The Effects of Spiral Educational Method through PBL : KIT Project Design Program

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INTRODUCTION

The effectiveness of problem-based learning and project-based learning (both abbreviated to PBL) has been accepted widely. Price reviewed the different types of

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active learning and concluded the support for all forms of active learning and PBL examined [1-2]. PBL has been applied to various courses, e.g. electrical engineering [3-7], computer science [8] and chemical engineering [9-11]. All of them showed their ingenious attempts of PBL and effectiveness in promoting learning outcomes or improving learning attitudes.

PBL is one of key components to guarantee the quality of engineering design education and to satisfy ABET (Accreditation Board for Engineering and Technology) criterion of the curriculum of engineering education. ABET and JABEE (Japan Accreditation Board for Engineering Education) define engineering design as the process of devising a system, component, or process to meet desired needs [12]. It is iterative and open-ended process.

Like PDCA (Plan-Do-Check-Act) cycles, multiple learning circles are also effective for solving open-ended problems. Jing et al.[8] proposed a spirally tight-coupled step-by-step educational method for embedded system engineers. Circles consisted of lecture, demo and lab, and they are repeated to master the fundamental knowledge and skills. Clark et al. reported the development of a project-based, spiral curriculum for chemical engineering education [9-11]. There, traditional four courses are combined and rescheduled to four levels spiral curriculum. It is shown that spiral-taught students showed better performance in educational activities.

To utilize the effectiveness of PBL and spiral method, Kanazawa Institute of Technology (KIT) applies PBL to the backbone of the curriculum, and names it Project Design Program [13-14]. It covers all 14 departments of KIT, which include Mechanical Engineering, Aeronautics, Architectural Design, Media Informatics, Applied Bioscience and so on. More than 1,500 students take this program every year.

Project Design Program is unique and somewhat different from those courses in above-mentioned literature which focus on specific engineering area. The program focuses more on the design process for problem solving and enhances innovation skills. It also pays attention on “*Ba*”, a shared space for emerging relationships [15-16].

This paper is organized as follows: Section 1 describes the pedagogical purpose and the program structure including course management. Pedagogical evaluation results are discussed in Section 2. Section 3 summarizes the conclusion.

1 THE DEVELOPMENT OF SPIRAL EDUCATION METHOD

1.1 Pedagogical purpose

KIT seeks to be the excellent pedagogical system that realizes a practical education required for global engineers. The system considers high school students as an input and grows them up into independently minded, actively engaged engineers. These engineers should be equipped with innovation skills and be able to create solution.

The problem with which an engineer encounters in the actual world scarcely has a clear answer like mathematics. And it is common that two or more specialists construct a team and are in charge of the problem solution. So engineers need skills to acquire necessary knowledge and solve various problems.

For that purpose, PBL has been carried out as the most important educational form in KIT since 1995. Engineering design class was introduced to aim at synthesis of the capability by problem detection and theme pursuit type education. The class provided a frame work of engineering design process, while not demanding skills that most of first- or second-year students have not acquired [17-18]. However the class had a

difficulty of students' getting a sense of accomplishment because the restricted short time made it difficult to produce a prototype or verify the function of their design.

It was developed expansively as Project Design Program in 2012 and the new program forms the backbone of KIT curricula. Fundamental courses and specialized subjects are arranged around it.

1.2 Spiral education program

The expert performance is closely related to the assessed amount of deliberate practice [19]. It is believed that a minimum 10 years of intense practice is needed to be an expert. It is also said "Fail often to succeed sooner [20]." Although such extended practice cannot be assessed in the education program, repeated practice is needed to get innovation skills.

Three types of education circles are embedded in Project Design Program. They are weekly preparation and review, iteration in a course, and repetition between courses. The weekly preparation and review are homework and form a small circle for a class. The design and oral presentation are iteratively-improved during a course. Semester courses act as the spiral educational method of raising active engineers. *Fig. 1* shows the image of the spiral education of Project Design Program for freshman and sophomore [21].

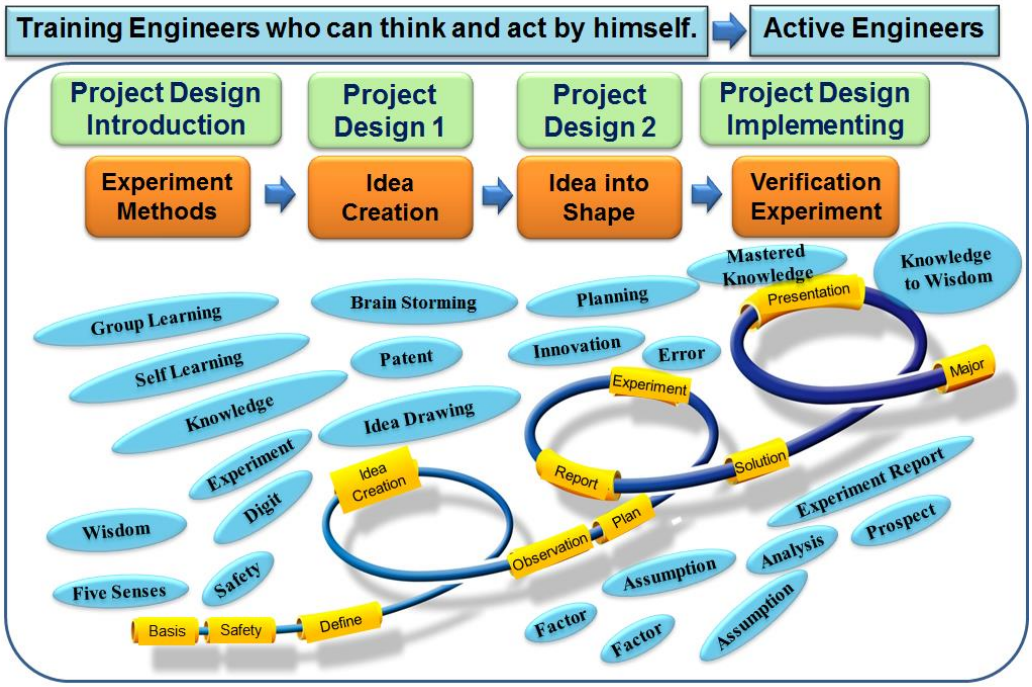

Fig. 1. Spiral Education of Project Design Program for freshman and sophomore (taken from [21])

1.3 Characteristics of each course

Project Design Program is consisted of 5 courses as shown in *Table 1*. They are compulsory for freshmen, sophomores and seniors in all four colleges, e.g. College of Engineering, College of Informatics and Human communication, College of Environmental Engineering and Architecture, and College of Bioscience and Chemistry. The students of the freshman of each college are about 900, 290, 340 and 160, respectively.

The courses for freshman and sophomore are semester courses held for 16 weeks, which are described below. Senior's Project Design 3 is a course for one year, and it is positioned as a capstone course of a graduation thesis.

Table 1. Project Design Program Courses and Main Contents

Grade	Freshman		Sophomore		Senior
Course	Project Design Introduction	Project Design 1	Project Design 2	Project Design Implementing	Project Design 3
Main Contents	Experiment methods	Idea creation	Idea into shape	Verification experiments	Graduation thesis

(1)Project Design Introduction

This is the basic experiment course held in the first semester. The main objectives of this course are to let students carry out experiments safely choosing the appropriate equipment with their own experiment plan and to give them a chance to work in a team towards the set-up objective.

The feature of this course is that students set up the experiment theme of a team freely by themselves. In high school experiment course, they are accustomed to watch a teacher do the experiment of a given theme. Therefore, they are puzzled to find out what to do in the beginning. They discuss in a team and determine an experiment theme of a team. Teachers only give them the advice from a safety aspect and the hint of theory. This process motivates them to the experiment. Some examples of their experiment theme are as follows: making a clip motor, flying a PET bottle rocket, making a paper helicopter which falls as slowly as possible, etc.

(2)Project Design 1 (PD1)

This is the engineering design course held in the second semester. This course puts emphasis on learning the process of creating ideas. The main objectives of this course are finding out a problem, collecting information required for problem solving, and reporting ideas. Three oral announcements are made in each phase.

The feature of this course is that students set up freely the design theme from a familiar problem in a team instead of teacher's giving ill-structured problem. This course does not require making a prototype. So they tackle various problems freely: how to prevent oversleeping, how to protect oneself from an earthquake, ideas for wearable 3D glasses for virtual museum, ideas for improving electric motorbikes, etc.

(3)Project Design 2 (PD2)

This is the engineering design course held for 16 weeks in the third semester. This course puts emphasis not only on the process of creating ideas but also making a plan to verify a function required for realization of the idea.

The feature of this course is that students set up the design theme from main topics which are related to their major. They are requested to find out their familiar problem relating the main topic and create ideas which can be implemented to solve the problem. A team of Department of Robotics tackled the theme "Cleaner robot which can climb stairs." They devised the idea which embedded pantograph structure in the axle suspension.

(4)Project Design Implementing and Operating (PDIO)

This course act as continuation from Project Design 2 and is the experiment course held for 16 weeks in the fourth semester. The feature of this course is that students set up the experimental models to realize and verify some of the functions of their ideas created in PD2. Through this course, students brush up the experimental

technique and improve their design based on the evaluation results. They also announce activity results by the open poster session.

Through these four courses, students develop innovation skills. They repeat and study literature search, idea creation, experiments, and presentations. They also learn the skills of acquiring knowledge. These four courses spirally lead them to actively engaged engineers.

1.4 Program operation

Some tips are required to carry out the PBL course which many students take as a compulsory subject. As mentioned before, nearly 1,700 freshmen (and also as many sophomores) take the course. For example, more than 200 students of Department of Information and Computer Science take Friday morning class. To deal with so many students, KIT has some features not only in its class operation but also in its facilities and faculty members.

(1)Class operation

Each class consists of a short lecture, a team exercise, and homework. Homework is assigned every week and there are individual homework and homework of a team. In the Friday morning class, 200+ students are arranged into teams of 5-6 members. One teacher takes charge of 6-7 teams. 7-8 teachers handle a class in cooperation.

(2)Facilities

There are three large laboratories for experiment courses (Project Design Introduction and Project Design Implementing and Operating). Each team can use laboratory tables and experimental tools freely based on the project theme. There are classrooms equipped with tables and whiteboards for team work for engineering design courses (PD1 and PD2). Each teacher gives a lecture to his teams in a classroom.

Other than classrooms and laboratories, there are 24-hour available study rooms and team work space. These facilities act as “*Ba*”, a shared space where ideas are born from team activities.

(3)Faculties

Most faculties have the experience of leading research and development projects in company. They are accustomed to handle projects and coach team members. They don’t teach so much but behave like an advisor to each team. They interview each team individually in addition to school hours.

2 PEDAGOGICAL EFFECTS

2.1 Evaluation by questionnaire

It is hard to analyse pedagogical effects of Project Design Program because it includes a variety of skills which are difficult to measure by test scores. No final paper examination is done to measure the learning knowledge in the program.

Therefore, questionnaire-based evaluation was carried out in order to measure pedagogical effects on students’ growth. Twenty-three questionnaires are designed to evaluate students’ self-confidence on the objectives of the courses. They are listed on *Table 2*. Questionnaires were held 3 times each during PD1 and PD2 courses: at the 1st week, the 8th week and the 12th week of each course. Students were asked to answer the questions on a 5-point scale; 5-OK, 4-possible, 3-uncertain, 2-not good at, and 1-cannot. Same questions were asked each time. Other than scaled questions, students were also asked to answer descriptive questionnaire.

Table 2. Questionnaires

N0.	Skills relating questions	Comments on questionnaires
A1-A4	Oral presentation	A2: presentation without manuscript
B1-B2	Writing a report	
C1-C6	Teamwork & Leadership	C1: keeping a deadline of a teamwork C5: showing leadership in a team
D1-D2	Ethic of an engineer	
E1-E3	Collecting information	
F1-F2	Problem finding	F2: setting project theme from finding problems
G1-G2	Required specifications	G2: creating a required specification
H1-H2	Idea creation	H1: the ability to create many ideas

2.2 Results and discussion

The survey was performed on Class 2012 and Class 2013. Class 2012 took PD1 in 2012 and PD2 in 2013. Class 2013 took PD1 in 2013 and PD2 in 2014. 1,476 students of Class 2012 and 1,667 students of Class 2013 completed the questionnaires. *Fig. 2* shows the average score of each questionnaire of Class 2012 for the 1st week (PD1W01), the 8th week (PD1W08), the12th week of PD1 (PD1W12), and the 12th week of PD2 (PD2W12).

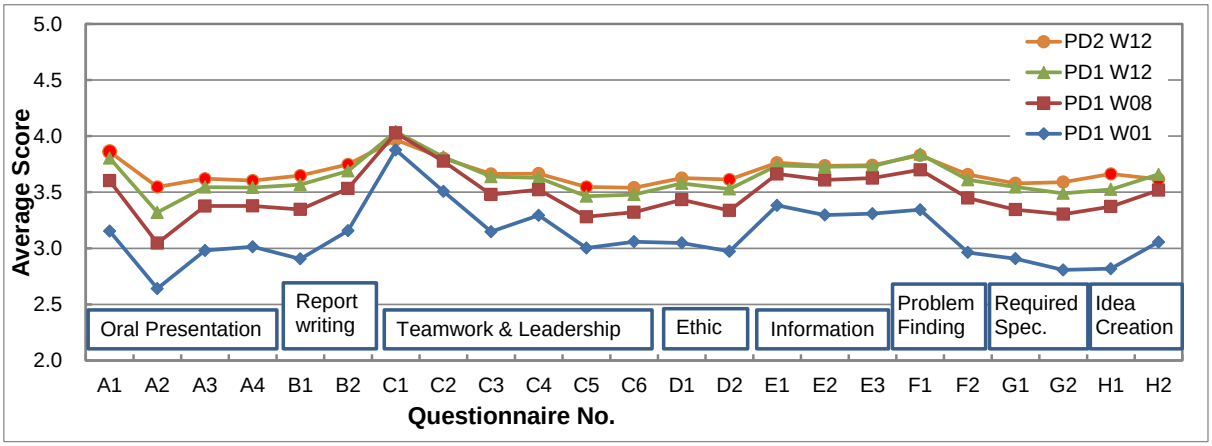

Fig. 2. The average score of each questionnaire of Class 2012

The improvements on skills were observed from the 1st week of PD1 through the 12th week of PD2. Answers to A1-A4, B1-B2, C5, G2 and H1 show the statistically meaningful improvements on each week by the p-value less than 0.05. The large amount of reply to the questionnaire made statistical evaluation possible. The survey on Class 2013 shows almost the same results.

These results showed the effectiveness of spiral education on skills of oral presentations, writing reports, team activities and idea creations. Two poster sessions are set in Project Design Introduction course to express experiment results of each team. In PD1 course, one poster session and tree oral presentation sessions are set to present their ideas. In PD2 course, some teams are encouraged to participate in the off-campus poster session or the oral presentation. In PDIO course, all teams show their results in the oral presentation and in the poster session open to public. Preparing the open presentation opportunity has led to the progress in skills of oral presentation.

On the other hand, the meaningful improvement from PD1W12 to PD2W12 was not observed on the skills of teamwork (C1-C4), collecting information (E1-E3) or problem finding (F1-F2). Although scores of these skills were relatively high at PD1W12, some device is required to improve furthermore. For teamwork, changing team members from PD1 to PD2 is one of reasons. For collecting information, there is too much information on internet and it is easy to get it. So at first students are supposed to feel they can collect information easily; however they soon find it hard to extract good knowledge from there.

On the free description of the questionnaire of PD2W12, most students wrote positive comments on their growth of communication skills, teamwork and leadership. They also commented about progress in motivation.

3 CONCLUSION

This paper has presented features of spiral PBL courses, KIT Project Design Program, which forms the backbone of KIT curricula. Three types of education circles are embedded in the program: weekly preparation and review, iteration in a course, and repetition between courses. With its class operation, KIT has the feature in its facilities and faculties.

A detailed pedagogical survey was discussed and confirmed the effectiveness of the spiral education methods of Project Design Program. Questionnaire-based evaluation of innovation skills was repeatedly carried out to students of Class 2012 and Class 2013. Statistically meaningful improvement was spirally observed on skills of oral presentations, writing reports, leadership and idea creations.

This study also revealed the necessity for the further improvement of the program about information gathering of the internet generation.

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