Design of an MSc Degree course in Aerospace Structures & Materials

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INTRODUCTION

The implementation of the Bologna Process in the Netherlands meant that all universities had to redesign their curriculum to meet the 2-tier system requirement of having a Bachelor and a Master. Until such time most university degrees were 4 – 6 year Master degrees with a broad base typically lasting anywhere between 2.5 and 4 years followed by a specialisation in a certain research direction under the direct supervision of research group and a professor. The initial solution across the Netherlands was to cut the degree in two parts: declaring the broad base the Bachelor phase and the specialisation the Master phase. In the case of the Faculty of Aerospace Engineering at Delft University of Technology this initially led to some many different Master specializations each under the direction of the research professor of that particular specialization. This untenable situation was quickly resolved by simplifying the number of specialization tracks to 5 with compromises being made to come to a single track. After an extensive revision of the BSc programme [1] the MSc track Aerospace Structures and Materials decided to redesign their MSc track to better match the needs of students and future employers. This paper discusses the process of change that took place to come to a new curriculum design and presents its new design. It starts by a short introduction of the Faculty of Aerospace Engineering, Delft University of Technology and the Dutch university system, followed by a section on the curriculum design process, and the final design. The paper is concluded by recommendations for others who want to undertake a similar process.

1 DESIGN SPACE & BOUNDARY CONDITIONS

In the section the context in which the new Track has to be designed is discussed. The section will adress the Dutch university system, the university, the faculty in which the track is situated and lastly the MSc track itself with an aim to explain the context and the boundary conditions within which the curriculum design took place.

1.1 Dutch University System

The Dutch Higher Education system is a two-track system. Bachelor degrees can be obtained in two tracks: a 3-year (180 EC) Bachelor degree at a University or a 4-year (240 EC) bachelor degree at an institute of Higher Professional Education who are allowed to call themselves University of Applied Science abroad.[2] The entry requirement of students entering the bachelor programme at a university is higher that of the universities of applied sciences. After completion of their Bachelor students have an option to start work but many of the university bachelor students go on to do a Master as the University Bachelor degrees typically prepare students for a relevant Master degree where as Universities of Applied Sciences aim to deliver students directly to the labour market. This does not mean, however, that all students from universities go on to do a Master degree or that none of the graduates of a university of applies science continue in a relevant master degree.

A master degree in the Netherlands typically last 1 year with the exception in medical studies, engineering and the natural sciences who typically last 2 years for engineering and natural sciences and 3 years for medicine and veterinarians. Currently about 75% of Dutch university students choose a Master degree at the same Faculty where they completed their Bachelor degree, with the other 25% opting to work or to choose a Master at a different Faculty or university (in the Netherlands or abroad)

Only students with a Master degree are allowed to continue to pursue a PhD degree. In the Netherlands until recently there was a strong tradition that the way you study and how you develop yourself into adulthood was at least as is important as completing your degree. This typically led to students taking much longer than the nominal duration of the degree to graduate. Students would often take longer internships, do extra electives or spend time on extra-curricular activities. The recent economic crisis and changes in the government funding of students and universities alike has put this system under pressure. This has resulted in an increased pressure on universities to ensure that the throughput of students in the system increases and that the mutually accepted delays (by staff and students alike) are considerably reduced.

1.2 Delft University of Technology

Delft University of Technology (TU Delft) was founded in 1842 by King William II of the Netherlands with an aim to train civilian engineers for service to the nation and trade. Over the years the institute developed into a polytechnic school, an institute of technology with its current status that of University of Technology since 1986, one of three such universities in the Netherlands. TU Delft currently has a student population of over 18,000 students (bachelor and master) divided over 15 bachelor and 30 master programmes offered by 8 faculties. To do this the university employs an academic staff of over 2,500 people (source: tudelft.nl).

Each faculty has their own (set of) bachelor programmes. To allow students to further broaden their knowledge students are free to choose a minor of 30 EC in the beginning of their 3rd year at a different faculty within TU Delft or even go as far afield as abroad on an exchange.

Every faculty offers a number of connecting Master programmes, some of which are even interfaculty. To minimise delays students within TU Delft are currently automatically accepted into a Master degree of a connecting Master and are offered two starting moments of the Master degree each year (in September and February). Although there are 2 starting moments this does not mean that all Master courses are taught twice a year, which adds another challenge to any curriculum design.

The university's policy at the moment is to increase the throughput of students and increase their "study success", minimising dropouts and delays. As a result, combined with alterations to the Dutch Secondary education system, many of the current bachelor programmes have over the past 4 years been overhauled raising the need to overhaul the master programmes also to ensure continued connectivity.

Fig. 1. MSc track structure (2 year)

1.3 Faculty of Aerospace Engineering

The Faculty of Aerospace Engineering at TU Delft was founded in 1940 and has since grown to become the largest Aerospace Engineering in number of students in Western Europe. It offers a bachelor degree in Aerospace Engineering and two Master degrees: Aerospace Engineering and together with 3 other European universities the European Wind Energy Master. Currently there are over 1,400 BSc students and close to 1,000 MSc Students. The Aerospace Engineering bachelor and Master degree operate from the principal of the T-shaped engineer. A broad Bachelor degree (the horizontal bar of the T) followed by a specialised Master degree (the vertical bar of the T) [3]. In order to allow students to sufficiently specialise students select a specialization Master track as they start their Master in Aerospace Engineering. They can choose from 5 Tracks:

I. Aerodynamics and Wind Energy

II. Control & Operations

III. Space Flight

IV. Aerospace Structures & Materials

V. Flight, Performance & Propulsion

Each of the tracks allow for further specialisation in to a profile. All tracks have a common set up as shown in the figure 1, with a set of core courses per track followed by profile courses and a set of electives. As part of the common set up all students must take courses in ethics and research methodology and carry out a 3-month internship in industry as well as complete a literature study and a 7-month individual thesis project. These restrictions form the boundary conditions to any new curriculum design within an individual track.

1.4 Aerospace Structures & Materials Track

The Aerospace Structures & Materials (ASM) Track is run by the Aerospace Structures and Materials department, which consists of the research groups Aerospace Structures and Computational Mechanics, Novel Aerospace Materials and Structural Integrity & Composites. The ASM MSc track currently attracts over 50 students (Dutch & International) on a yearly basis and its graduates go on to find jobs all over the world both within the Aerospace industry as well as automotive, offshore and non-engineering jobs in consultancy and finance. About 80% of the intake are holders of a BSc in Aerospace engineering from our own faculty and 20% coming in from other BSc degrees in engineering and (applied) physics and students coming in from abroad.

In the current situation students who register for the track are immediately required to pick one of the 4 profiles on offer for students to specialise in: Design & Production of composite Structures, Novel Aerospace Materials, Structural Integrity, or Aerospace Structures & Computational Mechanics. Each profile is very independent of each other with little overlaps making it difficult for students to change their mind during the course of their MSc degree and due to scheduling issues difficult for students to take profile courses from one of the neighbouring profiles as electives leading to unnecessary study delays. Also although the employment prospects of current graduates are excellent, partly due to shortage in highly schooled engineering staff, feedback was received from our industry partners for the need of an improved common ground of our graduates making them more versatile in the workforce. Finally, within the department, students indicated they would like more flexibility in their options to choose Master Thesis topics and supervisors. There is an increasing tendency of students to select their topic within wider context of the ASM department rather then within the constraints of a single research group. In order to facilitate this desire a broader core base allowing students to freely choose within the department was necessary.

2 CURRICULUM DESIGN PROCESS

In this section the design process is documented. It describes the steps taken and how the design was validated and embedded within the department and approved by the Management Team of the faculty.

2.1 Didactical Background

Experience shows that implementing didactical change is difficult [4]. As with any change process there are phases of mourning (denial, anger, bargaining, depression and acceptance [5] to be completed by those who have to take leave of their current courses and the current way of doing things.

A second challenge is the ‘language barrier’ that often exists between educational scientist and engineering scientist, each not necessarily speaking, and more importantly understanding, each other’s languages. To overcome these challenge the author decided to translate the educational approach in engineering language. As stated by Diana Laurillard at her keynote in the EADTU conference in Paris in 2013 based on her book [6] *‘teaching is a design science’*. If you further extend this statement curriculum design is nothing more than a simple engineering design challenge with the structure the scaffolding of the education system of the country in situ, the boundary conditions the local regulations and requirements of the institute in situ and the market analysis comprises of the needs of future employers, students and society as a whole! Giving engineering lecturers this challenge leads to a myriad of ideas and educational structures that will withstand the design requirements and the tests of time.

The process itself then does not differ from any engineering design process: Requirements analysis, concept development, trade off, conceptual design, final review and production of final design, followed (structural) health monitoring and design during life time (design maintenance). It has been the experience of the author that this approach leads to far less resistance and more understanding of the ground rules and boundary conditions involved in educational design by engineering lecturers.

2.2 Concept Development and Trade Off

Keeping this in mind all permanent academic staff were invited to an off-site kick off meeting lasting an entire day, which was kicked off by a design brief, highlighting the current short-comings, the boundary conditions of a future design and the minimum design requirements. After that the academics were divided in 4 groups each consisting of different member of each the 3 research groups within the department. Each team was asked to come up with a set of learning objectives for the track, a design for the core module and for an unknown number of specialisation profiles. This was done from the blank sheet of paper approach with no requirements with regards to keeping existing courses. Staff was asked to start with learning objectives and translate the need for courses from the learning objectives. At the end of the day each team reported back.

The day was concluded by discussion looking for commonalities and agreements on learning objectives and themes of the specialization profiles. It was during this phase that the idea was born to create one core module introductory module into the track in the first period worth 15 EC which would allow students to acquaint them with the track before choosing which profile to specialise in. The outcomes of the meeting was written up and reported back to the staff for final approval before continuing to the next design phase.

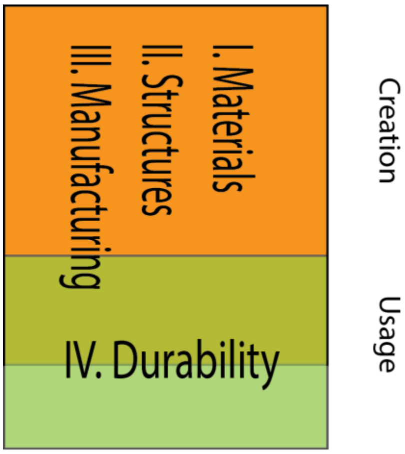

Fig. 2. Thematic Profile Overview

2.3 Conceptual design phase

Based on the discussions and outcomes of the away day a consolidated curriculum proposal was created by a small group of key people in the department. In this initial document the learning objectives and schematic track set up were proposed mindful of the need to provide a structured programme for students with some flexibility yet at the same time decreasing chances of unnecessary delays due to poor choices by the student or conflicting scheduling. In it was decided to create a natural flow of knowledge for students allowing them to specialise further as is shown in figure 1. This holistic approach makes it clear to students which courses are the fundamental courses and which courses are aimed at further specialisation leading on to their internship and thesis. It was opted to go for themes which overlap the different research groups within the department allowing students to travel freely between research groups when choosing their specialisation topic of interest rather that belonging to a specific research group from the start with little option to change as was the case until now. Based on the learning objectives formulated and the knowledge mapping that came from the learning objectives a core module of 5 courses was proposed and 4 thematic profiles consisting of 5 courses each from a total of 9 profile courses, again allowing for overlap between the different profiles offering students the possibility to complete two profiles if they wanted to as illustrated in figure 2. This offers students a broad knowledge base with the option to further specialise in the topics they are most interested in. To that end a number of specialisation electives within the track were offered.

Does this mean all existing courses were completely redesigned? The answer to that question is no, not entirely. Based on the learning objectives and the profile design it was decided on which topics and to what depth courses were needed. If an existing course matched this profile it was kept although its size, place or status (core, profile or elective course) within the curriculum may have changed. This way it also became clear where current courses ran from different different research groups overlapped and were then merged to minimise overlap and foster departmental cooperation. Finally, certain courses were completely abandoned as over time they had become obsolete due to research direction changes.

2.4 Design Approval and Final Review

The final design was written up and circulated once more for comments. In this part of the design phase approval was also sought of the current study body within the track with help of the track's own Student society. Their feedback was very positive and reinsured us that we had correctly interpreted signals from the student body over time. We also discussed our new proposal with our industry contacts receiving positive feedback particularly on our holistic approach to the track leaving behind traditional research group lines. Before rolling out the curriculum, it was also presented to the Educational Management Team and the Faculty's management team for approval, which was duly received.

The next steps were to create a scheduling matrix to identify the scheduling requirements and asking each lecturer to further develop and/or adjust their course as required. As the programme will go live in September 2014 PR material also needed to be drawn up and the final development phase is now running parallel with the recruitment. The new programme was presented to future students in March and initial signs at the time of writing are that enrolment is up from last year.

In June 2014 all lecturers convened for a final review of the detailed design. In this session each responsible lecturer presented their final detailed course design and during this session it is aimed to ensure that all courses connect properly, that work load in courses running in parallel is evenly distributed over the semester and that no overlaps or knowledge gaps exists. The real test will be on 1 September 2014 when the curriculum goes live.

3 FINAL CURRICULUM DESIGN

Although this paper primarily focuses on the process of how to create a new curriculum design, the actual design in terms of content is presented in this section. It starts of with the learning objectives, followed by the content of the core module, the profiles and the electives.

3.1 Learning Objectives

After completing the MSc Track Aerospace Structures & Materials the student will be able to:

- Develop design requirements for materials and structures
- Design lightweight structures and explain the reasoning and the physics behind the design
- Design a material suitable for aerospace application and explain the reasoning and the physics behind the design
- Analyse a structural design using Finite Element Methods
- Explain the manufacturing processes and their applications
- Select suitable manufacturing processes
- Manufacture a prototype
- Explain and predict how a design will perform over its lifetime and explain how the performance can be monitored

3.2 Core Module

The track will start of with one core module of 15 EC consisting of 5 courses of equal load. In this core module all aspects of Structures and Materials, from creation & design to analysis, manufacturing & life –time monitoring of durability, will be discussed along one common theme: the development of an aircraft wing. The 5 core courses are: Design of Lightweight Structures I, Designing Materials with

Aerospace Properties, Linear Modelling using Finite Element Methods, Manufacturing of Aerospace Structures and Materials and Fatigue of Structures & Materials.

3.3 Thematic Profiles and Electives

A total of 4 thematic profiles have been identified for students to choose from which not bound to a certain research group:

I. Material Analysis – if your intention is to be involved in developing materials.
II. Structural Analysis – if your intention is to become structural designers & stress engineers
III. Manufacturing – if your intention is to work in a production surroundings and translate the needs of the designer to production and vice versa
IV. Durability of Structures & Materials – if your intention is to work for Original Equipment manufacturers and regulators, and design for and monitor the structural health of structures & materials or work as certification engineers or crash investigator.

The profile courses are distributed over the profile as shown in table 1 in which the reader can clearly see the overlap between the profiles and the flexibility it offers students.

Table 1. Profile courses overview

Profile Courses	I. Materials	II. Structures	III. Manufacturing	IV. Durability
Polymers (5 EC)	✔	-	✔	-
Advanced Alloys (3 EC)	✔	-	-	-
Functional Coatings (3 EC)	✔	-	-	-
Sensor Materials (3 EC)	✔	-	-	✔
Trinity Exercise (4 EC)	-	✔	✔	-
Buckling & Structural Analysis I (3 EC)	-	✔	-	✔
Joining Methods (3 EC)	-	✔	✔	✔
Experimental techniques & NDT (3 EC)	✔	✔	✔	✔
Design & Analysis & Optimization of Composite Reinforced Structures (5 EC)	-	✔	✔	✔

A total of 16 electives are left over of which students typically will choose 3 or 4. In table 2 the full list of electives is shown. The number of 16 electives may initially look like a lot of electives to offer but this in part because it allows students to specialise in depth and in part because of the electives are also available to other tracks and other faculties within TU Delft and other universities of technology within the Netherlands. Next to this some of these courses are also offered online as part of the Open-to-Education initiative in Delft or as part of the Graduate School Programme for PhD students.

Table 2. Electives

Design of Lightweight Structures II	Design & Manufacturing of Wind turbine blades
Holistic Structural Integrity Process	Design & Analysis of Composite Structures II
Sheet Metal Forming	Stability & Analysis of Structures II
Structural Integrity and Maintenance	Aerospace Structures & Materials Industry Best Practice
Non-Linear Modeling (using F.E.M.)	Forensic Engineering

Aeroelasticity	Continuum Mechanics
Adaptive Aerospace Structures	Materials Characterization
Design of Self-healing materials	Material Selection for Mechanical Design

4 REFLECTION & RECOMMENDATIONS FOR THE FUTURE

With the design process completed and the design-for-life phase about to begin it is time to look back at the process and evaluate. It cannot be stressed enough that it is important to not have this process of curriculum design as a top-down process but as a bottom-up process. Although it is important that the need for change is identified by the management, it is equally important that the ambitions that are to be achieved by the change process are shared by all.

It is whole-heartedly recommended to use the design approach when asking engineers to undergo a curriculum change. The language of design with boundary conditions, design requirements and its review makes the process of educational change much easier for engineering educators who are not educational scientists to understand. It is equally important to ensure all boundary conditions and design requirements are fully investigated and understood before starting the process as this may otherwise lead to a design that can never be executed. A third critical success factor is to also identify the outside stakeholders in the curriculum change process such as the student body, the future employers and rest of the university. A small change can affect many. Finally, look after your designers in the process. Designers are passionate people who can do great things but they must be given the tools for the job and the facilities in order to achieve great designs and work together as a team to a shared goal.

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REFERENCES

[1] Kamp A. (2011) Delft Aerospace Engineering Integrated Curriculum; 7th International CDIO Conference 2011, June 20 – 23, Technical University of Denmark, Copenhagen Denmark

[2] Europedia: https://webgate.ec.europa.eu/fpfis/mwikis/eurydice/index.php/Netherlands:Higher_Education last accessed 12 May 2014

[3] Kamp, A. (2013) Self-Assessment Report 2013, Master of Science Aerospace Engineering, Delft University of Technology, The Netherlands

[4] Fullan, Michael with Stiegelbauer, Suzanne, (2000), The New Meaning of Educational Change, 2nd edition, Continuum, London

[5] Kübler-Ross, E. (2005) On Grief and Grieving: Finding the Meaning of Grief Through the Five Stages of Loss, Simon & Schuster Ltd

[6] Laurillard, Diana (2012), Teaching as a Design Science - Building Pedagogical Patterns for Learning and Technology, Routledge, London