use a red pen to add more concrete and specific thought on the card. In the end of the class, the lecturer shared all the ideas with the class by projecting the cards from every group on the screen. After class, students discussed ideas on the card they wrote in class in the time for independent study, using a mind map [6] to reorganize their brainstorming.

For creativity-enhanced PBL, the lecturer provided a real world problem related to the use of smartwatch for pressure and sleep monitoring, assisted with proper creative thinking skills and a web quest. All the group members worked together to decide how to develop and implement such an application based on IoT techologies, think up possible solutions and revise the solution based on feedback. In class, in addition to direct instructions of IoT-related course contents, the lecturer provided students with creative thinking skills and group discussion guidance as scaffolding; outside of class students met in groups every week to gather the information needed for class discussion time. The activities for the PBL group (C) and Creativity-enhanced PBL group (E) were shown in *Table 1*.

Table 1. Summary of instructional activities and time allocation for the control group (C) *and experimental group* (E)

Instructional Activities	Control Group (C): Project-based Learning (PBL)	Experimental Group (E): Creativity-enhanced PBL
Content delivery	PPT-assisted instruction (30%)	PPT-assisted instruction (10%)
Group Discussion	Lecturer-led Group Discussion and Class Presentation (15%)	In- and outside-classroom group discussion and Class Presentation (15%)
		Feedback from the lecturer (5%)
Creative thinking and Problem solving tasks		Group brainstorming based on card-exchange (15%)
Outside the classroom activities	User study (5%)	User study (5%)
	Independent study (40%)	Independent study (40%)
Assessment	Project Presentation (10%)	Project Presentation (10%)

3. DATA ANALYSES

Both quantitative and qualitative data will be collected for this study. Descriptive statistics will be used to describe the means, standard deviations, and adjusted means for the tests between the two groups. Next, analysis of covariance (ANCOVA) will be used to compare the final results between the control group and the experimental group at the end of this study, with pretest scores as covariates to eliminate the effect of any existing pretest differences in the results. For the qualitative evaluation, data will be collected from feedback forms during the last week of the class, through which we know students' acceptance of teaching strategies and how much improvement the students thought they can make.

4. DISCUSSION

At the end of this study, five respective descriptive statistics from the experimental group and the control group will be received. With the statistics, contrasts between pretest and posttest as well as the between-group comparison can be made. We hope that some expected results can be observed through these data.

1) Given that both groups used the same teaching material, the contrast between pretest and posttest from both groups can tell the content validity of teaching materials.

2) Receiving PBL instruction on the same project, both groups are expected to make improvement in obtaining basic knowledge of designing and implementing IoT systems.

3) Because the two groups adopted different teaching strategies, the contrast can be made by comparing the posttest results to see whether creativity-enhanced PBL can help students deepen their knowledge on the design and implementation of IoT systems and, at the same time, achieve a higher level goal – improved solving skills and creative thinking capabilities.

4) By involving creative thinking skills in PBL instruction, students' skill in designing and implementing IoT systems, along with their learning motivation can be

effectively improved. With such results, this research might be expanded and further analysis can be done. Hopefully, this creativity-enhanced PBL teaching strategy can make contribution and be extensively applied in all courses in Department of Computer Science. We expect students to be active and efficient learners whose potentials can be fully discovered through this intriguing and inspiring teaching strategy.

ACKNOWLEDGMENTS

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Learning Augmented Reality (AR) through Interdisciplinary Project-based Learning (IPBL)

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ABSTRACT

Augmented Reality (AR) is a technique that superimposes virtual content on top of physical objects in the video to provide the viewer with additional information. A well-designed AR system enables people to acquire information related to the real scene objects easily, which also makes further interactions with the real environment possible. Project-based learning (PBL) has been recognized as an effective approach to trigger learner's motivation, which can further promote their higher order thinking and acquisition of academia knowledge. PBL thus has been commonly used in advanced courses in engineering departments. However, it is quite challenging for engineering students to develop an AR system that is well-functioned and carefully addresses the demands of target users by using conventional PBL approach. The key issue alarms us is that developing a useful and satisfactory AR system requires interdisciplinary knowledge and skills from the areas of both computer science and design. Therefore, an interdisciplinary PBL (IPBL) has been proposed in this study, in which students from the engineering departments and the design departments are strategically grouped to work collaboratively on a medical training AR project. A wide range of evidence will be collected and analysed, which enables this study to investigate the effect of the IPBL course on the students' learning motivation, learning self-efficacy, creativity, and problem-solving skills that are necessary for innovation and excellence in their future career as professional AR application developers.

Conference Key Areas: Engineering Skills, Engineering Education Research

Keywords: Interdisciplinary education, Project-based Learning (PBL), augmented reality (AR)

INTRODUCTION

Augmented Reality (AR) is a technique that superimposes virtual content on top of physical objects in the video to provide the viewer with additional information. Usually, a built-in camera of a mobile device or smart glasses is used to capture the real scene, and the microprocessor of the device processes the input video with computer vision techniques to understand the image content and/or estimate the camera pose. Computer graphics technology is then applied to draw 2D/3D virtual content on the input image plane according to the semantics of the real object and the pose of the camera. A well-designed AR system enables people to acquire additional information related to the real scene objects, which also makes further interactions with the real environment possible. Therefore, there have been a lot of studies applying AR technology in different domains [1], especially in medical training and education [2][3][4].

Project-based learning (PBL) has been widely recognized as an effective approach to immerse the learners into a contextualized and authentic learning setting, thus has been commonly utilized to nurture the learner's creative problem solving capability in dealing with real-world problems [5][6][7]. Enabling the learners to work in designated task groups, PBL has also been suggested to promote the learner's 21st century skills, including higher order thinking, cooperation and collaboration, and communication and presentation skills. That is, PBL has secured its capability to broaden the learner's horizon, deepen their academic knowledge while exploring and engaging in real-world scenarios. Since PBL has a wide range of irreplaceable advantages, it is common to apply PBL for college students to learn AR system development. Nonetheless, it should be noted that It is quite challenging for engineering students to develop an AR system that is well-functioned and attentively addresses the demands of target users by applying conventional PBL teaching approach. The key issue alarms us is that developing a useful and satisfactory AR system requires interdisciplinary knowledge and a set of skills from the areas of computer science and design, while the expertise of computer science/engineering can help develop a system with adequate functions, the expertise of design can help improve the understanding of target users, better product ergonomics and aesthetics, and even redesign or create the services associated with the products. Therefore, an interdisciplinary PBL (IPBL) has been proposed in this study, in which students from the engineering departments and the design departments are strategically grouped to work collaboratively on an AR project that helps the users learn medical knowledge and skills more effectively.

For college education, courses that require great amounts of hands-on experience extensively adopt PBL to cement students' practical use of knowledge. However, to better prepare students for the future challenges, traditional PBL can be enhanced by specifically integrating 21st century skills, such as higher order thinking, collaboration and communication, and most important of all - interdisciplinary knowledge and skills. To serve this purpose, this study adopts an IPBL approach, which embeds interdisciplinary knowledge of Design and Computer Science in a course that encourages students to accomplish magnificent and practical AR systems. In our IPBL course, we emphasize the training and development of both AR system implementation ability and design thinking skills [8][9]. A real-world issue － the facilitation of medical training－ is used to foster creative problem solving skills. Furthermore, the basis of working in designated task groups enable the group members to work cooperatively and collaboratively whilst applying interdisciplinary knowledge and skills in AR system design for facilitating medical training purpose. Thus, it is expected that the students' communication and social skills can also be improved by participating in the IPBL course [10][11].

1 PARTICIPANTS

A total number of 90 participants aged 22-24 years old are recruited from a top tier university in Taiwan. The participants are randomly assigned to either experimental and control groups. In the experimental group, there are 60 undergraduate and graduate students studying in the departments of Computer Science and Information Engineering (CSIE)/Electronic Engineering (EE), or Industrial Design (ID). In the control group, 30 participants are exclusively recruited from the departments of Computer Science and Information Engineering (CSIE) and Electronic Engineering (EE), but without any design majored (ID) students. In total, 30 groups (2-3 participants per group) are formed with distinct interests in the PBL AR course, among them 20 groups are formed in the experimental group with IPBL course, whereas 10 groups are formed in the control group with Non-IPBL course.

2 RESEARCH PROCEDURES

This study adopts a pretest and posttest quasi-experimental design. The research design is illustrated in Fig. 1. The independent variable is instructional strategy, either interdisciplinary PBL (IPBL: the experimental group) or non-interdisciplinary PBL instruction (Non-IPBL: the control group). In order to investigate the effect of the course, a range of evidence will be collected and analysed to evaluate the student's' augmented reality technology knowledge, problem solving, creativity, learning motivation, and collaboration and communication skills. Furthermore, the student's project products will be consensually evaluated by multiple kinds of stakeholders, including the peer students, professionals, teachers, industrial practitioners, and end users.

As shown in Fig. 2, in the experimental group IPBL course, 60 participants are registered as undergraduate and graduate students studying in the departments of Computer Science and Information Engineering (CSIE)/Electronic Engineering (EE), or Industrial Design (ID). Carefully followed the principles of Double Diamond Design Process Model, the initiative of IPBL course is to promote the learner's interdisciplinary knowledge and skills [12]. The purpose of mixing students of different majors is to facilitate their practice of interdisciplinary knowledge and skills in product design and implementation. As discussed, the expertise of computer science/engineering (students with CSIE and EE majors) can help develop a system with adequate functions, the expertise of design (students with ID major) can help improve the understanding of target users, better product ergonomics and aesthetics, and even redesign/create the services associated with the products. Compared with the lectures delivered in IPBL course, the students in control group (Non-IPBL course) receive lectures with the same teaching materials, however, they are assigned to work with students of similar majors, that is, all members will be recruited exclusively from the departments of Computer Science and Information Engineering (CSIE) and Electronic Engineering (EE). The course is delivered by three professors with diverse professional backgrounds. One professor's background covers the disciplines of industrial design, information science, and psychology; one professor's professional background includes computer science and information engineering; whereas one professor's professional background consists of creativity and imagination education, educational psychology, guidance and counselling, and educational policy analysis.

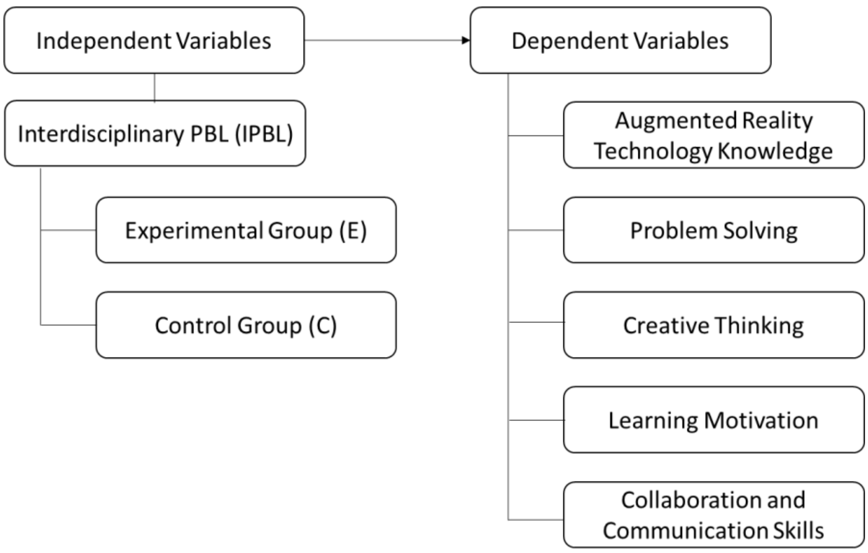

Fig. 1 Research design

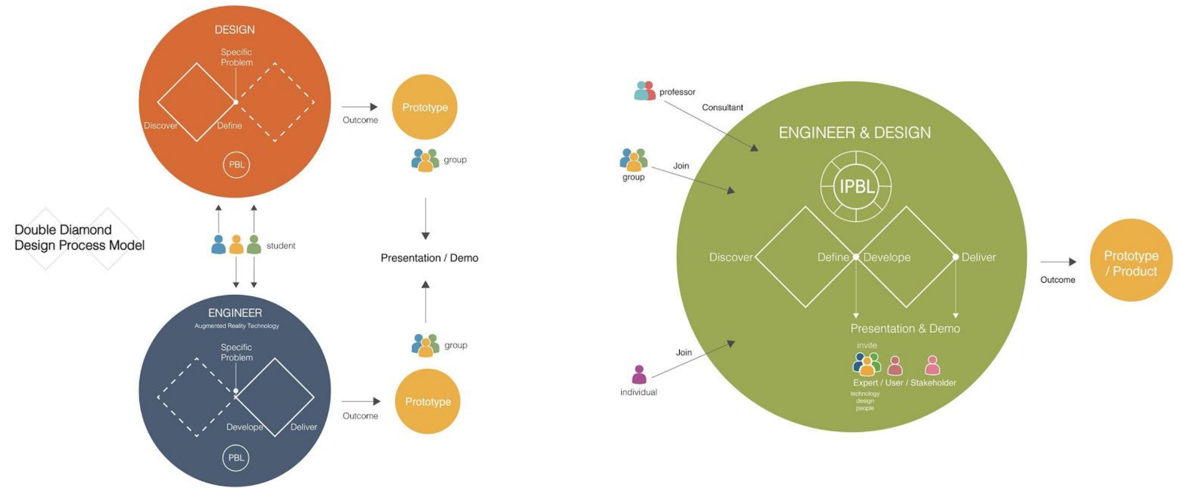

Fig. 2 Course Design of PBL and IPBL

Mainly inspired by Design Thinking approach [12], the 18-week IPBL course is delivered in four phases. The first phase is “discover”: the students are encouraged to discover the real-world issues of their interests and are required to use their empathy to develop a deep understanding of the challenge they are encountering. The second phase is “define”: the students are required to clearly articulate the specific problem they would like to solve through the use of knowledge and skills acquired throughout the course. The third phase is “develop”: the most important task the students need to accomplish is to brainstorm the potential solutions for dealing with the specific problem articulated in the second phase. Since the students of the experimental IPBL group come from diverse backgrounds, it usually takes a longer period of time in the ideation phase. Not only coming up with as many as creative solutions as possible, the students need to repeatedly ask themselves “what do we exactly want to develop?” It is in an essence for the members to select some particular solutions that are agreed to have appropriateness and feasibility. Later one, the students are encouraged to design a prototype (or a series of prototypes) to test the agreed solutions. Before entering the “develop” phase, a card deck named “Design with Intent (DwI) toolkit [13]” is utilized in the IPBL course to stimulate more and better ideas. The DwI toolkit provides real world examples of behaviour design which are drawn from many different disciplinary knowledge related to behaviour change. It is useful in moderating the disciplinary differences in the ideation process. The final phase of the IPBL course is “deliver”, the products developed by each group will be presented to potential users through iterative process, in which a range of stakeholders will be invited to ensure their feasibility, creativity, and usefulness of the products.

3 DATA ANALYSES

A mixed methods approach will be used to investigate the effectiveness of the proposed IPBL and PBL course. In the quantitative part, the new version of Chinese Torrance Test of Creative Thinking (TTCT) and the Motivated Strategies for Learning Questionnaire (MSLQ) will be used for the Pretest and Posttest. SPSS statistical analysis software will be employed to analyze the quantitative data collected throughout the study. Firstly, descriptive statistics will be used to describe general results, including the means, standard deviations, and adjusted means, of the tests between the experimental group and the control group. Secondly, analysis of covariance (ANCOVA) will be used to compare the final results of the two groups after the completion of the course, with pretest scores as covariates to eliminate the effect of any existing pretest differences on the results.

In the qualitative part of the study, feedback forms with a range of open-ended questions will be delivered to the participants of the experimental and control groups respectively, while the first feedback form will be collected in the midterm, the second feedback form will be collected after the completion of the course. Several kinds of questions will be asked in the feedback form, including the overall feeling towards the newly developed IPBL approach, the effects of the lectures delivered, and the suggestions for future improvement of relevant courses.

Furthermore, since the participants' final products/works will be consensually evaluated by a range of stakeholders (including the peer students, professionals, teachers, industrial practitioners, and end users), the participants' AR knowledge and skills, problem-solving skills, and communication and collaboration skills can be evaluated in a more comprehensive way.

4 DISCUSSION

A range of evidence will be collected and analysed to evaluate the effectiveness of the courses delivered to the two groups. The quantitative data includes the Pretest and Posttest results of the TTCT and MSLQ, whereas the qualitative data covers the participants' feedbacks towards the intervention of the course design (please see data analysis section for further details). Furthermore, the consensus evaluation on the participant's final products/works enables the study to explore the effect of the IPBL on student's AR knowledge and skills, problem-solving skills, and communication and collaboration skills. With the computation of the statistics results, the comparison of the Pretest and Posttest results between the IPBL and Non-IPBL groups can be made to test the underlying assumptions proposed by the study. Additionally, the complementary qualitative feedbacks collected in the midterm and endterm periods can be used to triangulate the findings.

1) Given that the same teaching materials and lectures will be delivered to both IPBL and Non-IPBL groups, the contrast between pretest and posttest found in the two groups can help identify the content validity of teaching material and the lectures.

2) Although different teaching strategies are delivered to the experimental and control groups, students of both groups will attend the lectures concerning AR system development and the application of computer science and design knowledge. It is expected that the content knowledge of the specific domains of computer science and design will be improved among the participants of both the IPBL and Non-IPBL groups.

3) Since the two groups adopted different teaching strategies, the contrast can be made by comparing the results of the two groups, which can be used to examine whether IPBL can better help students improve their augmented reality technology knowledge, problem solving, creative thinking, learning motivation, and collaboration and communication skills.

4) The initiative of IPBL course can be regarded as one of the frontiers in engineering education in Taiwan, it is expected that the experience of interdisciplinary learning and group working can help trigger the students' learning motivation, improve their

academic performance, collaboration and communication skills, and their so-called 21st century essential high order thinking skills. We earnestly hope that the initiative of IPBL course, delivered through an intriguing and inspiring teaching strategy, can make contribution in engineering education and be extensively applied to ignite the learners' passion and interests in engineering study and better their future career development.

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LA CONFLUENCE: A STUDY OF THE INTERPLAY OF NON-COGNITIVE AND COGNITIVE FACTORS IN DETERMINING THE SUCCESS OF STUDENTS ON UNDERGRADUATE ENGINEERING PROGRAMMES

Domhnall Sheridan
Michael Carr

ABSTRACT

Over the past twenty years, educational psychologists have become aware of the importance of non-cognitive factors on the academic success of students. The excitement generated by this research stems from the fact that many of these factors are learnt, and if detrimental to learning, can be unlearnt.

This paper looks at two key non-cognitive factors, Mindset, developed by Carol Dweck of Stanford University, which claims that people can have either of two mindsets, fixed or growth. A short test indicates into which category a student fits, and if it is the ‘fixed’ category, Dweck has a series of tutorials designed to move them into the growth mindset and improve their learning outcomes.

The second factor, Grit, was developed by Angela Duckworth of the University of Pennsylvania. Duckworth defines Grit as a combination of passion and perseverance, and through testing, she can determine a Grit score for each individual. This score, her research shows, is crucial for future success in life. Again, for individuals with a low Grit score, it is possible to learn how to be gritty.

This paper examines how Grit and Mindset score for engineering undergraduates correlate with academic success, and seeks to generate a single non-cognitive test that may be usefully employed to predict success for engineering students on their courses. This is a longer term goal, and is expected to take some three or four years follow-on work.

1. INTRODUCTION

Over the past twenty years, educational psychologists have become aware of the importance of non-cognitive factors on the academic success of students. The excitement generated by this research stems from the fact that many of these factors are learnt, and if detrimental to learning, can be unlearnt.

The term ‘non-cognitive’ is, of course, a misnomer, as all the activity being studied is cognitive, just not traditionally academic. Duralak [1] suggests the phrase ‘social and emotional learning’, but it has proven difficult to shift the long-used term ‘non-cognitive.’

This paper looks at two key non-cognitive factors, Mindset, developed by Carol Dweck of Stanford University, which claims that people can have either of two mindsets, fixed or growth. A short test indicates into which category a student fits, and if it is the ‘fixed’ category, Dweck has a series of tutorials designed to move them into the growth mindset and improve their learning outcomes.

The second factor, Grit, was developed by Angela Duckworth of the University of Pennsylvania. Duckworth defines Grit as a combination of passion and perseverance, and through testing, she can determine a Grit score for everyone. This score, her research shows, is crucial for future success in life. Again, for individuals with a low Grit score, it is possible to learn how to be gritty.

This paper examines how Grit and Mindset score for engineering undergraduates correlate with academic success, and seeks to generate a single non-cognitive test that may be usefully employed to predict success for engineering students on their courses. This is a longer-term goal, and is expected to take some three or four years’ follow-on work.

2.0 BACKGROUND

Two rivers meet in the French city of Lyon, La Saône and Le Rhône, just south of the aptly named Presqu'île. Once past that point, it is impossible to tell what water came from which river.

Figure 1: The Rhone at Lyon

This is a good analogy for the difficulty in doing educational research, where so many factors, from both nature and nurture, blend together, making it difficult, if not impossible to isolate direct causality in research.

The Latin word *educare* means to 'draw out.' The role of education is to draw out the natural ability of the child, an ability that is the melding of their genetic heritage (their genotype) and their environment (both shared and non-shared). Behavioral geneticists study this interplay and have come up with some important insights [2].

Everyone knows that some children have an aptitude and a taste for traditional academic work. Both qualities are influenced—but not determined—by genes. These pupils are the easiest for schools to handle, and they tend to do well in the current system. They are also the pupils that selective schools pick out and whose successes are then claimed by the schools to be the result of a superior education. Current policies and the "blank slate" philosophy hold up these children as models. They suggest that if we work harder then all children can be made to fit this mold. As a result, current approaches push nonacademic children to become mediocre generalists regardless of their natural abilities, interests, hopes, and dreams.

Studies of reading by behavioral geneticists identifies the genetic component as being between 60 and 80%. Knowing this, the task of the educator is to use the genes to their best advantage in each case, meaning that education, from primary to tertiary, should be personalized.

2.1 MINDSET

The US psychologist, Carol Dweck [3], identifies two mindsets, fixed and growth. Fixed minds make little effort, relying on their ability. If their ability is not enough, they quit, usually blaming someone or something for their failure.

Growth mindset people know they have to work. They accept failure along the way as a challenge, a lesson, not a reason to give up.

The fixed mindset is easy. You don't have to do any work, because you either have it or you don't. If you don't succeed, it's not your fault, it's someone else's: your teacher, the referee, your boss.

The growth people enjoy working to succeed, enjoying the challenge of getting there.

Malcolm Gladwell [4] put a rough number on the effort hours needed for complete mastery: 10,000. He reckons that's roughly the hours put in by diverse people, from a teenage Bill gates on his computer, to the young Beatles in Hamburg. Before their amazing success, there were years of work which moved them up a level from the rest of us.

Dweck has devised an eight-item self-answered survey, with a six-point Likert answer scale with possible responses ranging from 'disagree a lot' to 'agree a lot'.

The key lesson from Dweck's work is that Mindset is acquired, and can be changed. She has devised online workshops to help people make the change from fixed to growth mindsets, and this has resulted in improved academic scores.

2.2 GRIT

Grit for much of 20th century America was seen as an essential individual virtue to foster the frontier spirit that had made America great. In the early 21st century, grit was reinvented as an educational virtue by Angela Duckwork of the University of

Pennsylvania. Duckworth was a student of Martin Seligman, one of a number of graduate students in the 1960s who rebelled against the orthodoxy of American psychology, B. F. Skinner's behaviourism. Skinner had little time for conscious thought: humans, like other animals responded to conditioning (does the name Pavlov ring a bell?).

Seligman studied what he called learned helplessness, which he saw as a key factor in unipolar depression. People learnt to be helpless through failure, which led some to see all their actions as futile. Seligman believed that what could be learnt, could be unlearnt, and this was one of the key insights of what is now known as Cognitive Behaviour Therapy (CBT). This is crucial to Duckworth's educational research: people learn bad, or negative behaviour, which affects their success in life, but this can be unlearnt.

Duckworth's work as a graduate student in 2004 was focussed on grit, which she defines as a combination of passion and perseverance. In that year [5] she gave a basic Grit Test to the incoming West Point cadets. Their first real test was the Barrack's Beast, a seven-week -period of gruelling physical and mental exertions. Despite the huge effort needed to get into West Point, nearly 20% will drop out before graduation, many after the Beast. Duckworth found that her Grit Test was a better predictor of success in the Beast than any other tests. Of course, an obvious objection to this is that the Beast is all about grit. The US Army makes the cadet's life miserable for seven weeks to see who was the staying power.

Duckworth went on to study other areas, with notable success, such as graduate sales trainees and Spelling Bee contestants. All showed that a high grit score was the best predictor of success. Duckworth is hardly the first to study success, as far back as 1869, Darwin's cousin Francis Galton studied the biographies of successful people, and concluded the key factors were: 'they demonstrate unusual "ability" in combination with exceptional "zeal" and "the capacity for hard labour.' Darwin wrote back to him: 'Darwin. "For I have always maintained that, excepting fools, men did not differ much in intellect, only in zeal and hard work; and I still think this is an eminently important difference.'

The American psychologist William James, brother of the novelist Henry, wrote at the end of the19th century: 'The plain fact remains that men the world over possess amounts of resource, which only very exceptional individuals push to their extremes of use.'

Duckworth created her theory of grit after a bruising encounter with her supervisor, Seligman, who accused her of having none. She sat down to think about her research and came up with:

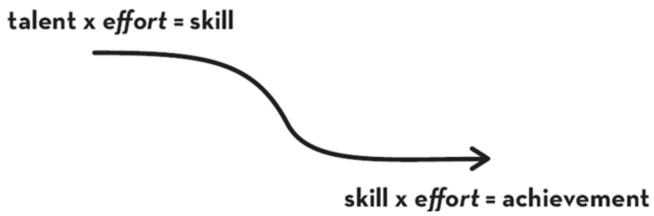

Figure 2: Talent and Effort, from [5]

"Talent is how quickly your skills improve when you invest effort. Achievement is what happens when you take your acquired skills and use them."

Duckworth, like Dweck, has devised a ten-item self-administered survey, with a five-point Likert response ranging from ‘not at all like me’ to ‘very much like me.’ Again, like Dweck, Duckworth has created a series of workshops for teaching grit, which has been shown to increase students overall academic performance.

Half the questions are on passion, and half on perseverance. Most gritty people score high on both, with most scoring slightly higher on perseverance. Interestingly, Duckworth doesn’t focus on the intensity of passion, but on its long-term consistency. A good musician needs a passion for playing that enables years of practice, not an intense passion that is easily frustrated when the skills don’t instantly appear.

Grit has four underlying components: Interest, practice, purpose and hope.

A person needs interest to begin, but purpose is required to maintain the application over time. And hope is required to overcome the inevitable setbacks that will occur.

Duckworth contends from her research that high Grit correlates with overall life satisfaction, which makes sense in that success encourages happiness more than failure does.

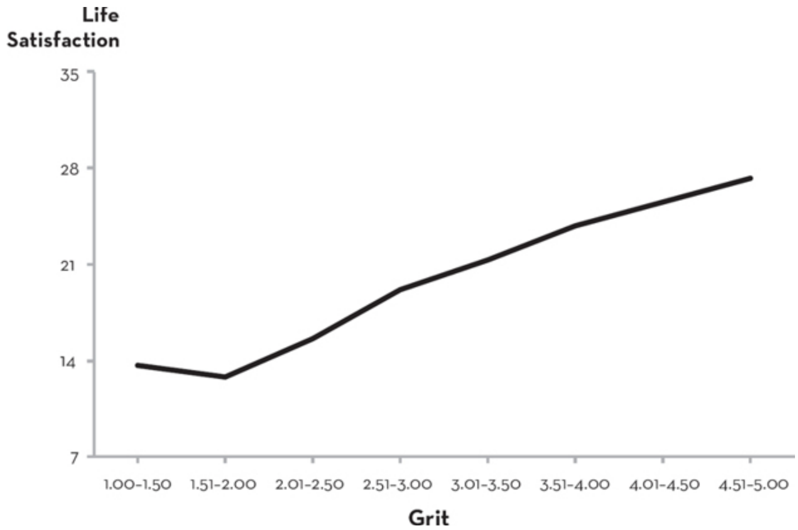

Figure 3: Life Satisfaction as a function of grit, from [5]

The American Psychological Association (APA) define five main personality characteristics, the so-called ‘Big 5’:

openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism (OCEAN).

Research has shown that Grit correlates strongly with self-control and conscientiousness, but Duckworth chose Grit as snappy and easy to relate to, especially for Americans.

In a 2014 report [6] for the Harvard Center for Educational Policy Research, Duckworth and others from Harvard and MIT looked at 1386 8^{th}-grade students and surveye them for Grit and Mindset, as well as the traditional ‘Big 5’ personality traits of the APA. They also tested them for self-control, using the Impulsivity Scale for Children, an 8-item survey designed to measure school-age children’s impulsivity, defined as the inability to “regulate behavior, attention, and emotions in the service of valued goals” [7]

The study found a good correlation between Mindset and Grit scores, with Pearson coefficients ranging from 0.43 to 0.66.

3.0 THE HIGHER EDUCATION SECTOR IN IRELAND

Ireland has seven traditional universities, ranging from the oldest, Trinity College (TCD, founded in1592) to the newest, NUI Maynooth (1997). Then there is the Dublin Institute of Technology, a member of the European Universities Association, with degree awarding powers to doctorate level as well as 13 other Institutes of Technology. There are also small private colleges and other independent colleges.

Admission to higher education in Ireland is via a central office; with access to programmes allocated on the basis of points obtained in the State Leaving Certificate examination (maximum attainable points were 600 over a range of six subjects, now 625 with a bonus for passing the higher level mathematics exams). Qualifications are graded according to a scheme devised by the National Qualifications Authority of Ireland (NQAI). In this scheme, Level 7 is an Ordinary bachelor degree, Level 8 is an Honours bachelor degree, Level 9 is a master's degree and Level 10 is a doctorate.

In this group, DIT has perhaps the most interesting history, having grown organically from a late 19th century group of technical colleges that dealt mainly with craft education, into a degree level institute – initially with degrees awarded by TCD. Since 1993, DIT has been a fully independent institution with degree-awarding powers, covering the full-range of higher education courses, from Level 6 certificates all the way to Level 10 doctorates.

3.1 THE DIT LEVEL 7 ENGINEERING STUDENT BODY

The first-year students of Mechanical Engineering in DIT constitute an above average (for level-7 nationally) group of students, with Leaving Certificate entry points typically around 350 (out a maximum possible of 625). In the Academic year 2016-17, the number of students was 60, with an average of 354 points. It is also worth mentioning the overwhelming male bias of the 2016-17 class, with only five female students on the course in that year.

4.0 RESULTS

Students in the Level 7 Mechanical Engineering Programme in DIT in the academic year 2016-17 were given the standard Mindset and Grit survey forms. Their Mindset and Grit scores were then compared with their exam performance at the end of semester 1, in December 2016.

Both first year and third years had similar average Mindset scores, 31.41 and 29.65 respectively. This puts both classes into Dweck's category G1, of which she says: 'unsure you can change your intelligence; you care about your performance but you don't really want to work too hard to achieve it.' That sounds about right for our students.

The average Grit scores were different, with first years having an average of 41.79 and third years an average of 29.65. The Grit scale is from 1 to 5, with 5 being true grit and 1 a complete wimp. The first year score of 4.2 is quite gritty, although the third year score of 2.96 displays a certain lack of same.

The analysis for Grit and Semester1 Mathematics was:

Regression Statistics	
Multiple R	0.054958766
R Square	0.003020466
Adjusted R Square	-0.028135144
Standard Error	5.968942387
Observations	34

The analysis for Mindset and Semester1 Mathematics was:

Regression Statistics	
Multiple R	0.149708171
R Square	0.022412536
Adjusted R Square	-0.008137072
Standard Error	4.578670047
Observations	34

As can be seen, the effects for both Grit and Mindset are small, but Mindset is significantly larger, with Pearson coefficients of 0.149 v 0.0549.

It is worth mentioning here the work of Jacob Cohen in his 1988 book, *Statistical Power Analysis for the Behavioral Sciences*. In Physics, an experiment to verify Ohm's law would result in Pearson coefficients well above 0.95; less than this would suggest faulty instruments or very poor technique. But in the social sciences, there is so much noise from a multiplicity of factors, that such 'perfect' correlations are almost never seen. Cohen [8] suggests the following for the social sciences:

Effect size	r
Small	0.10
Medium	0.30
Large	0.50

On Cohen's scale then, there is a small effect between Mindset and Mathematics in year one.

The results for the year 3 (final) students in Grit and Electrotechnology exam was:

Regression Statistics	
Multiple R	0.248357497
R Square	0.061681446
Adjusted R Square	0.02258484
Standard Error	6.326840452
Observations	26

The results for the year 3 (final) students in Mindset and Electrotechnology exam was:

Regression Statistics	
Multiple R	0.077362144
R Square	0.005984901
Adjusted R Square	-0.035432395
Standard Error	5.290870725
Observations	26

These results are more interesting, with Mindset showing weak correlation, but Grit, at 0.248, a medium effect. This suggests that the differences in first year are small, but over the course, Grit correlates better with academic achievement.

In fact, looking at the ANOVA for Mindset:

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	4.045102693	4.045102693	0.144502463	0.707188776
Residual	24	671.8395127		27.99331303	
Total	25		675.8846154		

It would be fair to accept the null hypothesis, H_o, that Mindset has no effect on the exam outcome.

5.0 CONCLUSION

This is very much a preliminary work, and as they (probably) say in Lyon, *une hirondelle ne fait pas le printemps*!

However, it is interesting, even with a small amount of data, that the influence of Grit increases from first to final year, as one would expect from Dr. Duckworth's work. A larger student sample, over a period of two years will allow for a more robust analysis, and also the possibility for a longitudinal analysis.

It is over one hundred years since Alfred Binet produced the first standardised IQ test. Binet was motivated to create the test to identify weak students, so that they could be given extra teaching, to bring them up to the standard.

Binet's insight that intelligence is malleable has been shown in recent years by the American psychologist, James R. Flynn. In his 2009 book [9], *What is intelligence*, he discusses what is now known as the Flynn Effect, the massive rise in average IQ scores over the 20th Century. As Asbury and Plomin discovered as geneticists, genes determine that which is constant, environment that which is variable. Education will have succeeded when the only variation between students is genetic, not environmental. The challenge for educators is to so personalize students' education that that goal can be achieved.

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12.

Gender and Diversity

Development of an Instructor Training Tool for Inclusive Teamwork

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ABSTRACT

A growing body of research has shown that women and students from other underrepresented groups often experience negative encounters and events when working on teams in engineering education. Given that teamwork is of central and increasing importance in developing future engineers, it is vital that engineering educators understand how to maximize gender inclusivity within their teamwork components. To that end, we created a training tool designed to help instructors facilitate more inclusive teamwork. This paper describes the collaborative development and content of a new, open-access, online training tool. The modules guide users through various ways in which teamwork can be problematic for women and other underrepresented groups. Users then complete activities in which they apply their newly gained knowledge to situations they might encounter in the classroom. Current efforts are now underway to disseminate the tool to engineering educators around the world.

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Conference Key Areas: Gender and Diversity, Engineering Education Research, Attractiveness of Engineering Education

Keywords: Teamwork, Inclusive, Collaboration, Faculty Development

1 INTRODUCTION

Teamwork continues to be central and of increasing importance in developing future engineers [1-5]. At the same time, research continues to amass surrounding the difficulties that women and other underrepresented groups face when working on teams in engineering [1–3]. Difficulties range from conscious and unconscious biases to the topic of the projects chosen by instructors. Given this, it is vital that engineering educators understand how to maximize gender inclusivity within their teamwork practices.

This paper describes a training tool that grew out of an interview study with engineering professors originally from ten different countries [5]. One portion of the interviews covered teamwork issues specifically. Participants were asked about their practices, decision-making, and experiences regarding forming teams, assessing teams, and students' experiences with teamwork. From these interviews, it was found that most participants spent little time thinking about the inclusivity of their teamwork practices and were unaware of the ways in which teamwork can act as a site for gender biases [4,5]. While undertaking this research project, we also identified a gap in the tools available to instructors in regard to inclusive teamwork practices. This led us to create a training tool designed to help instructors facilitate more inclusive teamwork called TARGIT (Training and Resources for Gender Inclusive Teamwork). We took an engineering design approach to create the teamwork tool. In doing so, we focused on the *process* of design which was done by distilling the teamwork literature into an easily digest format, targeting a specific audience, and working collaboratively. To-date, the TARGIT is fully developed and awaiting testing and dissemination to interested faculty members. The tool is specifically designed to be utilized by faculty members throughout the teamwork process. For example, a faculty member interested in evaluation can skip directly to that section and by-pass other sections.

2 OTHER TEAMWORK TOOLS

Tools such as Team Developer, CATME, and BESTEAMS have been created to assist instructors and students throughout the teamwork process, including team formation and assessment [6–11]. While they may be very valuable in helping instructors facilitate some aspects of teamwork, none of these tools prioritizes gender inclusivity or addresses most of the challenges identified during our literature review and faculty interviews. BESTEAMS aims to create teams that have learning style diversity, but not gender diversity [10]. Team Developer and CATME allow instructors to select different categories or criteria that they find are important and assign teams based on student responses relative to these areas (e.g., major, gender, industrial work experience, year in school, and/or cultural representation) [8,9,12–14]. The tool then automatically assigns teams based on the instructor's ranking of importance of the different categories chosen. Though the tools do have a category for "gender," and an explanation as to why it is important to consider, instructors do not always select it as most important and have been found to select a category such as "scheduling" as most important [15].

Additionally, the way CATME handles gender and race is to not solo females or minorities. As noted, this practice is found frequently in the literature, but is not as clear-cut as it is often presented [16]. Plus/Delta is used for peer and team assessment and feedback [17]. It allows for open-ended responses but relies on students to report problems. As we will discuss, students, especially minority students, may be unlikely to report problems. Overall, these tools do not address the many ways in which gender factors into teamwork. When they do, for instance in the more recent versions of CATME, the complexities of gender in team formation are not fully accounted for.

3 DESCRIPTION AND EVIDENCE OF WORK UNDERTAKEN

This paper describes the collaborative development and content of a new, open-access, online training tool. TARGIT was created by a team of two engineering education researchers and two faculty development specialists, who also have backgrounds in engineering education research. The work began with an extensive literature search about teamwork and gender. From there, the body of literature was distilled into four areas: team formation, team roles, team facilitation, and team evaluation. These four areas were decided upon through a combination of what was most prevalent in the literature and the findings from the interviews [4,5].

TARGIT begins with a welcome screen to introduce the training, including an explanation of the goals and objectives. Audio in the form of a speaker is used throughout the tool to guide users and present the material contained within each module. The modules contain interactive activities before users are given the opportunity to put their new knowledge to use in the Experience sections. The teamwork tool concludes with a list of best practices for instructors before wrapping up the training and providing a list of references and resources. TARGIT allows users to sequentially follow through the training or skip around to sections that would be most useful to them at any given time. The modules and interactive experiences are explained in greater depth in the sections to follow.

3.1 Team Formation

Team formation is often an aspect of teamwork that instructors do not devote much time to but can have a significant impact on the project outcome, team dynamics, and student experiences. As noted, while tools exist to help instructors assign teams, they do not fully account for the complexities of gender in team formation. Our tool therefore focused on providing users with a range of formation options, including the benefits and drawbacks associated with each one, such as the benefits of creating homogeneous teams [1,18–21] versus heterogeneous teams [22–30].

Users are given the choice to learn about instructor assigned teams or self-selection (figure 2). Within each selection method, users are exposed to a range of options within team formation and how these options can impact gender inclusive team formation. For example, TARGIT elaborates on the practice of “soloing” women and how it is generally a practice that should be avoided but not always so [1,16,31]. Overall, the module recommends instructor-assigned teams as they allow the instructor to take into account the unique attributes of each individual and to create teams accordingly.

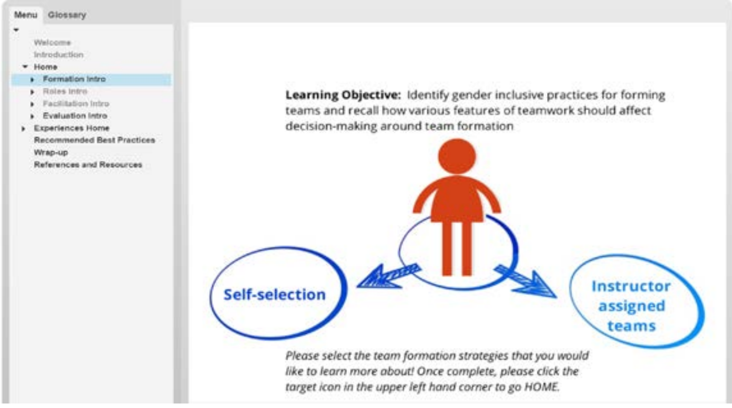

Figure 2. **Team Formation home screen**

3.2 Team Roles

Assigning team roles can mitigate one source of gender bias within teamwork [1,32]. When students self-select their team roles, there is a documented tendency for women to end up in the role of organizer, note taker, or secretary. While the "soft" or "professional" skills learned during these roles are important, they are also tend to be less highly valued in comparison to "technical" skills [33–38]. Therefore, it is not only important for instructors to assign roles but also to rotate roles throughout the teamwork activity so everyone has experience practicing technical and professional skills [1,32].

Users are walked through the importance of assigning team roles and rotating roles by explaining the value placed on professional and technical skills. The module goes into depth explaining this and provides easy to implement strategies to utilize in teamwork activities.

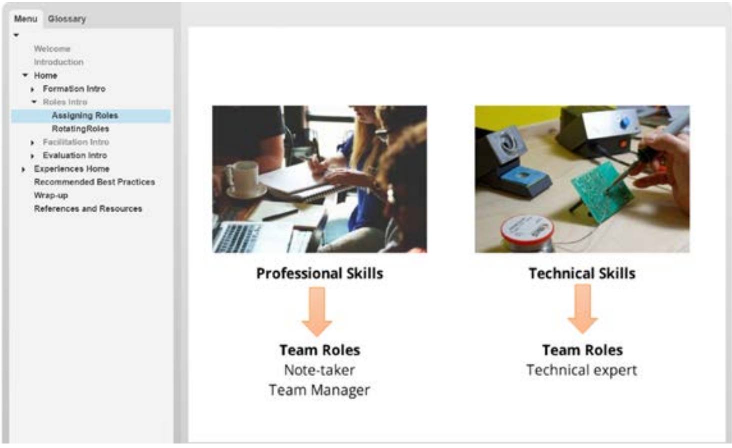

Figure 3. **Assigning Team Roles**

3.3 Team Facilitation

Women often have negative experiences and less positive views of teamwork than men [39–44]. Instructors can minimize negative experiences by actively facilitating teamwork, and TARGIT provides strategies for doing so. It covers four elements of teamwork facilitation: (1) Gender bias challenges, (2) Pre-teamwork, (3) Topic, and (4) Check-ins throughout the project (figure 4). For example, within the *topic* element, the tool explains how certain project topics can be seen as masculine (e.g. racecar engineering) and that other topics may be more gender inclusive (e.g. biomedical devices).

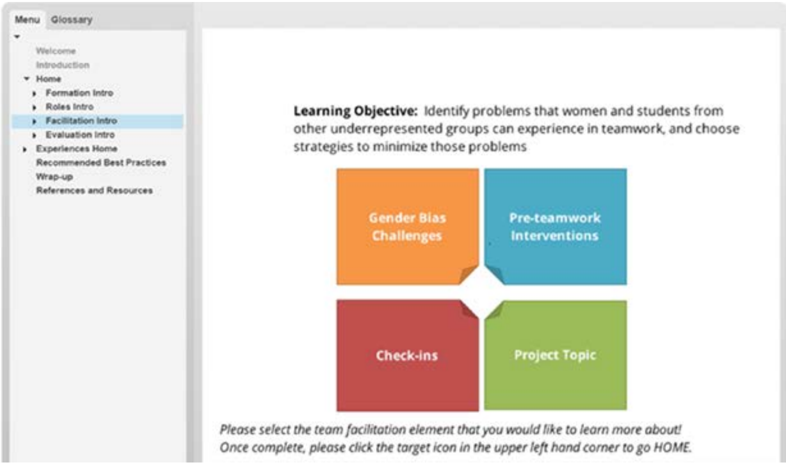

Figure 4. **Team Facilitation Module home screen**

3.4 Team Evaluation

Even though not intentional, gender biases can affect the way in which faculty evaluate teams and students evaluate each other. For example, men have been found to more harshly judge feminine speech characteristics which are often quieter, self-deprecating and less assertive [44]. These communication differences can have an impact not only during team discussions but also during group presentations. Furthermore, men often present more of the technical slides and are rated as more knowledgeable compared to women because of this [1]. Ensuring that women's contributions are explicitly shown or documented can assist in eliminating gender bias during team evaluations [45]. To raise awareness of these issues, users are exposed to the different ways in which gender may play a role in team presentations and peer evaluations. Users are given the opportunity to interact with the module by sorting statements that are either characteristically feminine or characteristically masculine (figure 5).

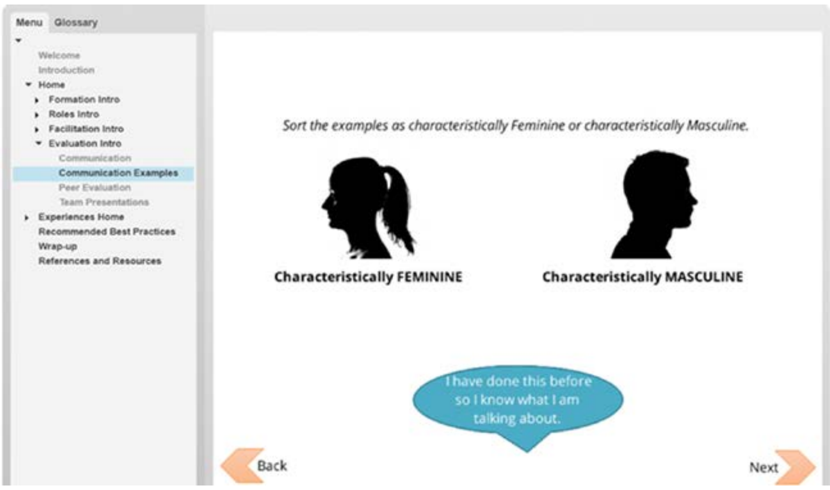

***Figure 5*. Gendered communication activity**

3.5 Experiences

Interactive "experiences" were created as a way for users to test and apply the knowledge they gained throughout the training. Experiences synthesize the modules into activities that ask users to apply their knowledge. For example, experience 1 presents users with a scenario in which the instructor plans on utilizing teamwork in their classroom. Users are then taken to a second screen (figure 6) to identify and sort the practices within the scenario that are either gender inclusive or gender biased.

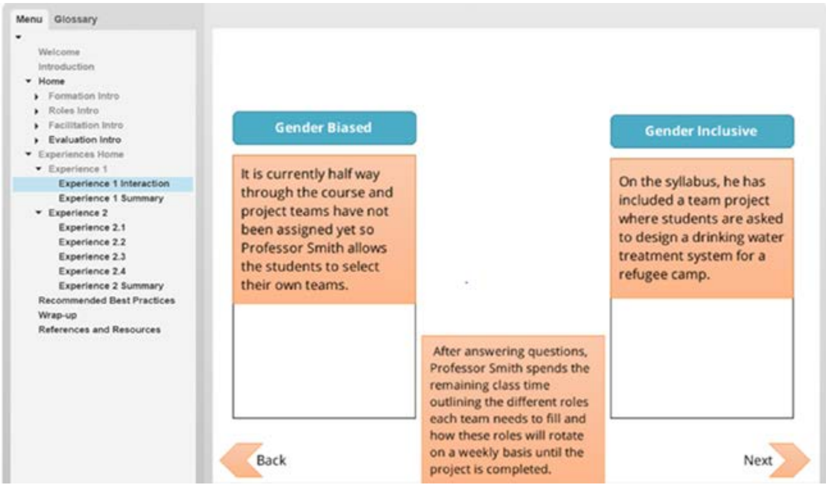

Figure 6. **Sorting exercise associated with Experience 1 in the training tool**

4 CONCLUSION

The strength of the teamwork training tool lies in the collaborative process that brought together engineering education researchers and faculty development specialists. While the researchers often had no trouble identifying and citing teamwork research, the faculty development specialists were able to assist in converting the research into an easy-to-digest platform that has the potential to reach users around the world. The collaborative process drew upon the strengths of the individuals to collectively produce a research-based training tool that can assist users in learning and implementing inclusive teamwork practices in their classrooms. Teamwork was essential in the success of this project and is of critical importance within engineering education. The tool created here can assist in educating instructors about how to incorporate inclusive teamwork practices into their classrooms and is one step to creating an inclusive environment and increasing diversity within the engineering workforce.

5 FUTURE WORK

Future work will focus on piloting and disseminating the training tool to engineering educators around the world. Efforts currently underway include conducting workshops, presenting posters, and conducting presentations at national and international engineering education and higher education conferences. TARGIT can also be updated as new research is published and as best practices change over time. The tool currently appeals to users who have not spent much time thinking about inclusive learning practices and is an entry point into the conversation about inclusive teamwork practices. Future work may expand TARGIT to audiences who are further along in their engagement with inclusive classroom practices. As of this writing the tool's URL is not yet available; it will be posted on http://www.sociologyofengineering.org/ when it is available.

6 ACKNOWLEDGMENTS

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Why Change Works so Slowly?
Occupational Choices of Women in STEM Between Motivational Strategies and Societal Gender Backlash

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ABSTRACT

The amount of first year students in Germany in STEM (Science, Technology, Engineering and Mathematics) fields is rapidly increasing. In winter term 2015, 40% of all first-year students chose a STEM study programme, from whereas 70% were male and 30% female. Ongoing initiatives and motivation projects by industry and science running now for years seem to have measurable impacts, though not in favoured speed and not in favoured amount.

This paper ought to bring some light on the relationship between the development of women's proportions in STEM and the occupational choices of women as well as looking at opposing trends: While the motivational activities seem to become successful, girls and young women are made insecure again in terms of their gender and professional roles by a gender backlash. This gender backlash is visible for instance in gendered toys, a refusal of research results of Gender Studies (in STEM and in general), a public debate about "the freedom of choice" for girls back into gender stereotyped job options, combined with well-known argumentations about their lack of mathematical skills and interest observable in Germany and all over Europe.

Conference Key Areas: Gender and Diversity; Attractiveness of Engineering Education; Engineering Education Research

Keywords: Motivation projects, university-industry co-operation, women in STEM programmes, gender backlash

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INTRODUCTION

In 2015, Germany had more first year students than ever before. 40% of them chose a STEM study programme [2], from whereas 70% were male and 30% female [2]. This means we exceeded the limit of marginalization [3], where a minority group does not express to feel as minority any longer and the single woman is not addressed as representative for all women (in STEM) anymore. The initiatives and motivation projects run over years by industry and science seem to show first effects, though not in favoured speed and not in favoured amount. Was this amount of new female STEM students a singular peak in the statistics or is it the beginning of a repeatable success?

A study on behalf of the “Arbeitgeberverband Gesamtmetall” (Federation of German Employers' Associations in the Metal and Electrical Engineering Industries) [1] shows the relationship between the development in STEM to open for more girls and women and the occupational choices of women. It documents the potency of systematic and evaluated run of several motivational projects based on scientific results about Gender and STEM. In consistency, recommended action was formulated to make the best practice projects more visible and transferable.

At the same time in Germany and all over Europe we observe the phenomenon of a gender backlash. This is shown e.g. by gendered toys [4] , a refusal of research results of Gender Studies (in STEM and in general), a public debate about “the freedom of choice” for girls into gender stereotyped job options, combined with well-known argumentations about their lack of mathematical skills and interests. That means: At the same time where motivational activities seem to become successful, girls and young women are made insecure again in terms of their gender and professional roles.

With respect to the conference topic, this research paper therefore longs to show results about all three sides: The successful motivational activities and rising numbers of female first year students and how study programme choices are made today as well as examples of backlash activities in Germany and Europe.

1 EFFECTIVENESS OF INITIATIVES FOR MORE WOMEN IN STEM

1.1 Goals of the study

In Industry, Science and Society we find three guiding themes in debates and initiatives for more women in STEM:

- A lack of personnel in technical fields, especially in Informatics / Digitalization, Mechanical and Electrical Engineering;
- Innovation strategies, finding scientific and economic potential between disciplines (interdisciplinary) and in stronger diversity of personnel in Research and Development;
- Equal opportunity as a political strategy to offer women and men, and as well people from diverse social classes, ages, with diverse cultural or educational background, same access to education and professions.

These three guiding themes influence each other and are the starting point for initiatives to motivate women to choose a STEM profession and to stay successful in in-plant training, studies and profession.

Our study had the mission to work out the state of the scientific knowledge, to describe the actual project situation and to find out gaps and recommended actions to optimize the activities.

In a first step, desk research was conducted whereas consisting of the acquisition and analysis of existing data material and research results. The disadvantage of desk research, which is only existing research can be analysed [5], proved to be an advantage for this project, as the existing gaps in research become visible. In the desk research process, over 260 contemporary sources were categorized along the influence factors as well as the learning places school, enterprise / training enterprises and university. To this end, the present studies are analysed, the desired and undesired interactions between these three levels were elaborated and gaps in research identified.

As next step, the current project practice in the field of scholars, professional orientation and STEM was highlighted. Hence a research in the project databases of central actors in the STEM area ("National Pact for Women in STEM" and "Navigator of STEM initiatives" at "MINT Zukunft schaffen" ("make STEM future")) as well as an experts workshop and two subsequent reflection discussions on the project selection and project typology structures were conducted. Together with detailed research and surveys of the STEM projects and offers in the field girls - vocational orientation - STEM and a standardised survey of all about 1080 projects, a total of 51 STEM projects were analysed and processed into detailed profiles. This enabled us to identify best practice typologies and representative projects, programmes and measures for educational purposes.

In the following sub-sections we present our scientific results on learning institutions schools, universities and finally by societal factors influencing occupational choices. Results regarding enterprises and their in-plant trainings are left out with respect to the conference topics.

1.2 Findings about school impact on occupational choices for STEM

Boys and girls show the same performance in STEM [6]. But over the phases of childhood a gender difference on STEM interest is proved [7][8]. At school, teachers take over a relevant role as agents for socialisation. Teachers have a central function in "doing gender" processes [9] and are relevant gatekeepers in the development of STEM interest and motivation [10]. Female teachers in STEM (e.g. physics) are acting as role models [11][12]. Positive relationships between female scholars and teachers strengthen this role model function [12]. If teachers act in a way gender blind and insensitive, girls may develop gendered preferences. Gender stereotypes about abilities, competencies and preferences work on their self-performance expectation and influence the choice of favourite subjects [10].

If female students at school choose STEM subjects this develops a positive effect on their self-performance expectation and motivation [14]. But in this decision phase, the scholars are also in their adolescent phase and very focussed on gender related behaviour. Therefore, gender stereotypes for vocational decisions become more relevant [15] and lead them to a gender specific self-selection [16]. First scientific results about the effectiveness of motivation measures in this field are available (e.g. [17][14], handouts for implementation and evaluation of STEM measures [18]), but these results are unfortunately not comprehensively used in programmes, projects and measures yet.

The next step on the way towards a gender sensitive professional orientation on a strategical level is to implement the knowledge about gender and STEM into the curricula for teachers and to develop gender balanced teaching material. Schools need to formulate their gender sensitive goals for professional orientation into their statutes in order to plan, act and check their measures. Here a wide spread of societies and initiatives exists to combine school curricular activities with extra-curricular projects (see for example the internet platform of the National Pact for Women in STEM [19].

1.3 Findings about university impact on occupational choices for STEM

The number of qualified and interested young women in STEM increased over the last years constantly. But even though they have better school diploma than men in average, this does not correlate yet in their applications for STEM study programmes [20]: In the winter term 2016/17 we had 48% women in the first semester over all, but in STEM 32% [21]. This relatively positive development in STEM and especially in Engineering shows that the activities and programmes of universities and departments over the last years are successful. Untypical study programmes become more attractive for women [16], also for those who didn't mention a STEM field as interesting earlier. It demonstrates as well that the female self-effacement bases on structural and cultural reasons and not on individual preferences [22].

Children from non-academic families, from families with low income and with migration background have still smaller chances to achieve a university degree [23]. Women with STEM affinity out of these fields demonstrate high motivation to start into a STEM study programme because they hope for social advancement. This group would therefore be a promising target group for recruiting STEM talents if systematically considered [23].

Universities and STEM departments offer a wide range of projects and measures to motivate women for STEM. Only some of them set changes in own working cultures, programme settings, content or didactical elements [24]. In many cases the projects, like summer schools or women-only courses, take place outside the universities mainstream programme. Linking to digitalization the mentoring programme “Cybermentor” matches around 800 female scholars per year with female students and research assistants online. The evaluation shows that 71% of the participants decide for STEM study programmes afterwards.

In some federal states of Germany, long-term interventions between industry and universities for female school graduates started (e.g. Lower Sachsony “Technikum”, Hesse “Technikum”, North Rhine-Westphalia “zdi-Campus”). They offer a combination of half year-trial study and industrial placement. This also seems to be successful: From 94 placement participants (“Technikantinnen”) in Lower Sachsony 2016, 89% decided for engineering professions.

Next step in this field would be a role out of women-only courses for all STEM departments and universities. Also, the state initiatives seem to be on a good way to convince interested women who are still unsure if STEM professions would be a professional perspective for them. Long-term online offers have a high range especially for women from rural areas. Scaled and structured information in combination with practical experience offers young women good chances for STEM decisions, particularly when they come from non-academic and low-income families. There lies still potential for more diverse research.

1.4 Findings about societal impact and backlash effects on occupational choices for STEM

The occupational choice process depends on several direct and indirect influences and interdependencies, described as a „multi-factorial process“ [25][26].

Gender stereotypes and different socialisation of boys and girls influence the occupational choice processes directly. In comparison to boys, girls have low experience with mathematics, natural science and engineering. Therefore, they develop later less knowledge and interest in STEM fields [16]. Their technical self-performance expectation and their self-assessment belonging their STEM performance is therefore often lower as it is shown from boys [14].

Gatekeepers, like teachers, vocational advisers and role models, have shown to have a great influence in the technical socialisation of girls and young women, as mentioned before. Parents and family members have a key function because they are not only the consultants for their children in vocational choice processes but also they impress the interests and abilities of their daughters with estimation, household work division, own affinity for science and engineering and through transferring their own perception of gender roles to their children [28].

STEM professions have a more and more relevant and active part forming economical and societal developments [29]. But young women (and men) do only have small knowledge about tangible working fields. Therefore, they are not able to estimate the societal relevance of these professions [8]. From their perspective, STEM professions are far from society and humans. Their image is still male connoted [30]. This perspective is intensified by media and by job titles, focussing the technical parts of occupation [8][10][28].

This is the context of “Industry 4.0”, on the one hand discussed as a chance for new and flexible work places and on the other as a risk in matters of ”atypical“ working requirements like mobility, entrepreneurship or digitalization as danger for human skills and work places. This all together affects occupational choice processes indirectly

[28][31].

Several nation-wide initiatives and campaigns try to raise the percentage of women in STEM. 1.7 million girls participated at the "Girls' Day" since 2001, each year schools and enterprises offer more than 10'000 STEM-oriented activities. Teaching material for schools was developed and used for preparation before and after the events. Evaluations show that a lot of the participants continue to come back every year. The "National pact for women in STEM professions", founded by industry, science, media, professional associations and the Federal Ministry for Education and Science (BMBF) in 2008 today builds a network of more than 230 partners to support a lot of nation-wide projects and activities at the several levels of the occupational choice process, as outlined in the chapters before.

While schools, industry, university and politics figure out best intervention for the STEM decision making for girls and young women and be more and more successful, a public debate started concerning gender roles and a "freedom of choice" for girls in gender typical professions. This debate is dominated by conservative and right-wing parties and their focal point on "re-traditionalism" of society. In their opinion, gender and diversity research practices manipulative brainwashing especially for men and women in case of their "natural" roles, abilities and interests [32]. In respectable newspapers, we read about girls who would be incompetent and incurious in math but treated into STEM; boys on the other hand would be better in school if they could act as "real men" and taught by male teachers. Journalists in TV talk shows explain that their own children always used gendered toys "naturally". Politicians stand up saying that all projects and initiatives of the last years wouldn't come to more women in STEM but instead only waste a lot of money. They all share a picture of "good old times" with traditionalistic gender roles, which does not stand on a historical basis but serves societal emotions.

That means: At the same time where motivational activities seem to become successful, girls and young women are made insecure again in terms of their gender and professional roles.

2 GENDER MINT 4.0: A LONGITUDE STUDY ON STUDENT TRANSITION FROM SCHOOL TO UNIVERSITY

Hence, we conduct an ongoing longitude study, founded by BMBF and supported by the social partners, professional associations, universities and other actors in this field, on the transition of women into STEM degree programmes from high school to university. The ongoing study examines the effects of different influences on the study choice and the study success of women in STEM, how gender and diversity-oriented change processes in universities and enterprises work in this context and how the interactions of the various influences on the process of career choices. To this end, a method mix of quantitative and qualitative social research is implemented: Students at High School, STEM Students at university, companies and universities are surveyed and interviewed to examine the course of studies and the career advancement of women and men in STEM fields in a deepening and comprehensive manner and to identify relevant cultural and structural changes in universities and enterprises. The results will lead to recommendations for the improvement of measures for gender and diversity-related generation of young people and serve the development of a specific further training format for actors in STEM fields. First results are expected to be available at the SEFI Annual Conference in September 2017.

3 CONCLUSIONS

It has been shown that the next strategic step towards a gender sensitive professional orientation requires the implementation of profound knowledge about gender and STEM in curricula and teaching materials. These ought to be developed further. Furthermore for universities and departments in STEM it would be recommended to offer more women.only courses. Also there is still a desideratum at STEM decisions and the link to structured information and practical experiences, especially concerning students from non-academic and low-income families. We are looking forward to the first results from the project “GenderMINT 4.0”.

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13.

Mathematics in Engineering Education

Preparing students for engineering mathematics

A collaborative approach between Vocational Education at second level and third level educational institutions

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ABSTRACT

Mathematics diagnostic tests in the UK, Ireland and Portugal have highlighted shortcomings in the basic mathematical skills of many engineering undergraduates. Many institutes throughout Europe have introduced high threshold tests in basic maths in the early years of third level Engineering.

On the other hand, many prospective students in Ireland are ineligible for enrolment on STEM programmes because they do not have an acceptable mathematics qualification. For example, a C3 in Higher Level Mathematics (or higher) is typically required for engineering programmes at honours level. This exam is taken as part of the Leaving Certificate, covering several subjects, and can only be repeated as part of a repeat of the entire Leaving Certificate. Failing or more often not doing Honours Mathematics (a lower level may be taken) then effectively cuts that student off from STEM programmes at honours level.

In this paper we discuss a joint project between several third level institutions in Dublin and the further education sector to introduce a new 1 year Mathematics course aimed at students who have left school without a higher Level mathematics qualification, but who wish to start a STEM discipline at college and at honours degree level. Currently, most third level institutes in Ireland will only accept a passing grade in higher level honours mathematics as an entry requirement for a STEM discipline. This 1 year module will focus on mathematics for STEM disciplines in particular and should form a viable alternative to the 2 year Leaving Certificate qualification for acceptance onto a STEM course for non-traditional students. This paper will focus on an automated testing component of this module which has been designed in collaboration between third level and further education colleges and specifically addresses the basic skills issue. Two further education colleges are now running these high threshold tests with others to follow. In this paper we discuss the set-up, the interaction with teachers and discuss the first results of the tests.

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Conference Key Areas: Mathematics and Engineering Education, Engineering Education Research, Curriculum Development
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INTRODUCTION

Currently in Ireland, students typically take the Leaving Certificate Examination before progressing to third level. This comprises 6 or more subjects (including English, Mathematics and Irish which are taken by almost every student). The examination can be taken in most subjects at Higher or Ordinary Level. The score for the best 6 results, together with any specific subject requirement, are then used to compete for places at third level institutions through a central applications process. For engineering disciplines at honours level a grade of C3 or better in Higher Level Mathematics is usually a specific subject requirement.

For a school leaver not getting a C3 there are very limited options to progress in an engineering discipline. Leaving Certificate Mathematics cannot be repeated as a single subject, but only as part of repeating the Leaving Certificate Examination as a whole. For this reason, few students repeat it. Worse still, as mathematics is, to all intents and purposes, a compulsory component of the Leaving Certificate, failing it gives the impression of a poor Leaving Certificate transcript and many students opt to take the lower level Ordinary Mathematics which again excludes them from Engineering at third level honours level. In response to this some institutions have developed their own entrance examinations. For example, the College of Engineering and Informatics at NUI Galway offers a Special Entrance Examination in Mathematics [17]. NUIG offers "an intensive five day preparatory course" for this. Several other colleges offer a similar option. Such provision begs the question of why a student should go through a demanding two year Higher Level course! The intensive course with exam is typically a response to "do something" about widening access. Data on the progression beyond first year of students who enter Engineering course using these special entrance Mathematics examinations are not publicly available. There are many other Engineering courses which can be taken without Higher Level Mathematics, but these will usually take longer to complete as students will have to begin on an ordinary degree and then progress from to honours degree.

Outside of the Leaving Certificate route, there are some other courses incorporating a mathematics component which are validated by Quality and Qualifications Ireland (QQI) and meet progression criterion for some third level courses, but none are deemed adequate for entry to honours programmes in Engineering by third level colleges. In particular, the assessment is over reliant on continuous assessment and does not test problem solving adequately. For example, the Dublin Further Education College Coláiste Dhúlaigh offers a FETAC level 5 Engineering award which contains sufficient mathematics to access Dublin Institute of Technology ordinary degree programmes, but not their honours degree programmes. In response to this, Mary Hickie, the Principal at the Further Education college Coláiste Dhúlaigh and Ms. Patricia Carraher their Maths Teacher proposed the idea of a one year course to meet this need.

For this one year course to be adequate for the purpose of preparing students for honours Engineering programmes at third level and that third level colleges would have confidence in the course, it was decided that a new form of course development which involved a deep collaboration between mathematics educators from second level, further education and third level would be critical. In this paper we discuss the design of the one year (300 hours of student effort) mathematics course for students who wish to progress to an Honours Degree programme in Engineering which resulted from the collaborative effort between several third level institutions (Dublin Institute of Technology (DIT), Institute of Technology Tallaght (ITT), Institute of Technology Blanchardstown (ITB)) and the Further Education Sector. This collaboration has been key to the design, implementation and assessment process. Several constraints have had to be met to make this process successful:

- To allow take up by the Further Education Colleges across Ireland learning outcomes and assessment methods must be provided in detail. Centralised resources for assessment should be available as teachers have heavy workloads (typically 22 hours per week)
- There must be 'buy in' on the project from some third level institutions from the start. These institutions must be confident that the course really does produce students who are at a level comparable to C3 on honours Leaving Certificate mathematics.
- Learning outcomes and assessment approaches must be compatible with the current implementation of the Higher Mathematics course at Leaving Certificate, providing a source of textbooks, familiarity for teachers and students and easy comparison with that state exam.
- There must be 'buy in' from teachers in the further education colleges. They must see that it is important to third level colleges and collaboration is key to that.

Before describing the design, implementation and assessment elements associated with the one year mathematics course we need to position the development in context. We will provide a brief overview of the Further Education sector and also a description of relevant recent second level Mathematics curriculum reform in Ireland.

1 OVERVIEW OF FURTHER EDUCATION IN IRELAND

In Ireland any education that occurs after second level but that does not form part of the third level system is known as Further Education. This sector is very diverse encompassing Post Leaving Certificate (PLC) courses, Vocational Training Opportunities Schemes (VTOS) (second chance education for the unemployed), programmes for early school leavers, adult literacy and basic education. There are approximately 250,000 students in this sector including 34,000 studying on PLCs [18]. A fully comprehensive overview of the Irish Education system can be found at [19] . About 6000 students who completed PLCs proceeded to third level in 2014 with a target of 9,000 to proceed in 2016 [18].

Most stakeholders view Further Education systems as having two main objectives, to prepare people for the labour market and also to increase social inclusion levels [20 p33]. However there does appear to be diverse views among stakeholders on which the two objectives should take priority, with some feeling that its primary role 'is ultimately to provide the economy with the skills and expertise…. that is needed' while others argue that the Further Education sector role is in 'developing the human person' [20 p.34-35].

As with the sector itself, the possible pathways of progression from Further Education is very diverse. There are several issues with gaining accurate progression statistics, for instance people can be classed as both employed and in third level education or there is often no progression data available [20 p. 94]. However it does appear that main progression routes for students on Further Education programmes are (not given in order) progressing to employment, progressing to third level, progressing to another Further Education programme and leaving to become unemployed.

Historically many of these Further Education students would struggle to cope with the demands of STEM courses at honours degree level. In an effort to widen access Quality and Qualification Ireland (www.QQI.ie) formed a group of experts to develop a new standard entitled 'Mathematics for STEM'. It was important that this group comprised of Directors of further Education Colleges (FEC's) and senior academics, mathematics lecturers and administrators from several third level institutions. This gave the third level colleges confidence that the one year module would be fit for purpose and gave the further education colleges confidence that it would be seen as such.

1.1 Project Maths and an overview of STEM level 8

Internationally there has been a trend towards more problem-centred mathematics instruction [4]. Significant changes have been made to the second level mathematics curriculum with the introduction of 'Project Maths'. This new curriculum places greater emphasis on student understanding of mathematical concepts, enabling students to relate mathematics to everyday scenarios with increased use of contexts and applications. The goals of project maths are "strikingly similar to the goals of the reform movement led by the National Council of Teachers (NCTM) in the US" [14].

2. DESIGN OF THE HONOURS ENGINEERING DEGREE COMPLIANT MATHEMATICS PROGRAMME.

In an effort to better prepare students who enter STEM courses at third level from the further education sector, and to realign the teaching of maths in further education in conjunction with the changes at second level, an expert group was formed for the design of a special purpose award. The view was taken by the expert group that the philosophy, learning outcomes and materials of the new second level curriculum should be absorbed into the new one year programme. With some small changes (most notably the inclusion of logic into the programme) the one year programme is a subset of Higher Level Leaving Certificate Mathematics. The module consists of 6 sections

1. Number (Including percentages, indices, scientific and engineering notation in context, length, area, volume, numerical integration, binary and complex numbers)
2. Set Theory and Logic
3. Algebra (Including linear inequalities)
4. Functions and Calculus
5. Geometry, Synthetic Geometry (as an introduction to proof) & Trigonometry
6. Probability and Summary Statistics
A detailed breakdown and the courses' validation procedures can be found at https://qsearch.qqi.ie/WebPart/AwardDetails?awardCode=5S2246

As for Project Maths, the material is set in the context of applied problems and problem solving. The assessment consists of several components:

1. A high threshold short answer/multiple-choice “core skills” section worth 20% with a pass threshold of 80%. Students are allowed three supervised attempts to reach a mark of 80%. Pass in the section is **mandatory** for overall pass of this award. This test consists of 14 questions across the learning outcomes below.
2. Two assignments worth 15% each to cover at least two of sections 2, 4, 5 and 6 above.
3. Two exam papers worth 25% each covering all material. Students must achieve an average of 50% on both papers.

The learning outcomes of the first “core skills” part of the module is set out below. These “core skills” form a well-known set of materials that students on STEM courses struggle with. We have seen this in the results of diagnostic tests carried out in many Higher Educational establishments in Ireland ([9], [1], [3], [11]) the United Kingdom [13] and in Portugal [2] to name a few countries. The course has this problem specifically in mind and the course designers wanted to make it clear to students how important these skills are in STEM disciplines.

Number

- Master the operations of addition, multiplication, subtraction and division in the N, Z, Q, R, domains. Represent these numbers on a number line. Understand absolute value as a measure of distance on the number line.
- Be able to make basic calculations without any errors, with and without the use of a calculator. Verify the accuracy of these calculations using estimates and approximations.
  Convert fractions to percentages, and numbers to scientific notation and calculate percentage error.
- Solve practical problems by choosing the correct formula(e) to calculate the area and perimeter of a square, rectangle, triangle, and circle, giving the answer in the correct form and using the correct units.
- Solve practical problems by choosing the correct formula(e), to calculate the volume/capacity and surface area of a cube, cylinder, cone, and sphere, giving the answer in the correct form and using the correct terminology
- Solve problems using the rules for indices and the rules for logarithms.
- Demonstrate a fundamental understanding of binary numbers. Represent a number as a binary number. Perform binary addition. Convert from binary to base 10 and base 10 to binary.
- Understand the concept of a complex number and illustrate their representation on an Argand diagram, be able to add, subtract and multiply complex numbers and calculate and interpret the modulus of a complex number.

Algebra

- Distinguish between an expression and an equation.
- Evaluate, expand and simplify algebraic expressions.
- Transpose formulae and perform arithmetic operations on polynomials and rational algebraic expressions.
- Multiply linear expressions to produce quadratics and cubics.

- Reduce quadratic expressions to products of linear expressions through the use of inspection to determine the factors. Use this to solve quadratic equations.
- Solve linear inequalities.

Table 1: Core skills learning outcomes

Creating an assessment tool for this core material and making it available to all participating Further Education Colleges has been a key focus of the collaborative effort between the teachers in the FEC's and the lecturers in the third level colleges.

For the other assessment components and as part of the project, assignment and exam materials are to be archived and shared as a resource for all participating FEC's so as to provide consistency of approach, ease the work burden for teachers and provide ongoing confidence in the qualification for third level colleges. All assignments and exams are also to be independently assessed by an external examiner from third level to further provide confidence in the qualification. Overall, students need 50% for a Pass, 65% for a Merit (which is classed as equivalent to Honours Leaving Certificate C3) and 80% for a Distinction.

3. CREATION AND OPERATION OF ASSESSMENT TOOL

As part of the project an assessment tool covering material from Number and Algebra was required. Five maths lecturers from DIT, ITT and ITB together with five maths teachers from five FEC's in Dublin populated the question bank. Documentation was produced by the third level mathematics lecturers on authoring questions, creating and running tests and accessing scores. Training sessions were also organised jointly by the Dublin Education Training Board together with DIT. Further training will happen on an ongoing basis as issues arise and more FEC's join the project.

The assessment platform is Moodle. Moodle is free, is already in use in much of the further education sector and is usually compatible with existing IT structure. The short questions will be a combination of MCQs and short answer questions. Question types are in categories (58) which are grouped into Learning Outcomes. These categories currently comprise over 800 questions, most of which have randomized parameters. Teachers create a quiz by randomly choosing questions from each learning outcome, each choice giving a variety of possible questions, both in content and type. Each student can then see a quite different quiz compared to both other students and to subsequent attempts.

Normally the assessment will last 1 hour but the individual centres will have flexibility around this. Grades and feedback are generated automatically. Feedback is in the form of links to Khan Academy material for that topic. The pass mark for the test is 80%, and repeat tests are easy to schedule.

3.1 Using the assessment tool

In the current academic year, beginning September 2016, five Further Education colleges were to take part in the initial running of the course. While all five took part in course design and assessment creation, student numbers meant that only two colleges could run the course with 31 students enrolled in total. This was disappointing but it is hoped all five colleges can take part fully in 2017 and that we might extend to further colleges outside Dublin.

The idea in the test design was that students would try similar questions in class and perhaps do an online test as practice. Since they were getting three attempts at the real test they would then use tests done to link to the learning material (and review their notes!) to prepare for further tests. This was far from how testing occurred in practice. **Table 2** below shows that some students were given unlimited access to the actual test to practice on.

Number of practice test attempts	**2**	**4**	**5**	**7**	**9**	**11**	**12**	**15**	**17**	**19**	**21**	**23**	**39**
College 1	2		2		2				1	1		1	
College 2		1	1	2		1	1	1			2		1
Totals	2	1	3	2	2	1	1	1	1	1	2	1	1

Table 2: *Uptake of practice tests*

The first row shows the number of practice tests and other rows the number of students taking that many tests. Clearly, several students have attempted to learn the test rather than learn the material with one taking 39 attempts! The teachers running the test were unfamiliar with Moodle and may not have been aware of this possibility and this will be discussed during external examiner review for next year. Notably, 8 of the 31 students did not attempt any practice tests (only two of those got less than 80% in the real test), and 8 of the 31 students did 12 or more practice tests (of whom 5 got >80%, two did not sit the test and one got 76%)!

Over the first ten practice test attempts the average score shows a general upward trend as Figure 1 shows. After that, scores oscillate for the students taking large numbers of attempts indicating that they are trying to learn the test rather than the material and techniques.

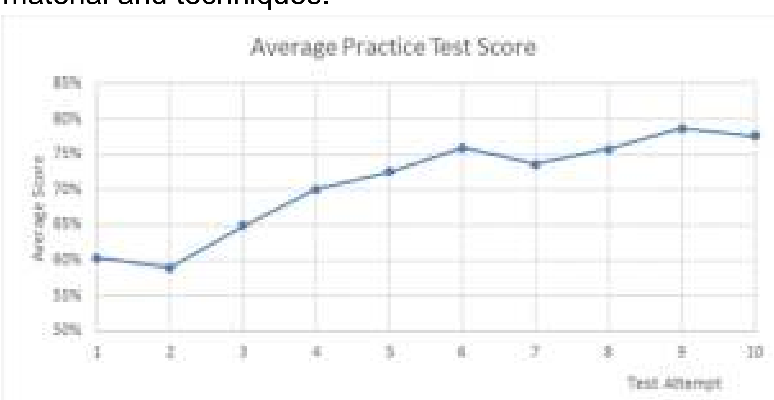

Figure 1: Average score in practice tests in each attempt

Four students did practice tests but not the actual one and have probably dropped out, leaving 27 students taking the actual tests. It is interesting to note that 23 of the 27 students taking it had a real test final mark of greater than 80%. Pass in this section is mandatory for an overall pass of this award, so that 23 out of 27 reaching this mark is quite impressive.

4. FURTHER TEST ELEMENTS

A detailed external examiner review of all test materials and student work will be held between the teachers and a third level mathematics lecturer in May. This will allow us to see what worked well in terms of both content and assessment and make changes for 2017. We will also have further training on our online assessment tool and begin the process of archiving and making available test and possibly notes material for all present and future Further education Colleges who participate.

We hope that this unique collaboration will set a template for further collaboration between Higher Education Institutes, further education and second level teachers in Ireland.

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Collaborative learning in Mathematics for Aerospace Engineering

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ABSTRACT

Learning/teaching is a complex dichotomy that with modern techniques may be unclear as it moves to a coaching and, indeed, it has been so quite often at advanced levels as Master and PhD programs. What seems to be clear after the upcoming of Bologna process is that teaching/learning is moving from a teacher centered methodology to a student centered methodology and how to implement this new approach is taking many facets such as blended learning and flipped learning. After having advanced in these two issues for a number of courses last year we have been deepening on some modalities that enhance punctually collaborative learning in Mathematics while getting

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ready for relevant moments of evaluation in the development of a Mathematics course in First Year of Aerospace Engineering at Technical University of Valencia (Valencia, Spain).

In this paper we present the activities undertaken which involve some transversal competencies such as scientific and technological communication, collaborative working and critical analysis, in addition to the specific mathematical competences.

Conference Key Areas: Mathematics and Engineering Education, Skills and Engineering Education, Continuing Engineering Education and Lifelong Learning

Keywords: Mathematics in Engineering Education, Assessment and Evaluation Strategies/Approaches, Teaching & Learning Experiences in Engineering Education, Collaborative Learning

1 INTRODUCTION

One of the objectives under the Bologna Process was to encourage students to take an active part in their own learning process [1]. This meant to turn the tables over from their usually more passive-like attitude in the classroom and several methodologies have arisen, such as problem-based learning, flipped learning, collaborative learning, online learning, etc. Combining some of these methodologies, the so called blended learning have started to emerge, so that students can learn on their own, alone or in groups, and always maintaining focus on the acquisition of specific competences during the learning process [2].

On the other hand, the competences and skills developed in the subject of Mathematics are basic in all Engineering studies, and in particular, at Aerospace Engineering where we will focus our attention, the methods being easily exportable to the rest of engineering fields. At university level magisterial classes has been the methodology traditionally used, perhaps due to the fact that usually first courses, where maths subjects are mostly allocated, have got a ratio instructors/students very high where other forms of instruction may be difficult when not impossible to be adopted.

Our groups are in the range of 50/75 students for theory and problem solving classes, numbers that drop to 25 for computing lab sessions which enable other methodologies.

The methodology used is blended since collaborative learning, flipped classroom and others, including some magister classes, are involved as detailed in Section 2. In Section 3 we comment on results and analyse the students' opinion about the collaborative learning applied in the subject. Finally, in Section 4 we discuss the results and the questionnaire with the students' opinion.

2 THE SETTING

2.1 The subject

Mathematics I is a compulsory and annual subject delivered in the first year of BEng Aerospace Engineering [3] at the Higher Technical School of Design Engineering (ETSID acronym in Spanish) of the Technical University of Valencia (Universitat Politècnica de València, UPV). It has got 12 ECTS from which 75% of them correspond to Theory/Problems (TP) sessions and the remaining 25% to Lab practice (LP).

In the Degree of Aerospace Engineering, all students should acquire the basic competence of ability to solve the mathematical problems that may arise in Engineering. This should be achieved basically through the subjects of the Department of Applied Mathematics, Mathematics I being the first of them.

In this Degree there are two different groups: one is High Academic Performance (ARA), with teaching in English, and the other not ARA, with teaching in Spanish. Both groups follow the same methodology in Mathematics classes and there is no difference in topics, assignments or exams. Language used as mean of instruction is the only difference.

Instructors of Mathematics I encourage the collaborative learning between students to develop activities related to the specific competences that must be acquired in that subject. This collaborative learning facilitates the continuous assessment of students and allows to customize their improvement needs in particular cases.

The methodology is extendible to the other mathematics subjects of this degree and in general to all those related to Science, Technology, Engineering and Mathematics (STEM).

2.2 On collaborative learning

Collaborative learning arises when two or more people learn or attempt to learn something together. Unlike individual learning, people engaged in collaborative learning get benefit from other's knowledge, resources and skills by asking one another for information while evaluating one's and other's ideas, resources and skills, [4-6].

Thus in collaborative learning learners engage in a common task where each individual depends on and is accountable to each other. Collaborative learning comes out when groups of students work together to search for understanding, meaning, or solutions or to create an artifact or product from their learning activities.

Hence collaborative learning redefines traditional teacher-student relationship in the classroom which some authors claim that results in controversy over whether this paradigm is more beneficial than harmful, [7-8].

In general, collaborative learning activities can include collaborative writing, group projects, joint problem solving, debates, study teams, and other activities. These different approaches bring out a wide variability in the amount of in-class or out-of-class time built around group work, [9-12]. In some approaches this collaboration arises in an unplanned form and may be closely related to cooperative learning, which is not our case as we will detail alter on.

Goals and processes of collaborative activities vary widely. Some faculty members design small group work around specific sequential steps, or tightly structured tasks. In some collaborative learning settings, the students' task is to create a clearly delineated product; in others, the task is not really produce a product, but rather to participate in a process, an exercise of responding to each other's work or engaging in analysis and meaning-making.

2.3 Our collaborative learning approach

The fundamental purpose of the application of collaborative learning is to maintain or increase the acquisition of specific competences in Mathematics, while developing the analytical and critical spirit of the students and their specific communicative competences in Mathematics.

All this is developed within a continuous evaluation process that is based on a strong increase in the number of evaluation control points.

Thus, our approach is framed as part of the process of specific competencies achievement while other transversal competencies are facilitated. For the former the traditional form of assessment is by means of individual tests but in the process collaborative and even cooperative learning might take place.

The collaborative learning is facilitated by the realization of in-class activities that are the final phase of preparation of the subject before individual traditional exams take place. Little weigh and assessment are given to these pre-exam activities (15% of the theoretical/problem solving general assessment) by evaluating individual and group tests based on assignments that are made public 2 weeks in advance to the classical exam.

The assignments are designed with different level of difficulty. After they have been working on them by themselves, students can take them to the individual test so that students can consult them while performing the tests individually. We can see the students doing this test in *Fig. 1*.

Immediately after each individual test, students are required to participate in a collaboration within a small group to discuss the options that they believe valid and collect their opinion on the correct answer to each item.

We can see the students doing this work in *Fig. 2*. Collaborative groups include up to four students.

Fig. 1. Students doing the individual test

Fig. 2. Students doing the group test

In this phase student cannot use their solved test nor their solved assignments so that they must communicate and defend their choices without any support but that from their knowledge and communicative skills.

By doing this, we encourage the development of other key competencies such as oral communication skills concerning scientific and technological language, leadership, critical thinking, and ability to adapt to other environments confronting other opinions.

Students, not being able to use their individual test results, must defend their opinion by just using their oral communication skills and achieved mathematical competencies without the support of solved exercises that might simplify their posing point of view by just pointing out a result.

In this way, the potential deficiencies and strengths of their mathematical specific competencies arise while they have to use their communication skills in order to ask or defend their selected answers by discussing with peers.

Thus, the realization of the same test in group form is the facilitator of collaborative learning after the accomplishment of individual tests and is done by means of lively discussions between students just after them working introspectively each of them on the proposed exercises.

This methodology involves a greater involvement of the student in the achievement of the objectives of the course given that he/she can obtain continuous feedback of his/her level of achievement, while receiving aid in order to orient his/her efforts on those specific areas of the subject that require more practice or deeper learning.

Increasing the number of control points implies that the perception of results is more immediate, which will also result in a greater motivation of the student and a channelling of their efforts towards a homogenization in their levels of acquisition of the competences of the subject. Furthermore, the students` perception of their level of acquisition of the specific competencies increases and the collaborative discussion of their results between them facilitates the development of transversal competences such as critical analysis, problem solving and communication among others.

Finally, the early detection of students with more difficulties, makes it feasible to complement their activity in order to achieve the final objectives of the subject.

Clearly the objective is not only an increase in the number of control points of the continuous evaluation, but to facilitate the collaboration between the students so that they increase and develop both specific competencies of the subject and others of transversal type.

The specific objectives of our methodology can be summarized in:

- Facilitating collaboration among students in a group form while increasing their evaluable checkpoints. This should not imply saturation with more activities, but adapt them to collaborative learning.
- Integrating collaboration as a self-assessment and diagnostic procedure
- Encouraging the active participation of the student in the design of his / her curricular adaptation

3 RESULTS AND STUDENTS FEEDBACK

Results and rates of achievement are good as the students have very high cut marks and less than 10% of students have problems to follow it. It is necessary to have procedures that detect these situations early and guide and help them adequately.

The students' opinion on this system of work was requested. In concrete students were asked to answer some questions. The statements and the distribution of the answers are shown in *Table 1* and in *Table 2* and graphically in *Fig. 3* and in *Fig. 4*.

*Table 1.*Concerning the **individual tests** I think that:

	ARA	NoARA	Global
By doing them, I get aware of my level of competence and they influence my learning process	8 (16%)	14 (19%)	22 (18%)
By doing them, I do not change my perception of what I know, and they influence little on my learning process	20 (42%)	26 (35%)	46 (37%)
I would rather not do them as they do not influence on my learning process	20 (42%)	35 (46%)	55 (45%)
	48	75	123

Table 2. Concerning the **group tests** I think that:

	ARA	NoARA	Global
They are a good idea, and after doing them, I am more aware of my level of competence	4 (8%)	4 (5%)	8 (7%)
They are a good idea, and with them I usually learn something	23 (47%)	34 (45%)	57 (46%)
I would rather not do them as they do not influence on my learning process	8 (16%)	18 (24%)	26 (21%)
They add little value respect to the individual test, but I like doing them	4 (8%)	9 (12%)	13 (10%)
They are a loss of time	10 (20%)	10 (13%)	20 (16%)
	49	75	124

…………

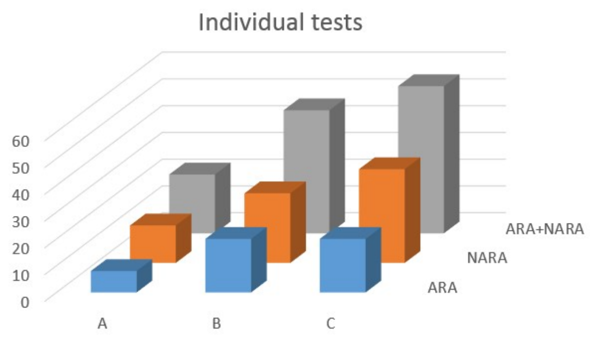

Fig. 3. Students opinion about individual tests
(A): They help me in my learning
(B): They influence little on my learning
(C): They influence little on my learning and I would rather not doing them

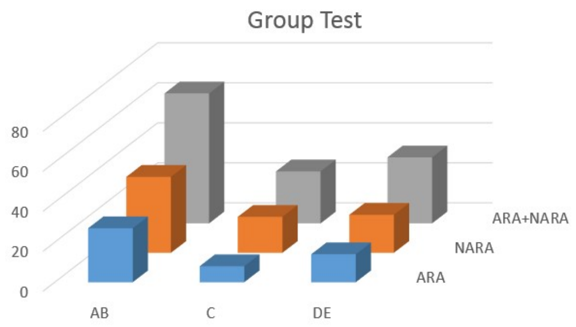

Fig. 4. Students opinion about group tests
(AB): They help me in my learning
(C): They add little value to the individual test
(DE): I would rather not doing them, they are a loss of time

Tests are done via multiple choice questions and require close attention in order to distinguish the right answer from the group of four possible answers provided for each question.

In general, we may notice that students have got a positive perspective from the collaborative part of each test and a negative one from the individual part. This may be understood if we have in mind that the first part is closely related to the previous assignment and this involves work, hard work.

When the collaborative part comes into play, interaction with mates is fun and helps them to clarify and fix ideas, and they like it. Apparently, they are not fully aware that the whole setting helps them to achieve mathematical competencies while practising with others. The final, collaborative stage, has sense in our setting once individual performance has taken place in first instance.

Perhaps they would like to skip the individual part but the input they would get from the experience would not be the same. In order to improve the perception of the students on the individual test, the instructors should make them aware of the relevance of this internal insight that enables the ulterior collaborative work based on their personal introspective work.

4 SUMMARY AND ACKNOWLEDGMENTS

Due to its situation at early stages of their studies, we have considered relevant that at the same time that specific mathematics competencies are achieved by the students, they do it by facilitating the development of other transversal competencies such as scientific communication, collaboration with partners, critical thinking all of which prepare them to their continuous education and lifelong learning.

The collaborative work developed in class facilitates a deeper achievement of specific competencies. Students should be aware that this collaborative work is undertaken once they have achieved some mathematical competence and personal critical thinking that enable them to communicate and discus with their peers. The relevance is not in the test itself or collaborative work but on the mathematical and key competencies they are developing that will get their outcome in the mathematical competencies they will show to have achieved in the ulterior individual exams.

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Computer Assisted Assessment in Mathematics

Daniela Velichová

ABSTRACT

New scenarios of organization of education process considerably influenced also the form of assessing knowledge and depth of understanding acquired by students. Computer Assisted Assessment (CAA) is a common term used for any form of the assessment of student learning outcomes, in which computers are used to manage or to support the assessment process. This can have several forms and follow various goals. In spite of a bias towards science and technology subjects in the use of CAA, there are increasing examples of its employment in many disciplines. Forms and variants of CAA adopted out at some European technical universities will be discussed, and analysis of results with application of CAA in Maths courses at the Mechanical Engineering Faculty of STU in Bratislava will be presented.

Conference Key Areas: Mathematics in Engineering Education, Open and Online Engineering Education

Keywords: ITC in education, on-line pedagogy, computer assisted assessment

INTRODUCTION

Computer Assisted Assessment (CAA) is assessment of student knowledge and learning outcomes utilising computers to manage or to support the process of assessing in any feasible form. Most typically this concerns a formative assessment, which is aimed to help students to discover whether they have learned what they were supposed to and to what extent they were able to grasp the knowledge. These forms of tests also provide timely feedback to educators on how to teach the subject for better students' understanding, which is particularly important in mathematics education. CAA can be also developed as summative, with a limited feedback typically being given at the end of a course and serving to grade and categorise the student's work. Occasionally, it can also be diagnostic, e.g. by testing for pre-knowledge or partial knowledge that students reached after completely covering of certain topics.

Well-written computer assisted testing is more likely to be objective testing that can be marked objectively, and thus it offers a high reliability. Great benefit is that the tests can be marked quickly and easily, and adapted to meet a wide range of learning outcomes, see in [1].

1 BASICS OF COMPUTER ASSISSTED ASSESSMENTS

1.1 Advantages of CAA

CAA tests have the following potential:

- they can incorporate a wide range of media
- online assessments can be directly linked to feedback
- hints can be incorporated into test questions
- other learning activities can be assigned based on the test results
- randomized selection can be made from a larger question banks
- tests can be administrated easily
- CAA also allows better test management.

It is, however, important to consider whether CAA technology is the appropriate method of assessment in the particular subject. If it is implemented, it should probably only be used for part of the course's assessment strategies, and not as the only way of testing students' knowledge. In mathematics, particularly, a great attention has to be paid to conceptual understanding. This knowledge is not easy to be recognized and assessed by simple multiple choice tests, which are the most prevailing on-line testing forms developed usually as the first attempts when introducing CAA approach. Authors must be therefore aware of many drawbacks and disadvantages that this form of testing can bring when adopted.

1.2 Disadvantages of CAA

CAA approach can have the following limitations:

- It is usually associated with testing knowledge skills rather than conceptual understanding, because of the frequent use of multiple choice questions formatting, which is believed to test at a lower level of understanding when related to Bloom's Taxonomy
- Construction of good objective tests requires skill and practice and so it is initially rather time consuming
- Implementation of a CAA system can be quite costly
- Hardware and software must be carefully monitored to avoid any failure during examinations
- Security issues can be a problem in web based CAA
- Students are required to have adequate IT skills and experience to undertake this particular assessment type
- Assessors and invigilators need training in assessment design, IT skills and examination management
- A high level of organization is required of all parties involved in assessment (academics, support staff, computer services, and administrators).

2 RECENT DEVELOPMENT

2.1 General situation

Computer assisted assessment of higher order skills such as comprehension, application and reasoning is difficult to attain. Recent research has produced an improvement in CAA's ability to test these skills, and allowed for implementation of the suitable and sophisticated tools to be used on the Web. Areas for development include graphical hotspot questions, which involve selecting an area of the screen by moving a marker to the required position. On-line text assessment is also being developed, with interactive respond providing hints in case of not correctly posed answers. Various learning platforms and environments with implemented tools for test development are available, both free as e.g. Khan Academy, Moodle, GeoGebra learning platform, or commercial solutions as e.g. SOWISO learning platform for Maths & Science [2], or Math-Bridge [3]. Math-Bridge is the first Pan-European e-learning platform for online bridging courses in mathematics developed as a joint effort of 9 universities from 7 countries. It allows students and teachers to work with more than thousands of mathematical learning objects (theorems, proofs, definitions, instructional examples, and interactive exercises) written in 7 languages. There are available many pre-defined courses that can be adapted to specific needs by a provided adaptive tool, and also own courses can be build.

Platform “its learning” is a learning management system that enables teachers to better facilitate instructional delivery and engage today’s “digitally” wired students. Teachers can develop lessons, distribute and collect assignments, assess quizzes and tests, or introduce on-line discussions with students to practise collaborative learning, engage students with online quizzes used for exam preparation, and use messages to keep students informed about their subjects. Platform itslearning also helps in organisational work, including improving dialogue with students and giving feedback [4].

A number of institutional Computer Based Assessment development projects (many funded by higher education initiatives) offer free or relatively inexpensive assessment tools, which do not require the purchase of costly licenses. Universities provide digital campuses to support staff and students with new digital workspace, which gives new tools and offer easy way to work online, share information and collaborate within teams. Teachers can create on-line interactive assessment tools quickly and easily without much prior knowledge about design of HTML webpages or scripting languages. Its aim is to provide online interactive tutorials and assessment environment, which should enhance the learning resources available to the student, whilst requiring a fairly minimal time investment on behalf of the tutor or course developer. Effective question design means that assessment questionnaires can test different cognitive processes (e.g. comprehension, application and evaluation) as well as the ability to recall facts. Examples are for instance E-MATHS-CH, e-learning platform for Mathematics at the University of St. Gallen [5], or M-learning Platform for Engineering Mathematics designed at the Hong Kong Polytechnic University, Hong Kong, China [6].

Recently, Delft University announced their move from the Blackboard Learning Management System to a new system enabling digital examination, which is a challenge for technical university. In exams, there are a lot of mathematical graphics and most of the software doesn’t support that yet. The new learning environment also has to offer good integration with other educational software, such as software used to practice solving mathematical problems, but also with tools from student startups on the Delft campus, such as Feedbackfruits, which offers professors and students interaction possibilities inside and outside the classroom in an innovative way. University choice was D2L Brightspace, an excellent top product based on innovation and development capability. The supplier of the D2L showed it understood TU Delft’s strategic goals by offering modules the university didn’t ask for, but that fitted its educational vision [7].

2.2 Initiatives

In 2004, the SEFI Working Group on Mathematics and Engineering Education started to conduct an assessment project focused on investigation of various forms of examination and assessments used at some of the European technical universities in basic Mathematics courses. Project had three main purposes:

1. to survey the methods of assessment used in engineering mathematics across Europe;
2. to stimulate debate on appropriate and efficient methods of assessment;
3. to spread good practice in assessment.

The project findings were reported in the proceedings of the 12th SEFI MWG seminar held in Vienna in June 2004 [8]. In addition, there was a round-table discussion at the seminar on issues relating to assessment. Summary of the main ideas that delegates put forward during these discussion and the report of findings can be found at the Working Group webpage [9].

In the recent publication of updated curricula for mathematics in engineering education [10] published by SEFI, chapter 5 is devoted to assessment and its various forms. Here one can find summary of ideas presented by participants at the SEFI MWG bi-annual seminars reflecting practical experience of maths teachers at technical universities throughout the Europe with many various forms of assessments they have adopted in their pedagogical practise. Related to the innovative concept of curriculum based in developing mathematical competencies and conceptual understanding prior to calculation skills and memorised facts, ideas about how to assess competencies are presented, too. Technology supported assessments is discussed also, namely in connection to drawbacks that have to be overcome developing more sophisticated computer aided solutions. More attempts are appearing recently towards complete, computer-supported systems, the so-called Intelligent Tutoring Systems (ITS), where the student gets information not only about his/her errors or mistakes but also about underlying misconceptions or lack of knowledge, together with support to fill the gaps.

There are also specific problems arising with the legal certainty when IT devices are used in assessment, as computers at universities are connected to a network and to the internet. To prevent cheating the network connections and some other features of communication and usage of computer programs must be blocked, which can cause organizational problems, not speaking about possible insufficient number of available computers for large groups of students to be assessed at the same time. The need for randomization of tests questions, in order to avoid similarity that could privilege students taking test later and discriminate the last ones, is obvious. Attempts to allow students to take the on-line test out of campus or out of office hours were registered too. This approach puts more work on examiner who should avoid cheating by developing the test very carefully, cleverly posing questions focused closely on studied and tested material, as he does not know who actually took the test.

2.3 Project FutureMath

The FutureMath is project funded by the EU under the ERASMUS+ Program, with reference 2015-1-FI01-KA203-009044. It aims to respond to the requirements of modern society and to make mathematics' learning and teaching more digitalized, effective and accessible. Additionally, the aim is to explore and develop the most motivational, learner centred methods, techniques and resources for engineering mathematics learning and teaching with the help of technology. All the learning resources developed in the project will be made available for free under the idea of Open Source or Open Educational Resource (OER). The underlying notion is to support digitalization of European engineering mathematics education in a large scale. By these means, it is supposed to improve the efficiency, accessibility and quality of mathematics teaching and learning on European level which is one of the four common objectives of EU's Strategic Framework of Education and Training 2020. Additionally, as an impact of the project, improving of transversal and basic skills (ET2020), such as digital skills and mathematical skills, will be a central focus. With these actions, it is expected not only to develop innovative learning approaches but also to enrich the teaching, support personalised learning and increase the flexibility and attractiveness.

In addition to the mathematics learning platform, project aims to develop innovative pedagogical methods, techniques, materials and resources not only to teach and learn mathematics but also to assess mathematics' learning. The key approaches while planning the resources are i.e. collective thinking, collaboration and shared problem solving skills - the skills that are necessary for success in working life. Furthermore, project resources will respect individual learning solutions. Therefore, different learning types will be taken into account in the project's material production. In this way, it is also possible to decrease the inequality among different kinds of learners.

Overall, the one main objective of this project is to increase the global large-scale awareness about the possibilities ubiquitous technology offers for mathematics learning throughout MLP. Global aim is to make mathematics learning more motivational, interesting and to increase accessibility and the alternative modern methods for mathematics learning.

The project consortium consists of 4 partners, TAMK – Tampere University of Applied Sciences, Finland, TUCEB – Technical University of Civil Engineering Bucharest, Romania, STUBA – Slovak University of Technology in Bratislava, Slovakia, and UPM – Technical University of Madrid, Spain, working in two teams: team mathematics and team technology. TAMK, TUCEB and STUBA mostly participate in mathematics team and UPM and TAMK are engaged also in technology team. These two teams closely cooperate, while team mathematics is mostly responsible about the developments related to the mathematics (assessment, pedagogy, production of learning resources etc.), whereas team technology is responsible for the technical innovation and implementations. The project coordinator is TAMK [11]. Mathematical learning platform has been opened recently, with innovative learning materials developed for general usage and share for all interested party.

3 ASSESSMENT STRATEGIES AT STU IN BRATISLAVA

3.1 Blended solution

Mathematics educators at the Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, Slovakia, introduced (several years ago) blended system of assessment of faculty students in basic mathematics courses Mathematics I and Mathematics II for bachelor study programmes scheduled in the first two semesters of the first year. The idea of implementing partially also computer assessment solutions originated in connection to lack of academic staff with overwhelming duties to examine great groups of university freshmen. Facing the consequences of overall development with decreasing mathematical competencies of secondary school graduates arriving to university study, specific pre-tests had to be developed, in order to assess level of basic maths knowledge. Based on test results students were advised to take additional exercises in maths, in both semesters, to support their needs in reaching the standard level of necessary knowledge for their successful performance in basic courses Mathematics I and II. E-learning platform with various digital and interactive learning materials was provided in Slovak to support students' needs.

Final formative assessments for passing additional maths classes were designed as classical multiple choice tests in written form. Results were compared with the pre-tests with visible knowledge gain for almost all students. Simultaneously to additional classes students attended normal classes of Mathematics I (first semester) and Mathematics II (second semester). They had to pass 2 tests during each semester. First test was a classical written test, the second test was performed as CAA in computer laboratory. Students had to prove their knowledge and abilities to solve few more difficult problems using computer algebra system available at university, namely Wolfram Mathematica. In spite of the fact that our students worked in computer laboratory with the Mathematica system throughout the whole semester, computer assisted tests displayed considerably worse results than the traditional ones. Analyses of problems that students encountered when enrolled in the CAA, we came to the following conclusions:

- In classical written tests students concentrate entirely on the essential mathematical problem they solve / in computer assisted tests, concentration of attendees has to be split between mastering operations on the digital media first, and solving initial mathematical problem itself, that is at the second place.
- Writing of maths symbols in the classical written tests is much easier and more natural for students then scripting in the symbolic language of used CAS, which leads to more time wasted on scripting than on solving during the testing period.
- Some traditional calculation skills are no more necessary when using CAA.
- Many partial problems hidden in and necessary in step by step calculations that are actually giving the evidence of a profound mastering of the tested mathematical task can be solved by CAS without understanding, which is leading to weak surface knowledge not sufficient for sustainable conceptual understanding in mathematics.
- Solving complex problems, which is often very time consuming, is not possible in traditional way of testing / CAA becomes more complex and complicated, as chosen problems are often more difficult than in the traditional testing scenarios.
- Students rely on CAS provided offerings and try to solve given problems automatically, without proper reasoning and using knowledge they should acquire from the course, which results in more frequent occurrence of not-correct solutions caused by improper interpretation of the problem.
- Good students performed better in CAA when they were allowed to use CAS, as they could concentrate more on the solution strategies than on the manual calculations necessary to perform the test tasks/ weaker students had more problems in CAA then in classical testing, as they were not able to cope with two different tasks – maths problem and computer mastering, at once.

4 SUMMARY AND ACKNOWLEDGMENTS

Computer assisted assessment in mathematics is a complex issue that is still not well analysed due to various reasons. Keeping in mind the fact of the ongoing lack of suitable tools for easy management of mathematical formulas communicated via ICT devices, concentration of test attendees will be inevitably disturbed by the double burden of solving and scripting all solution steps. On the other hand, some parts of the solution might be skipped or solved by used CAS, which can easily lead to false understanding of solved mathematical tasks and often also to incorrect solutions caused by misunderstanding and weak surface knowledge. Further decrease of mathematical skills has been registered in connection to usage of digital technologies, both in learning-teaching and in assessment. Anyhow, all consequences and real impact of digitalised education on mathematical abilities, calculation skills and conceptual understanding of students were not expected and absolutely not envisaged. In some situations the results of digital technologies introduction are far from promising assumptions of great improvements in delivery of mathematics courses, at technical universities in particular. Recently, students prefer face-to-face consultations and direct contact with teachers during preparation for exams to self-study and usage of available e-learning resource and interactive on-line materials.

Positive aspects of CAA introduction can be seen mainly in gained time that can be saved when assessing large groups of students using computer assisted testing. Better performing students are thus equipped with powerful tools enabling them to concentrate more on real and therefore more complex mathematical problems and their solutions than on tedious manual calculations. On the other hand, for some of the weaker students just the opposite might be true. They were able to solve more complex problems due to availability of CAS powerful tools for performing calculation of merely trivial tasks as these could cause fatal problems. Therefore, students were able to deal with more complicated mathematics without its deep understanding.

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Evaluation of change in approach to problem solving through developing spatial thinking

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ABSTRACT

In this study, we examine the transfer of spatial skills training to the ability to solve word problems in mathematics. A sample of freshman engineering students was recruited from an engineering school in the US consisting of 53 participants, 28 female and 25 male, categorized as 'weak visualizers' based on a spatial ability test. Of these, 30 (18 female, 12 male) enrolled in a spatial skills training course delivered during the autumn semester and the remaining 23 participants (10 female, 13 male) did not take this course. All participants were administered a spatial skills test and a measure of math problem solving ability at the beginning and end of the semester. Both those enrolled and not enrolled on the course made significant gains on the spatial ability measure but the gain was significantly higher for those enrolled on the course. No significant differences in the math pre and post-test scores were found for either group. Transfer of improvements in spatial ability to math problem solving ability were not manifest in this case.

Conference Key Areas: Engineering Education Research, Mathematics and Engineering Education, Gender and Diversity

Keywords: Spatial ability, problem solving, cognitive development

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INTRODUCTION

"*I stand at the window of a railway carriage which is travelling uniformly, and drop a stone on the embankment, without throwing it. Then, disregarding the influence of the air resistance, I see the stone descend in a straight line. A pedestrian who observes the misdeed from the footpath notices that the stone falls to earth in a parabolic curve*". (Einstein, 1920, p. 8)

Conceptions of general intelligence evolved over the 20th century from unitary models such as Intelligent Quotient (IQ) to more complex multi-dimensional models that allowed for individual expression of strengths and weaknesses across a range of cognitive abilities (Andrade & May, 2004). Spatial ability has long been regarded as one of those dimensions (e.g. Thurstone, 1938) and while initially receiving less attention than other dimensions such as verbal, memory and perceptual abilities, its importance as a factor in the structure of human intelligence is being increasingly acknowledged (Johnson & Bouchard, 2005). Spatial ability is now regarded as an extremely important component of our overall cognitive ability that profoundly influences human performance in many roles and contexts.

Indeed, many famous scientists have been categorised as highly visual thinkers (Lohman, 1996). As Einstein's quote above shows, he relied heavily on visualizing scenarios to create hypotheses he would then test on the journey towards his theories of relativity. The works he is most famous for emanated from thought experiments that were highly visual in nature as compared to the more mathematically focused efforts of his later years (Isaacson, 2007). These scientists created the scientific principles and theories that we expect science, technology, engineering and mathematics (STEM) students to master. This is an arguably easier task for those students who are also highly visual thinkers whereas those students who enter STEM education with weak spatial abilities face a greater challenge in grasping these concepts.

It is unusual to see spatial skills development formally included in the STEM curriculum. Compare this with mathematical skills which are formally developed throughout the STEM curriculum and often further enhanced by math learning support centres. There are exceptions to this rule, an example being a group of US engineering schools who recently added spatial skills development to the curriculum through their participation in ENGAGE Engineering, a National Science Foundation funded project that began in 2009 ("ENGAGE Engineering," n.d.). Their motivation was to improve retention rates of low spatial ability students based on findings from Michigan Technological University (MTU) [1]. Over a period of several years, students with initially weak spatial skills at MTU who participated in an intervention course consistently earned higher grades and graduated at higher rates than students similar in spatial ability who did not participate in the intervention course [2].

While improvements in retention following completion of the course are very encouraging it is not immediately clear how spatial skills training leads to improvements in retention rates and grades. Changes may occur in cognitive and/or affective domains, each of which encompasses a broad range of attributes and abilities. A cognitive ability that is reusable across the engineering curriculum is the ability to represent and solve problems and it was hypothesized that spatial thinking might play an important role in problem solving and that improvement in retention as a result of spatial skills training could be attributed, in part, to improved problem solving skills. The purpose of this paper is to address this hypothesis by examining the impact of the aforementioned spatial skills training course on the ability to solve story problems in mathematics. The study was conducted with participants from first year engineering at Ohio State University (OSU) in the fall semester of 2016.

1 LITERATURE REVIEW

1.1 Spatial ability

Spatial ability came to prominence as a factor of intelligence through the work of Thurstone [3] who listed ‘spatial visualization’ as one of seven primary factors of intelligence. What exactly the factors of intelligence are, or, indeed, whether intelligence is best modelled as a set of factors at all is a matter of much discussion, e.g. , [4], but studies that are based within the factor analytic or psychometric tradition consistently identify three dominant human abilities – verbal, quantitative and spatial ability [5]. No more than the challenge of defining intelligence, spatial ability is a construct that has been hard to capture and over the years has been subdivided into different factors with an even greater number of ways of testing each factor and confusion as to which factor or factors a test belongs to. As noted recently by Uttal et al. (2013, p. 353), “*unfortunately, the definition of spatial ability is a matter of contention, and a comprehensive account of the underlying processes is not currently available*.” Despite this confusion, it is clear that spatial ability is a key aspect of human intelligence and, therefore, likely to play a key role in education.

This key role was highlighted by an analysis [6] of data collected from Project Talent, a study that collected a broad set of psychometric data from 400,000 high school participants and was conducted in the US in the 1960s [7]. Included was a follow up questionnaire distributed 11 years later to determine which, if any, higher education degree awards had been obtained by the participants. Wai et al. [6] focused on the three key abilities which they labelled as verbal, math and spatial and grouped the Project Talent sample based on higher education discipline and level of award. They found marked differences in high school ability profiles between those who were destined to pursue higher education in fields such as engineering versus humanities. Compared to the humanities group, a large difference in math ability was found in favour of the engineering group but the biggest difference was revealed by the spatial measure. Together, math and spatial abilities appeared to act as a filter for both career choice and success in higher education in the 1960s.

1.2 Problem Solving

Project Talent data did not indicate where in the STEM curriculum one is rewarded for having strong spatial ability. A significant relationship between scores on the Force Motion Concept Evaluation (FMCE), an assessment of conceptual understanding of Newtonian mechanics [8], and measures of spatial ability have been reported [9], [10]. The FMCE is a test of reasoning about force and motion using scenarios similar to Einstein’s thought experiment provided at the start of this paper. Similarly, scores on a test of electric circuits concepts called DIRECT [11] have been found to correlate significantly with tests of mental transformation and spatial visualization with the correlation almost entirely explained by questions related to physical aspects of circuits [12]. In chemistry education, spatial ability has been found to be significantly related to tasks that require problem solving [13]. In a meta-analysis, the highest correlations between math tests and spatial ability occurred for math tests that required a significant element of reasoning and the spatial test was mental rotation [14].

1.3 Research question

A common theme linking these studies was the need for some form of problem solving in each of the measures of subject knowledge. It was therefore decided to address this research question:

> *To what extent does a short course on spatial skills development transfer to changes in problem solving ability for both male and female participants?*

Gender was included because research studies have consistently found gender to be a factor in spatial ability with males outperforming females on tests of mental rotation in particular [15].

2 RESEARCH DESIGN

2.1 Instruments

The PSVT:R (Guay, 1976) consists of 30 multiple choice questions designed to measure 3-D mental rotation ability. One of the two practice questions provided at the start of the test is shown in Figure 2. This question involves the rotation of the object by 90° around the vertical axis. The participant must apply the same rotation to the second figure and select from one of the 5 options below a match of the rotated figure. There are 30 questions on the test with variation in the number of axes involved in the rotation and the type of figure the participant must mentally rotate. The test is timed so both speed and accuracy are assessed. Reliability measures for the PSVT:R are reported by (Yoon, 2011) with Cronbach's α = .81 measured using data collected from a sample of 180 education major undergraduate students enrolled in mathematics courses. The PSVT:R was selected as it has been used in previous studies of spatial skills development among engineering students [add ref after review].

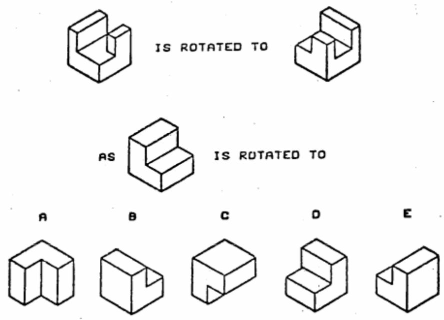

Figure 2-1. A sample question on the PSVT:R [16]

Two sets of math problems, pre and post-test, were prepared for this study. The pre-test contained 8 problems that were obtained in various ways from internet searches of math tuition websites to a database of math problems prepared by the University of Limerick. The post-test was created from the pre-test by changing the quantities used in each problem but keeping the mathematical competencies, format, style and nature of question as consistent as possible. A trial run with some of these problems had revealed a significant correlation with spatial ability [add ref after review]. Forty five minutes were allowed in both the pre and post-tests to complete the problems. Reliability was measured using Cronbach's alpha and found to be .360 for the pre-test and .520 for the post-test. These are both low values and indicate there is little correlation between the different questions on the test with each other, particularly for the pre-test. In other words, performance on one question is a poor predictor of performance on another, at least in the context of this sample of participants.

2.2 Method

Ethical approval for the study was obtained from the Institutional Review Board at the university who requested that all participants be fully informed about the study before consenting to participate. The sample was drawn from students who were enrolled in first year engineering at OSU 2016/2017 and who were identified as weak visualizers based on their score on the PSVT:R that was administered during the orientation phase in the summer of 2016. Those who scored 18 or lower on the 30 item PSVT:R were categorised as weak visualizers and were advised by their academic department to enrol in the spatial skills training course in the fall semester. At the very beginning of the semester a request for volunteers to participate in this study was issued to all weak visualizers including those who opted out of the course. In total, 53 responded to the request, 30 (18 female, 12 male) of whom were enrolled in the spatial skills course and 23 (10 female, 13 male) who were not. All were invited to attend a problem solving observation at the beginning of the semester (August 2016) and again at the end of the semester (December 2016). After each session they were remunerated for their efforts with a gift voucher.

The format for each problem solving session was the same. Each participant booked an individual time slot and, on arrival, informed consent was obtained. The set of math problems was administered in two parts. A think aloud observation was made for the first five problems that lasted 30 minutes. A break then occurred during which the participant was fitted with an electroencephalogram (EEG) hat so that EEG data could be recorded while the participant solved the remaining three problems in silence. EEG data were required for a connected study. PSVT:R data collected during the orientation were entered as pre-test results and post-test data were collected at the end of the semester by administering the same PSVT:R test in class for those enrolled in the course and after the problem solving session for those who did not enrol.

2.3 Data Analysis

Data consisted of scores from the PSVT:R pre and post-test and solutions to each individual problem on the math pre and post-tests. Each math problem was scored as correct or incorrect with some discretion used in the definition of correct – if the answer was incorrect because of a minor computational error at the end then it was scored as correct. The problem scores were added to provide a math test score for each test with a range of 0 to 8. Descriptive statistics were then calculated for each measure. Differences within and between groups were calculated using paired and independent samples t-tests to determine changes between and from pre to post-tests. Correlations using the Pearson method, were determined between each variable. A factorial repeated-measures ANOVA was conducted to determine the significance of test time and spatial skills training on both the PSVT:R and math tests and to also check for any interaction between gender and training

3 RESULTS

3.1 Pre to post-test statistical comparisons

The sample was grouped by enrolment in the course and changes in each measure – PSVT:R and math problem solving – from pre to post-testing were determined within each grouping using a paired samples t-test (*Table 1*) and between each grouping using an independent samples t-test (*Table 2*).

No statistical difference between the PSVT:R pre-test scores of the two groups were observed implying they were equal in spatial ability at the beginning of the semester. Both groups scored significantly higher on the PSVT:R post-test but the gain was higher for those who enrolled in the course – they finished the semester with a mean PSVT:R of 23.07, significantly higher than that of the group who did not enrol whose mean PSVT:R post-test score was 20.61. They finished the semester at different levels of spatial ability. With regard to problem solving, there was no difference between the two groups on the math pre-test but this situation remained unchanged at post-test math scores, both in terms of mean scores and difference between means. Neither group made a significant improvement in the math score from pre to post-test. While the group that did not enrol on the course have a slightly higher post-test math score it is not significantly different to that of the group that did enrol. Correlations between the measures were checked next to determine the significance of the relationship between math and spatial abilities at each time of testing. These were calculated based on the Pearson correlation coefficient and are presented in *Table 3*.

Table 1. Paired samples t-tests of post to pre-test scores.

	n	PSVT:R Pre M (SD)	PSVT:R Post M (SD)	t-test (p)	Math Pre M (SD)	Math Post M (SD)	t-test (p)
All	53	16.58 (3.86)	22.00 (4.55)	8.266 (.000)	2.17 (1.50)	2.30 (1.60)	.599 (.552)
Spatial training	30	16.33 (3.94)	23.07 (4.35)	7.697 (.000)	2.03 (1.52)	2.00 (1.51)	-.101 (.920)
No training	23	16.91 (3.80)	20.61 (4.52)	4.173 (.000)	2.35 (1.50)	2.70 (1.66)	1.283 (.213)

Table 2. Independent samples t-test of pre-test and post-test scores.

	Spatial training (n=30)	No training (n=23)	t-test
PSVT:R Pre	16.33 (3.94)	16.91 (3.80)	.539 (.592)
PSVT:R Post	23.07 (4.35)	20.61 (4.52)	-2.004 (.050)
Math Pre	2.03 (1.52)	2.35 (1.50)	.752 (.456)
Math Post	2.00 (1.51)	2.70 (1.66)	1.591 (.118)

Table 3. Correlations between the math and spatial abilities measures.

	PSVT:R Post	Math Pre	Math Post
PSVT:R Pre	.366**	.424**	.173
PSVT:R Post		.093	.034
Math Pre			.466**

The correlation between the pre and post-test scores on the PSVT:R was measured to be $r(51) = .366$ ($p < .01$). This is relatively small for two measures of the same test but can be explained by the significant change (improvement) in the test scores, i.e. participants responded very differently the second time. For the math tests, the correlation between them was measured to be $r(51) = .466$ ($p < .01$), which indicates some variation shared (22%) between the two measurements. In the case of problem solving, there was no significant change in the test scores from pre to post. With regard to correlations between the math and spatial tests at the two times, values of $r(51) = .424$ ($p < .01$) and .034 (N.S.) were measured for pre and post events respectively. A sizeable and significant correlation observed at pre-testing was completely diminished at post-testing.

3.2 Interaction between gender and spatial skills training on spatial and math

Based on the results from a factorial repeated-measures ANOVA, we found significant main effects of test time on the PSVT:R scores ($F(1,49) = 62.84$, $p < .001$). There was also a significant interaction effect between test time and spatial skills training ($F(1,49) = 5.633$, $p < .05$) which indicates that the spatial skills course had a significant effect on the spatial test scores. There was no significant interaction between test time and gender ($F(1,49) = .074$, $p = .787$) nor was there a significant interaction between test time, training and gender ($F(1,49) = 2.783$, $p = .102$). With regard to math pre and post-test scores, nothing of significance was found using the repeated-measures

ANOVA – neither test time nor interactions with training and gender were found to be significant.

4 DISCUSSION AND CONCLUSIONS

Significant gains in spatial ability were made between pre and post-tests by both groups, those who did and didn't enrol in the spatial skills training course. However, the group that enrolled made a significantly higher gain than those who didn't. It appears that the passage of one semester at OSU first year engineering leads to improved spatial ability while the passage of time plus spatial skills training leads to even greater improvement in spatial ability. Others have observed gains in spatial tests over time in the absence of focused training and have attributed this to a practice effect, i.e. one becomes better simply by taking the test a second time [17]. This hypothesis might be supported by the finding that independent samples of students on all four years of Bachelor of Electrical Engineering programme were found to be equal in spatial ability [12]. That paired samples reveal improvement over time but independent samples do not lends some credence to the practice effect idea. If so, then the group who did not enrol have improved because of test practice and not spatial ability whereas the group who did enrol have improved because of both practice and improved ability.

No significant changes, either positive or negative, were observed in math problem solving and it therefore appears that improvements in spatial ability did not transfer to improvements in solving math story problems. Either transfer is possible but was not found in this case or transfer is not possible. The former could be explained by the poor reliability ratings of the math pre and post-tests leading to excessive scatter in the data – in their appearing to the participants these math questions require so many different skills that a pattern related to spatial ability failed to emerge. Although all the problems are relatively straightforward – they are of PISA standard [18] – and have one correct answer, the results contained much variation in the success rates of each problem pair, as shown in *Table 4*. In parentheses in column three are the number of participants who got either the corresponding pre-test or post-test problem correct.

Problem Name Pre/Post	Incorrect on both	Correct on 1 (pre/post)	Correct on both
1 Rain/Engine Oil	31	20 (3/17)	2
2 Jars/Strawberries	16	19 (7/12)	18
3 Blood/Cylinders	29	19 (16/3)	5
4 Track/Earth Band	33	18 (1/17)	2
5 HCl/Salad Dressing	38	11 (5/6)	4
6 Lawn/Picture Frame	33	19 (13/6)	1
7 Jug 1/Jug 2	17	22 (8/14)	14
8 Cans 1/Cans 2	37	15 (15/0)	1

Table 4. Success rates by test and problem.

For problems 1, 3, 4, and 8 the difference in success rates is greater than 10 (out of 53). For five problem pairs, more participants were correct on the post than pre-test version of the problem, e.g. problem 1, while for the other three, the reverse was true. If practice effects occurred in the math test they were limited to so few problems that they cannot be observed in the total problem scores. The lack of transfer could also be explained by insufficient time spent on spatial skills training or that different aspects of the training need to be emphasised to maximise the transfer to problem solving.

Alternatively, transfer between spatial skills training and problem solving improvement is not possible but this seems at odds with significant relationship that was observed between spatial ability and problem solving. However, correlation does not imply causation, the latter necessary for improvement in one variable to cause change in the other. To follow this line of thought raises the possibility of a third unknown variable that is common to both and provides a reason for the correlation. In the literature review it was established that spatial ability is a key factor in STEM education and that tests of mental rotation such as the PSVT:R are relevant to non-routine problem solving and reasoning. We therefore feel it is justified to conduct a more qualitative analysis of the pre/post data to examine the problem solving process in more detail and search for aspects that may not have been revealed to date.

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E-Assessments to increase the perceived importance of Mathematics in the introductory phase of Engineering Education via bridging tasks

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ABSTRACT

This article presents a project designed to increase motivation and perceived impact of mathematics for engineering students in the first year of engineering studies at Hamburg University of Technology.

The aim of this project is to demonstrate to students the importance of mathematics for any engineering subject, specifically for mechanical and electrical engineering as the main subjects of their respective study programs. This is achieved by posing problems linking both mechanical and electrical engineering, respectively, to mathematics via e-assessment. By explicitly showing the relevance of mathematics for their chosen major subject, we increase student motivation during mathematics classes and, therefore, their performance.

We comment on why we chose e-assessment as the tool to implement the applied problems, bridging the gap between mathematics and the fundamental subject of the two study programs, provide examples of the kind of problems we have found to be successful in achieving our goals and discuss our experiences.

Conference Key Areas: Open and Online Engineering Education, Gender and Diversity, Attractiveness of Engineering Education

Keywords: engineering education, e-assessment, introductory phase

INTRODUCTION

At many universities, and especially in the introductory phase, courses are taught simultaneously for students of different major subjects of study due to organisational reasons. A typical example is a mathematics class for first year engineering students which, for example at Hamburg University of Technology (TUHH), is attended by students from 12 different study programs, ranging from civil engineering to mechanical engineering, process engineering and mechatronics to computer science, environmental engineering and logistics. Thus, these courses are attended by hundreds of participants (1300 in our case) which are very inhomogeneous with regards to skills, knowledge, interests, and motivation for learning mathematics [4].

In order to deal with such a heterogeneous audience, the obvious solution for the lecturer would be a reduction of the material and possible applications to the largest common denominator, which typically is just the pure material. As a consequence, the students typically do not feel that the course is of practical importance for their personal studies, which results in decreased engagement in the course and frustration on all sides.

In this article, we present a project where we, within the same class, pose different problems to students of different study courses. These problems come from applications specific to the study programs but are, when reduced to their mathematical core and needed skills, equivalent in formulation and method of solving for all study programs. In order to enable students to use a mastery approach towards learning mathematics, they need to be able to recognize how content relates to their own goals [16]; that being able to “do” mathematics is worth the effort given the value they attribute to their chosen subject [12]. Therefore, we point out the necessity of learning mathematics in order to excel at their own topics, supporting the development of their professional identity [11]. Also in order for content from one course to be accessible in a different one, connections between courses have to be made explicit [15]. Lastly it is important that students attribute successes to their own efforts [17] and hence experience competence [13]. Supporting students during their first year of study is important because they often feel isolated and under extreme pressure [4, 2], need support to study continuously [3] and wish for feedback [19].

Due to the size of the course, the problems are posed within an e-assessment platform and available information on the students' major subject is used to assign the appropriate tasks. The idea to use e-assessment as a tool to assess students and train students individually is certainly not new [18, 9, 7]. However, our approach is new in the sense that we use specific tasks for specific study programs within one and the same class.

In Section 1 we describe the framework of the course as well as its organisational details, and also present the key facts to the innovation. Section 2 motivates the choice of e-assessment as the tool for implementation instead of including the problems into the lectures or other alternatives. Concrete examples of tasks are given in Section 3, followed by comments on evaluation and our experiences. In the final Section 5 we discuss our project, the obtained results and give a short outlook.

1 THE COURSE AND THE INNOVATION

1.1 Boundary conditions of the innovation

We focus on the mathematics course for first-year engineering students at TUHH. It is a mandatory course for around 1300 students from 12 different study programs. Although it is a mandatory course, it is not a major subject of any of the study programs. Hence, in order to awake and subsequently increase the students' motivation, we have to relate the course material to the students' study programs, assuming they chose those based on interest for the subject.

The course is taught within 2 large lectures per week, one large exercise session, 40 tutorial sessions with approximately 30 students each, weekly problems sheets (where solutions are provided later on) and weekly individual randomized problems on an e-assessment platform for somewhat continuous assessment and formative feedback during the course.

We are using e-assessment as a formative tool in class since 2010 [8]. Concerning the bridging tasks with applied problems linking the content of different courses, we are still in the implementation phase, and we are incrementally building more tasks for different target groups. During winter semester 2016/17, we posed six problems coming from mechanics applications and six problems coming from electronics applications in parallel. During the previous academic year, we only had applied problems related to mechanics, where we had five problems in total.

1.2 Key facts of the innovation

In a first step, we divided the course participants – i.e., the 12 study programs – into two different groups: those students having mechanics as one of their major subjects (e.g. mechanical engineering, ship building, ...), and those students having electronics as one of their major subjects (e.g. electrical engineering, ...). In this step, we implemented applied problems related to mechanics as well as electronics.

In order to find appropriate and interesting applications for each of the groups, we first mapped the topics and the course schedules for the mathematics course with the schedules for mechanics and electronics. This was done by comparing course materials and creating a weekly schedule for all the three courses and identifying the mathematical content and concepts within the mechanics and electronics course for each week. After that we compared with the corresponding weekly mathematics schedule. Now, we tried to make the program of these three courses as coherent as possible by interchanging topics within courses. Note that this step required at least three lectures form different departments to communicate about the curriculum of the students. Additionally, the internal logical structure of each of the subjects had to be taken into account.

After having generated a schedule for the three courses, one can start developing problems suitable for the two groups. We emphasize that we are still dealing with one single mathematics course. Therefore, first we generated a mathematics problem suitable for the mathematical content. Then we rephrased this problem in a way that there is some relationship to the applied courses. For example, when the mathematical task is to solve a linear system of equations, the mechanics application could be the computation of the forces in a truss structure, whereas the electronics application could be the computation of currents in an electric circuit.

It may happen that for a given mathematical task there is no suitable application in one of the engineering fields, or even in neither. Then just the group for which an adequate task exists is asked to solve an applied problem, the other group (or groups) will still have to solve the “purely mathematical task” which would have been the default before our innovation.

In order to increase students' participation in solving these problems, apart from relating the mathematical content to their major subjects, we introduce incentives such as bonus points for the final exam for solving these problems (i.e., an optional incentive, [1]). Another possibility would be to include these problems into a formative part of the final evaluation (i.e., a mandatory incentive). This, however, depends on the rules and regulations for exams, and in our particular case we can only use optional incentives.

2 WHY CHOOSE E-ASSESSMENT

The first big design choice to make–while attempting to individualise students' mathematics teaching–was how to distribute the problems to the students, how to mark assignments and how to provide feedback. Below we will describe the reasons that led to us choosing e-assessment.

2.1 Advantages of e-assessment

Posing problems electronically has many advantages. First, every student can be identified uniquely by their user login. This gives the opportunity to automatically specify problems individually for every student, or groups of students, dependent on multiple possible criteria like their chosen major, their demonstrated level of skill, and many more.

There are quite a few assessment tools available on the market. In our case of mathematics instruction, many of the tools are based on computer algebra systems (CAS). Since CAS allow for random input parameters within problems, one obtains a large variety of realisations of the same problem very easily, so students cannot copy and paste solutions form their classmates and they have a large pool of similar tasks to practice with. The CAS can also automatically mark the students' answers. Furthermore, one can implement an automatic feedback based on the students' performance and the random input parameters. After finishing an assignment, the instructor can get an automatic item statistic for each task without further effort. Although all of these properties can be achieved also by pen-and-paper problems, the cost for creating an adequately large pool of problems, marking them and giving feedback does not scale with the size of the course, but rather stays constant. This makes this approach very attractive for large groups. Note that there are pools of problems available online. However, these problems still have to be adjusted to the concrete course taught due to possible differences in contents, notation, technical platforms used and many more reasons.

Due to the randomisation and individualisation, problems can be re-used: a student can have multiple attempts at the same assignment, working on different realisations of the problems in each attempt, without remembering the answer form previous attempts. So, the use of e-assessment with random inputs is very sustainable.

2.2 Disadvantages of e-assessment

Of course, there are also disadvantages when using e-assessment platforms. Especially when creating problems with random input parameters, there is a lot of effort to be done to obtain "nice" quantities (e.g. when generating a matrix with random elements but one is interested in the eigenvalues of the matrix, then the random elements of the matrix should be chosen in a way such that the eigenvalues are nice, i.e. integer-valued). Therefore, the initial effort for creating one realisation of a task to be used in e-assessment is indeed much higher than for pen-and-paper problems. However, it is important to keep in mind that a good task template with adequately chosen variable ranges generates many task realisations simultaneously.

Moreover, making use of an electronic platform always requires some sort of technical support for the platform. Even though this may be included in some commercial products, it has to be organised by the instructor in open source solutions and can in any case become a huge hassle if the system is not working as promised and hundreds of students call to inquire what is wrong and whether this will impact their grades.

For the students as users of the platform, the technical equipment to actually use the platform is required. Fortunately, many of the available systems are web-based, so one just needs a computer with access to the internet and an up-to-date browser, to which student have access [14, 20].

In summary, the disadvantages of e-assessment boil down to higher costs when creating the problems. Nevertheless, these higher costs pay off in the long run due to re-usability and the usability in large classes.

2.3 Why not include the applied problems into the lecture, exercise sessions or tutorials?

One may ask why we are not including the applied problems, bridging between mathematics and the engineering subject, within the lectures, exercises or tutorial sessions. The first reason is that due to students from 12 different study courses attending the lecture, not all students attend the same engineering classes (i.e. mechanics or electronics). Thus, when including a mechanics problem into the lecture, the students not attending mechanics will not necessarily be especially motivated to see mathematics they are not interested in in the first place applied to an engineering topic they are not interested in, either. And even if they are motivated to follow, they might, due to their missing background in mechanics, not be able to understand the problem appropriately. Moreover, to be fair, one would need to include applied problems for all groups, which would increase the volume of content to be dealt with during a lecture.

One could be tempted to include discussion of applied problems into the tutorial sessions instead of lectures, where the groups are much smaller. However, this would require tutorial sessions dedicated to specific study programs, which increases the organisational effort and may not be doable in practice (which is exactly the case at TUHH). Thus, from an organisational point of view, individualisation within the lectures, exercise class or tutorial session may be impossible.

3 EXAMPLES OF TASKS

In this section, we demonstrate two examples of problems for applied tasks.

3.1 Example: Periodic functions

One easy problem we posed was related to periodic functions with the intended learning outcome of familiarizing students with the interpretation of graphic displays of such functions. Students were asked to read the amplitude and the frequency off a given plot of a periodic function. The parameters of the function displayed in that plot varied to show either sine or cosine, an integer amplitude between -6 and 6 (excluding -1,0, and 1) and an integer period between 2 and 8. Furthermore, the range for the plot varied from half a period to 2 periods on different positions on the real axis.

To motivate this kind of task to students interested in mechanics, the students were told the given plot described the vertical position of a mass hanging on a spring pendulum as a function of time, and their task was to read off the parameters: How large is the oscillation of the mass around its position of rest? What's the period of the oscillation?

On the other hand, we put this problem into an electronics framework by considering an LC-circuit. The given plot was then describing the time-oscillating voltage and the students were asked to identify the amplitude and the frequency of the voltage.

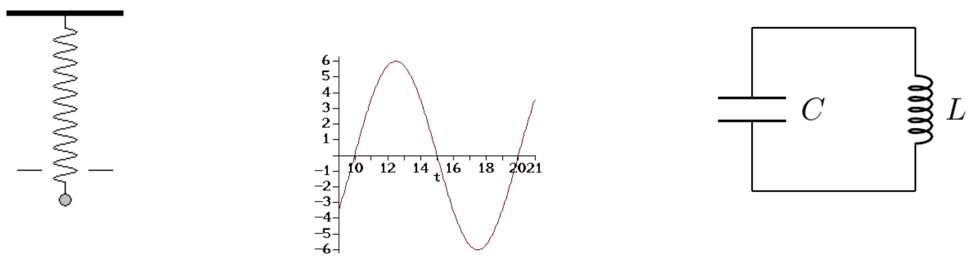

Fig. 2. Pictures describing the applications for the problems. Left: spring pendulum. Middle: One possible graph. Right: LC-circuit.

3.2 Example: Solving linear systems

In this problem, the students were asked to solve a linear system of 6 equations in 6 unknowns, where the random entries of the coefficient matrix were “nice”.

The students from the group related to mechanics were asked to compute the forces at the trusses 1, 2, and 3 and the forces at the junction A (see Fig. 3). The size of the cuboid (i.e., a, b, and c) and the gravitational force were randomized.

The formulation for the group of students from electronics was the following: Given an electrical network with randomized voltage sources and resistances, compute the corresponding currents.

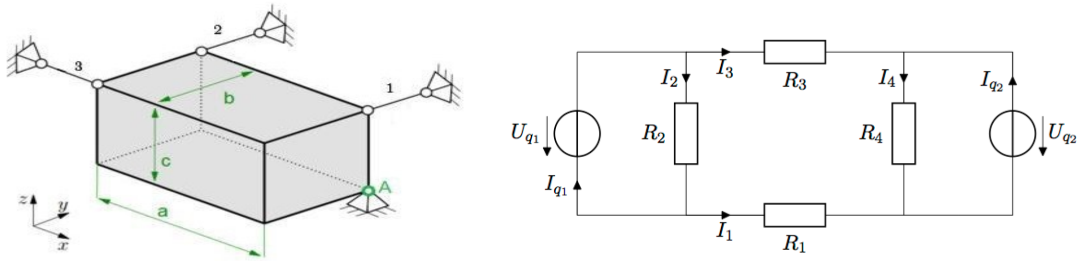

Fig. 3. The pictures describing the application for the problems on solving linear systems. Left: Sketch of a cuboid. Right: An electric network.

4 EVALUATION OF THE PROJECT

We restrict the evaluation of the project to the winter semester 2016/17. There, we had 1264 students registered for the e-assessment of the corresponding course at the platform. We asked three questions for evaluating the project. With a response rate of approximately 16%, students overwhelmingly agreed or were neutral to whether the applied tasks were helpful (89%), whether they helped transfer knowledge between courses (91%) and wanting more applied tasks (90%).

One may also ask the question of whether students were actually willing to use the e-assessment platform. In the course under consideration the students were asked to solve weekly assignments, 12 in total, where they could earn 3 points per assignment (so 36 points in total). Figure 4 shows a histogram of the points earned, so students actually worked continuously on the platform. Around 2/3 of the students got at least half of the points. This corresponds to a typical drop-out rate of 1/3 of the students in this course who chose to leave the study program at TUHH.

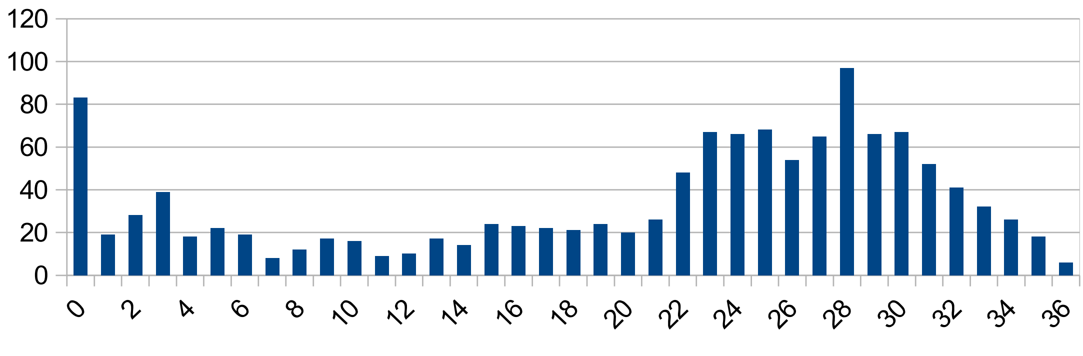

Fig. 4. Histogram of students earning e-assessment points.

5 DISCUSSION

As mentioned above, several tasks needed to be done in order to realise such a project. All of these tasks required personal and technical resources. In our case, we had two employees working part-time (50%) on that project for one year. Moreover, we had student tutors for implementing the problems at the e-assessment platform. Furthermore, the e-assessment platform itself causes costs (either in support for open source systems, or in licence costs for commercial systems). However, these costs have to be compared with the number of students (around 1300) and the possibility to give continuous individual feedback on their performance at this course. This would not have been possible with pen-and-paper solutions. The personal impression (as a lecturer for this course, and the parallel engineering courses) was that the bridging tasks helped students to motivate for the mathematics class, and also to transfer knowledge from one class to the other. So, in our opinion, the costs are worth it. Possible adverse effects of incrementally accommodating students more and more every year are discussed elsewhere [5, 6], however we take care to not fall into the traps described there. To conclude, we are very satisfied with the outcome of this project and will continue to work in this direction. Moreover, we are willing to cooperate with lecturers from other universities on such a kind of project.

6 ACKNOWLEDGMENTS

The authors gratefully acknowledge financial support from Stifterverband für die Deutsche Wissenschaft through their teaching innovation fellowship program.

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Workshops

Increasing interactivity in lectures

Workshop

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ABSTRACT

Perhaps the only thing that e-learning has problems to replace from traditional education are lectures. Some people believe that lectures are the epitome of education, while others believe they are a relict. Still, the average student, throughout the human history, probably experienced much more boring and useless lectures than the exciting ones.

The most important property of live lectures, in comparison with all other educational tools and methods as well as in comparison with lecture's stepbrother – recorded lecture, is interactivity: the ability to ask and answer questions.

The true interactivity is bidirectional: both the lecturer as well as the audience can, and should, ask and answer questions.

The workshop will deal with questions like: why is there so little interactivity in live lectures? How to overcome students' problems which prevent them from asking and answering questions? How to overcome teacher's problems? Which other methods improve interactivity beside Q&A? How can information technology be used to improve interactivity of live lectures? Is there a way to make e-learning interactive? How to substitute or simulate interactivity in recorded lectures?

The aim of the workshop is that each participant carries away at least one useful idea, method or tool which she or he can use immediately in their practice. The workshop itself will be conducted in a highly interactive manner leveraging most of the techniques and methods that will be discussed. It will use an equilibrium of traditional methods to foster interactivity as well as technical tools.

Conference Key Areas: Attractiveness of Engineering Education, Engineering Education Research, Open and Online Engineering Education

Keywords: Lectures, Interactivity, ICT

Addressing Attrition: Changing Students' Futures: A Problem-Based Workshop

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Workshop Aim:

To provide colleagues with a framework for tackling student attrition at institutional level.

Rationale:

Starting with the research question "*How can we reverse the negative impact of failure on engineering students' futures?*", this workshop focuses on student attrition. It builds on the emergent findings of a five year Action-Research Project [1] which aims to directly tackle student attrition by identifying and addressing the socio-pedagogy of failure and by putting in place and testing a series of solutions.

Workshop Outputs:

Participation in the workshop will provide colleagues with the means by which they will be able to develop a bespoke approach to attrition which may be applied at an institutional level.

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1 Andrews J. & Clark, R. (2016). "The Changing Futures Project: An Evidence Based Approach to Attrition & Retention". UK & Ireland Engineering Education Research Network. Annual Symposium. University of York. October.

Workshop Format:

Building on previous research [2], [3] to critically examine the issues underpinning failure and attrition, the workshop will involve small group activities and interactive discussion. It will a 'problem-based' approach and will comprise four distinctive stages:

- **Stage 1: Introduction – *What is the problem?***
  Working in small groups colleagues will consider the issues around attrition and failure at an institutional level. By working in international groups from different institutions colleagues will be able to gain an international perspective of the various issues. Three distinctive factors underpinning attrition will be considered: Student failure: Individual engagement & attitudes: Socio-economic barriers.

- **Stage 2: Study Support – *What are the academic issues?***
  Taking a cross-disciplinary perspective, colleagues will be encouraged to identify the main 'study' based problems in their institutions. Using examples from Maths and Study Skills, the workshop will look at different mechanisms for addressing such problems; whereupon colleagues will be have the opportunity to consider how to begin to develop similar resources for use in their own institutions.

- **Stage 3: Non-Study Related Support – *What non-academic difficulties do students face?***
  The workshop will then turn to individual / socio-economic causes of attrition. It is anticipated that the participants' different organisational and cultural perspectives will result in a rich discussion that will form the basis of future interventions.

- **Stage 4: Plenary**
  The plenary will bring together all of the discussions and outputs from the first three stages, identifying the main problems and considering what the solutions should be. Colleagues will leave with a 'plan of action' for addressing attrition at an institutional level

Conference Key Areas:

This workshop will focus on student support in all areas of engineering education and thus is relevant to all conference themes. It is particularly aligned with:

Engineering Education Research
Curriculum Development
Continuing Engineering Education and Lifelong Learning

Keywords: Attrition: Retention: Failure: Student Support

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Attractiveness of Engineering Profession in Europe

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ABSTRACT

There is no doubt that the public perception of the work and profession of the engineer has an important influence on the attractiveness of engineering education and young peoples' professional choices. However, the image of engineers differs widely among European countries and varies from very positive (e.g.: in Finland) to respectful (e.g.: in Deutschland) and prestigious (e.g.: in France) to a less glamorous (e.g.: in the UK). This large diversity in the social perception of engineers is not surprising as it is derived from the very different historical, cultural, economic and social contexts in which engineering education developed in each country.

In this workshop, we would like to discuss and share knowledge in order to better understand the social perception of engineering work and profession (e.g.: its usefulness, its social status, the associated stereotypes…) in the different European countries. To what extent do these images contribute to the attractiveness of engineering? How is the work and profession of the engineer perceived by young people? What things attract and repel them?

The main objective of this workshop is to explore these questions in an international and multicultural setting and to confront the different points of views of the participants, aiming, through contrasts and comparisons, to attain an across-the-board overview of the image of the profession. The workshop will allow the participants to exchange their views and ideas about the perception of engineering work and profession in their country and compare them with those views dominant in other countries.

We hope to develop a prolific discussion to improve our understanding and knowledge about this subject, which as of present has received very little attention in the literature. In order to achieve our objectives, we have planned a five-stage workshop organization process based on the participants' teamwork.

The results of this workshop will give us a broad panorama which will take into consideration the country-specific contexts of engineering work as seen from varying

economic, social, cultural and educational perspectives. Also, it will hopefully give us an indication of ongoing tendencies and generate emergent ideas for improving the attractiveness of engineering profession for the younger generation.

As work of the SEFI WG of Attractiveness in Engineering Education, this workshop aims to build foundation for future projects concerning motivation and needed talent/competence profile of students.

Conference Key Areas: Attractiveness of Engineering

Keywords: attractiveness of engineering work and profession, multicultural and international perspectives

The Online Learning HUB
a tool for teachers to develop and run online courses

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ABSTRACT

The Online Learning HUB [https://onlinelearninghub.tudelft.nl] is a platform and community to support the development of open and online education. The HUB is created by the Delft University of Technology (TU Delft) with the purpose of supporting staff members in developing good quality open and online education. The HUB helps to structure the course development process, makes the support more consistent, open and accessible, and is embedded in TU Delft's Education Quality Cycle.
The aim of the workshop is to explore, test and reflect on the online HUB service for staff development in higher education institutions that produce (or plan to) and execute online and open education, keeping their staff aligned with the latest developments in the field. The model will be accessible for all after the workshop and can be implemented by each individual higher education institution, and connected into a network of institutional models that might speed up the development of open and online education in Europe and worldwide.

Conference Key Areas: Open and Online Engineering Education, Continuing Engineering Education and Lifelong Learning, Curriculum Development

Keywords: Online Learning, Staff Development, Alignment

INTRODUCTION

This workshop will present and open up the Online Learning HUB and aims to let all participants explore, test and reflect on an online HUB service for staff development, for higher education institutions that produce (or plan to) and execute online and open education, keeping their staff aligned with the latest developments in the field. The model can be implemented by each individual higher education institution, and connected into a network of institutional models that might speed up the development of open and online education in Europe and worldwide.

1.1 Objectives of the workshop

- Explore, test and reflect on the Online Learning HUB as a tool to support the development of online courses;

- Conceptualize a HUB for their own context / institution;
- Compare to their current way of working and discuss the added-value of a HUB.

1.2 Justification of the importance/currency/need for the proposed workshop

Online education is considered critical to the long-term strategy of Higher Education (HE) with consequences for the current professional development policy. While online learning has continued to increase, professional development opportunities for online educators have not been able to keep pace. At the same time most lecturers at brick-and-mortar universities don't have any experience in online teaching and online learning. Improved professional development strategies are needed to facilitate and support faculty to cope with these demands.
Therefor TU Delft Extension School developed the Online Learning HUB [https://onlinelearninghub.tudelft.nl], a platform and community for staff development that supplies operational support for the production of open and online education that complies with quality standards. The purpose is to promote learner-centered professional development which involves teachers (developers, course teams, i.e.) as active and reflective participants.

1.3 Format of the session (provisional agenda)

1. Introducing presenters and participants
2. Why a HUB and how is it used?
3. General HUB setup - challenges
4. Create your own HUB
5. Discussion
6. Wrap-up, feedback and follow-up

1.4 Presentation format

Participants will be introduced to the Online Learning HUB and be able to explore its structure and content using their own device, engaging in tasks provided by the presenters. In the second part of the workshop, active participation will be required to conceptualize a new or adapted HUB to their own context/institution, discuss in small groups and in the end present their ideas to all participants and receive feedback.
It is possible to have virtual participants. We can send the presentation and activities (challenges and design template) to virtual participants interested in our workshop. They will be invited to share their products on social media during the workshop. Results/activity will be shared live on social media.

1.5 Outcome measures

The outcome of this workshop will be:
a. To understand the HUB concept as a new way to support staff development;
b. To understand the HUB as a tool for the development of open and online courses;
c. To develop a first concept for a personalized Online Learning HUB, adapted to the participant's own context / institution and sketched in a canvas template.

We also expect to gather feedback and ideas to further develop the existing HUB and start collaborating with partners interested in the concept.

Demonstration of the Engineering Education Research to Practice Cycle Using a Cyberlearning System for Environmental Education and Research

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ABSTRACT

In this presentation, the authors will share their experiences of developing and implementing a cyberlearning system called the Learning Enhanced Watershed Assessment System (LEWAS) at Virginia Tech (VT), USA. The LEWAS is an environmental monitoring system that monitors water (quality and quantity) and weather data using sensors from an urban watershed that includes VT campus. The development and enhancement of the LEWAS follows the innovation cycle of educational research and practice. This system enables users to visualize and access the high frequency (1-3 min.) historic and real-time LEWAS data using a system called the Online Watershed Learning System (OWLS: http://www.lewas.centers.vt.edu/dataviewer/) for research and education. As of this writing, the OWLS/LEWAS has been implemented in 26 courses, across 8 academic institutions in 3 countries. Three PhD and six Masters level research projects have been completed using the LEWAS data.

Recently, a user-tracking system with log-in functionalities is built on the OWLS to analyze the learner-specific pathways for solving an environmental problem using the OWLS, thus allowing the evaluation of the individual learning and engagement within this cyberlearning system. This work is targeted at advancing personalized learning in the context of environmental monitoring and is related to one of the 14 Grand Challenges advocated by the U.S. National Academy of Engineering. In spring 2017, the OWLS with the user-tracking system was implemented in two sections of a junior level course on “Monitoring and Analysis of the Environment” at VT. A total of 26 students participated in the study, and completed an in-class OWLS-based environmental monitoring task along with a post-survey. The task was graded with a rubric to understand their actual learning, while the post-survey was used to collect data on their perceived learning, and their perception towards the various components of the OWLS. The user tracking system used a database to collect individual student’s actions with timestamp that provided information for approximating the level of engagement within the OWLS. Analysis of the data showed that students found the OWLS to be an effective leaning tool for environmental monitoring education with an average perceived learning value of 5.27

out of 6. The user tracking data described differences and similarities in learning behavior among students (males vs. females and various ethnic minorities) when using the OWLS for an environmental monitoring task. Additional results will be shared in the presentation. Lastly, the attendees will be invited to participate in a "live" demonstration of the LEWAS/OWLS to explore their interests.

Conference Key Areas: Sustainability and Engineering Education, Engineering Education Research, Open and Online Engineering Education.

Keywords: Cyberlearning, Environmental Education, Personalized Learning, Research to Practice.

WORKSHOP

Interdisciplinary Project Management in engineering education

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ABSTRACT

The aim of the workshop is to in an international and multidisciplinary environment, personal characteristics essential in the field of Interdisciplinary Project Management: a sense of responsibility, critical attitude, decision-making ability and integrated problem handling. Within the workshop the current state of interdisciplinary environment will be evaluatedIt, followed by an open discussion of key obstacles on the way to resolving the problem, resulting in practical recommendations how to create and develop an interdisciplinary environment at universities.

Types of activities: problem-driven rather than theory-driven, requiring participants to be active and participatory. Small-scale training and intensive cooperation: active interaction in the framework of individual and team work including expert evaluation of interdisciplinary environment development, barriers and recommendations on how to enhance interdisciplinary environment at university.

Conference Key Areas: Curriculum Development, Engineering Skills, University-Business cooperation

Keywords: Interdisciplinarity, engineering education, project management, teamwork

Closing the gap: Cooperation between secondary schools and Engineering institutions

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ABSTRACT

The readySTEMgo project aims to improve the retention rates of higher education STEM programmes by focusing on the academic readiness of incoming STEM-students. Led by the University of Leuven (KU Leuven), the project is carried out by three key partners (Hamburg University of Technology [Germany], University of Žilina [Slovakia] and KU Leuven [Belgium]), three supporting partners (Budapest University of Technology and Economics [Hungary], Aalto University [Finland], and University of Birmingham [UK]) and the European Society for Engineering Education (SEFI) as a network partner.

We aim to identify those students with an increased propensity of dropping out in an early stage. To achieve this goal, three objectives were realized: the identification of the key STEM competencies that are required to be successful in a STEM study programme (objective 1). Existing diagnostic tests are selected and their predictive power on study success in the first year will be gauged in order to identify students at-risk (objective 2). Finally, we will investigated which intervention tools can support these at-risk students and we will measure the effectiveness of current remediation programs (objective 3).

Goal of the workshop

In this workshop we will introduce the most salient findings of the readySTEMgo project at KU Leuven. Access to higher education in Belgium is based on an open-admission system: if students hold a diploma in secondary school, they are allowed to go to university. This results in a heterogeneous inflow of incoming students in terms of both math/science prior knowledge and attitudes and motivation. An increased propensity to drop-out of university often traces back to students' educational background in secondary education. We have prepared infographics to inform students about the effects of their educational background on future academic success and we have disseminated our results on a large scale to secondary school teachers and staff members, government responsibles, teaching assistants at university, etc.

The prime focus of this workshop is to discuss the cooperation with secondary schools in different countries:

- How can we transfer our research findings to secondary schools?
- What are initiatives that can enhance cooperation of secondary school teachers as full partners in the transition from secondary education to higher education?
- How can we actively reach out to secondary schools and actively involve them in closing the distance between university and secondary education?
- How can we successfully align secondary and higher education curricula both in open admission and selective institutions?

Conference Key Areas:

- Engineering Education Research;
- Attractiveness of Engineering Education;
- Skills and Engineering Education

Keywords: Please select one to four keywords

- Study skills
- Achievement
- Secondary schools
- Open-admission university entry

Employability of Engineering graduates

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ABSTRACT

PREFER project

Engineering graduates frequently display (1) a lack of transversal skills required by the labor market and (2) a lack of self-awareness of their own strengths and weaknesses and of who they are as an engineer.

The objectives of the PREFER project are threefold. First, we aim to construct a Professional Roles Framework wherein the different roles engineers can take on in the beginning of their career are described, independent of the engineering disciplines (e.g., electronics, chemistry,...). Each role will be characterized with an associated set of transversal skills. Thereafter, a Test System will be developed in order to (1) increase engineering students' awareness of the multitude of professional roles in engineering and (2) to make them reflect on their own engineering identity and their interests, strengths and weaknesses. Third, we will explore how to implement these innovative tools into the engineering curriculum by running a number of pilots in the participating universities.

In order to realize the PREFER objectives, a well-balanced consortium was built with both universities (University of Leuven [Belgium], Delft University of Technology [The Netherlands] and Dublin Institute of Technology [Ireland]) and companies (Engie, Siemens and ESB) involved. In order to develop reliable and valid test material, an experienced test development partner (BDO) is a member of the project team. To establish a stable connection with the engineering labor market, the three national engineering federations in Belgium, The Netherlands and Ireland were brought on board. These federations play an essential role in connecting higher education institutions with a large number of companies and SME's hiring engineers. Validation in a wider European network of universities and companies will be tackled by respectively SEFI and FEANI.

Goal of the workshop

In this workshop we will discuss how engineering students can familiarize themselves with the wide variety of engineering positions in the labor market during their educational programmes. We will start from a couple of good practices that are currently organized at the university partners of the PREFER consortium (for example, company visits and short-term internships). Next, participants will be put to work in smaller groups to discuss what are the facilitating factors and/or barriers to implement such initiatives into the curriculum. Also, participants will be asked which transversal skills are considered important by their industry partners and which of these transversal skills young recruits often lack. Finally, we will jointly reflect on how engineering students can be triggered to reflect actively about their position in the labor market as an engineer and how we can motivate them to train specific transversal skills.

Conference Key Areas:

- Continuing Engineering Education and Lifelong Learning
- Skills and Engineering Education
- Curriculum Development

Keywords:

- Labor market entry
- Transversal skills
- Professional roles
- Skills mismatch

Teach as you preach:
Professionalizing teaching assistants in engineering science within the 2020 context

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ABSTRACT

INTRODUCTION

The Faculty of Engineering Science at KU Leuven has over ten years of experience in providing an educational training programme for teaching assistants (TAs), usually PhD students with a teaching assignment. In September 2014, the new training programme SWEET² or 'Starters Week of Engineering and Education: Training for TAs' was introduced. This didactic programme aims at offering TAs support and guidelines for their teaching assignment. Besides enhancing the TAs' teaching skills, the improvement of the quality of education is aspired. The guiding principle in developing this TA training is the 'teach as you preach' principle (TAYP) [1].

The structure, keystones and principles of the training programme will be described to the participants, with emphasis on the TAYP-principle.

DEMONSTRATION

Subsequently, some of the formats used during the training programme, will be demonstrated by performing them on the participants themselves. Doing so, the participants will be able to experience the techniques themselves and share their findings and observations with the workshop-coaches during the reflection and discussion afterwards.

Possible formats for the demonstration:

Format/exercise	**Training-Module used in:**	**Topic**
“Speeddate” (role playing)	Master’s thesis	Student characteristics / Reflection on teaching style
“Build an observation post on Mars” (cooperative excerise)	Problem based learning	Group dynamics
“Facebook profiles” (buzz groups)	Exercises sessions	Student characteristics
“Placemat: What’s good guidance” (buzz groups)	Master’s thesis	Reflection on teaching style, student characteristics, activating strategy’s
“Build a wall” (peer teaching)	Problem based learning, Master’s thesis	Reflection on teaching style
“Video” (testimony)	Exercises sessions, PBL	Communication within didactic team
…..		

QUESTIONS

During the final part of the workshop, a discussion will be held, focusing on the following questions:

- Did you recognize the TAYP-principle? How?
- How do we evaluate these sessions in a more efficient way? How can we maintain quality in a feasible way?
- How do we transfer this to an online-module since the TAYP-principle is not transferable. Or is it?
- And now…lab sessions!
- Other ideas? Suggestions?

As a conclusion of the workshop, the coaches would like to have feedback and ideas emerged from a broader perspective than their own institution. On the other hand, the coaches hope to inspire their peers who face similar challenges or projects.

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Conference Key Areas: Skills and Engineering Education, Quality Assurance and Accreditation, Engineering Education Research

Keywords: Professionalisation, educational development, activating students, TA training

Future development of teaching & learning in Engineering Education – A national Danish approach through the IUPN network

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ABSTRACT

This workshop will address strategies to enable a sustain development of teaching and learning in Engineering Education (EE). Different development strategies from the Danish EE institutions will be presented and how CDIO and PBL actively are used. The activities within the Danish Engineering Education network for teaching and learning (IUPN) and how a national network can contribute to the development of EE will be addressed. The work in IUPN focus on strategies for continues teaching development for important reasons. EE need to ensure engineer students an efficient learning environment and thereby provide them with the capabilities they need to develop new and sustain solutions to present and coming challenges in the automatized future. An identified challenge is how to organise educators' daily work that allows resources and time for research, teaching, teaching development and administration. In Denmark, there is a long tradition for promoting Active Learning and Project and Problem Based Learning in EE as well as in the entire Danish education system. Aalborg University is one of the leading universities globally developing and using Project Based Learning and the university holds a UNESCO-chair in PBL. Active Learning and Design Build Projects are cornerstones in the teaching paradigm CDIO. CDIO is the acronym for the engineering work process Conceive-Design-Implement-Operate and a teaching framework designed special for EE (Crawley et.al 2014). The Technical University of Denmark joined the CDIO network early and has ever since been taking part in the development of CDIO. Most of the providers of EE in Denmark are partners in the global CDIO network. At University of Southern Denmark, the DSMI model is used which has many similarities with CDIO (DSMI, SDU, 2015). Use of these paradigms is a natural development in Danish EE due to the teaching tradition based on Active Learning and projects. In Denmark, it is stated by the consolidation act regarding Higher Education that all staff new in the role as educators must go through a systematic supervised introduction to teaching and learning in order to proceed in their academic career. To meet this requirement there are mandatory teacher training programmes for new educators at all universities in Denmark. The conclusion is that there is a strong tradition to focus on teaching and learning development at the Danish universities and especially in Danish EE. In order to promote the development of Active Learning and enhance a continuous competence development in Teaching & Learning

among educators in Danish EE a national Danish network for teaching and learning development in EE has existed in different formats since early 21 century. The present network is IUPN. The main objectives in IUPN is to create meeting places for educators to share good teaching practises, participate in discussions about the future of Danish EE and extend their network. Activities are working groups around three focus areas; innovation, sustainability and internationalisation, and the international conference “Exploring Teaching for Active Learning in Engineering Education” (ETALEE).

Conference Key Areas: Attractiveness of Engineering Education, Curriculum Development, Quality Assurance

Keywords: Teaching and Learning development, CDIO, PBL, national network

Publishing in an engineering education research journal

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ABSTRACT

Engineering education research (EER) is a broad-based, rapidly evolving, diverse, interdisciplinary, and international field in which scholars apply the methods of educational research to address a variety of issues pertaining to teaching and learning in engineering. Engineering faculty who are accustomed to publishing their research in specialist engineering journals may encounter initial challenges in selecting a journal in which to publish their education research.

This hands-on workshop will be particularly appropriate for participants who are relatively new to publishing engineering education research and will provide guidance in selecting a journal in which to publish. It will also look at research design and the preparation of papers for submission, addressing issues such as style, methodology, research question as well as keyword selection using the Taxonomy adopted by a number of journals as part of their submission process.

Conference Key Areas: Engineering Education Research.

Keywords: engineering education research; publication, journals, taxonomy of engineering education.

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