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Lessons from a capstone design course with a 3D printing project

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ABSTRACT: The purpose of this study was to consider lessons learned from the Industrial and Management Engineering (IME) capstone design course at Hankuk University of Foreign Studies (HUFS) in the Republic of Korea, from 2011 to 2017. Challenges to improve the IME capstone design to meet a project-based learning goal are examined through a best practice case carried out by a student project team. The case study gives an overview of a successful student project with a 3D printer to solve a real industrial problem concerning medical support instruments. Included is a summary of recent experience that led to improvement in the design and development of projects through new technology and interdisciplinary methodologies in the IME capstone course. It provides a benchmark for new project-based learning courses or to enhance existing ones for engineering, social science, economics and management disciplines.

Keywords: Project-based learning (PBL), capstone design course, industrial and management engineering (IME), 3D printer, best practice, case study

INTRODUCTION

It has become important to increase students' practical problem-solving abilities in higher education [1]. A number of teaching strategies and methods have been suggested to reduce the incongruence between the real world and the classroom. Among these, an effective solution is project-based learning (PBL), especially for engineering students. The application of the integrated reality-entrepreneurship project-based learning model helps increase students' ability in skills creation [2], and so PBL is the best way to fulfil industry needs [3]. In most engineering schools the capstone design course based on project-based learning seeks to prepare engineering students for work in industry by challenging teams to synthesise solutions to open-ended, real-world industrial problems [4][5].

Participation in the capstone design course provides students with the opportunity to transition from student practice to professional practice, i.e. from the classroom to real industry. Further, working with a client-advisor from the field (industrial engineers, start-up companies, company representatives, teaching staffs, laboratories, their alumni, and so on) in a type of apprenticeship, students are challenged with real-world needs. Capstone design, therefore, is inevitably based on multidisciplinary learning and team-based collaborative learning. In several studies [6-8], capstone teams with effective communications had greater learning and higher satisfaction with employment and job activities after graduation. Typically, in one or two semesters of the course, teams define a problem, plan their approach, propose creative solutions, analyse the proposed solutions, produce or implement the solutions, and then communicate them internally and externally.

The industrial and management engineering (IME) programmes of most universities have multidisciplinary learning based on many diverse courses, including those in areas such as computer science, statistics, management and economics. To use a PBL model in an IME Department requires taking account of Department specific learning requirements and capstone design course including the multi-task related project [9] and case-driven course [10].

The industrial and management engineering capstone course at Hankuk University of Foreign Studies (HUFS) in the Republic of Korea lasts 16 weeks, and is mandatory for undergraduate IME students in their seventh semester. Students are required to work in teams of 3-5 students to develop a real project. There are many and diverse projects proposed by faculty members from their private or public contract R&D work, projects from within the engineering school, projects based on exhibitions held by outside institutions and student-originated projects. To assist student projects and enhance the innovative capability of students in the capstone course, the IME Department of HUFS has provided several computer-aided manufacturing (CAM) tools, educational robots, drones, big-data processing and computer optimisation software. Using 3D printing technology is a meaningful and effective approach for introducing engineering students to the design process as they found it both interesting and enjoyable [11]. The Department adopted 3D printing recently to help students realise their creative ideas through the design and development of real prototypes.

First, the focus of this study is on the experience of the IME-HUFS capstone design course for the seven years from 2011 to 2017. Second, an overview is given of a successful student project using a 3D printer to solve a real problem of the medical support instruments industry as a best-practice case in designing and developing a project in the IME capstone course. Lastly, discussed in the study are the lessons and challenges from the experience. Considered are the advantages of the PBL course and new product development with a 3D printer by a student team of the IME-HUFS; the conclusions are then drawn.

IME-HUFS EXPERIENCE OF PROJECT-BASED LEARNING

Project-based Learning Courses at IME

The PBL class is based on learner-centred or self-directed learning and its application to engineering education. It has many advantages for students viz:

- participate in PBL to develop teamwork skills;
- cultivate leadership and sense of ownership through problem solving;
- self-regulation and nourish competitiveness;
- understand multidisciplinary engineering application problems;
- cope professionally with actual engineering application problems;
- review or reflect on the results of each project task, and develop documentation, present and communicate;
- deal with incomplete or inaccurate information [4-12].

Such educational and professional advantages have encouraged universities to develop PBL courses, from freshman to senior level.

The IME Department of HUFS has adopted diverse types of projects from freshman to senior level. In the seven semesters from 2015 to the first semester of 2018, the total number of classes with a team project was over 50%. The number of project-based classes has increased, as shown in Figure 1. The second semesters have more project-based classes than the first, except for the first semester of the seniors with the highest percentage 81.3%.

The first semester of seniors includes the capstone design course. Shown in Figure 2 is the finding from analysis of the average reflection proportion of project result in final evaluation of each class during the same period. While the average proportion of project results reflected in the final evaluation increased slightly until junior grade, the first semester of seniors accounted for the highest percentage, 68.46%, which was due to influence of the capstone course. For higher years, PBL and collaborative learning are emphasised in the IME Department at HUFS.

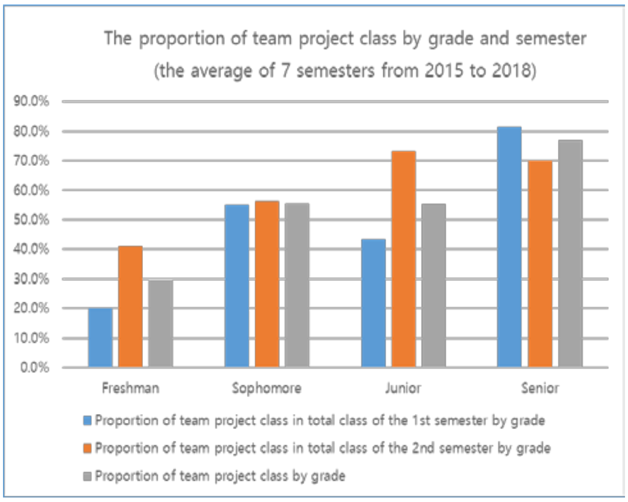

Figure 1: Ratio of project-based classes in IME.

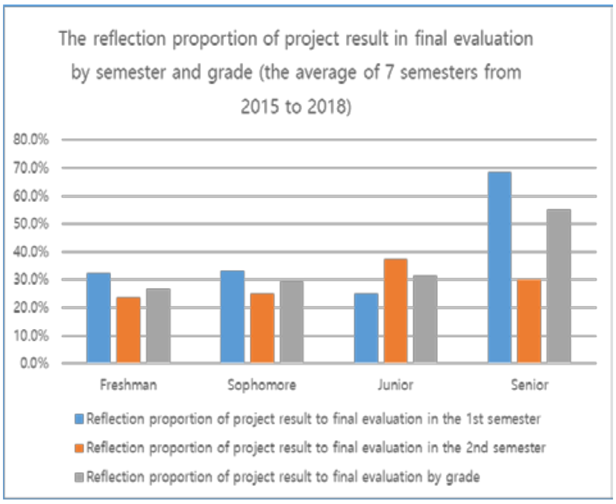

Figure 2: Impact on evaluation of project-based classes.

Capstone Design Course

In general, the capstone courses in colleges of engineering last for one or two semesters in the fourth year. In the case of the IME Department at HUFS in Korea, such a course has been provided for fourth-year students for more than 20 years during the spring semester and is worth five academic points. Students taking this course select their teams and projects autonomously. Usually, the teams comprise three to five members. Although the projects are based on real problems, they are diverse, e.g. projects formulated by students themselves from needs of the industrial sector; projects proposed by faculty members from their private or public work; projects proposed by the needs within the engineering school; and projects based on subjects from exhibitions held by outside institutions. Projects concerned with actual industrial issues are usually recommended to students.

In fact, nearly 80% of capstone design projects are associated with actual industrial issues. The capstone design course consists of the following four elements: the participant (project team); the project itself including client companies; the educational system of the IME Department that provides necessary knowledge; and information and resources of the Department supporting each project. Thus, each project team interacts with the other three components, as shown in Figure 3.

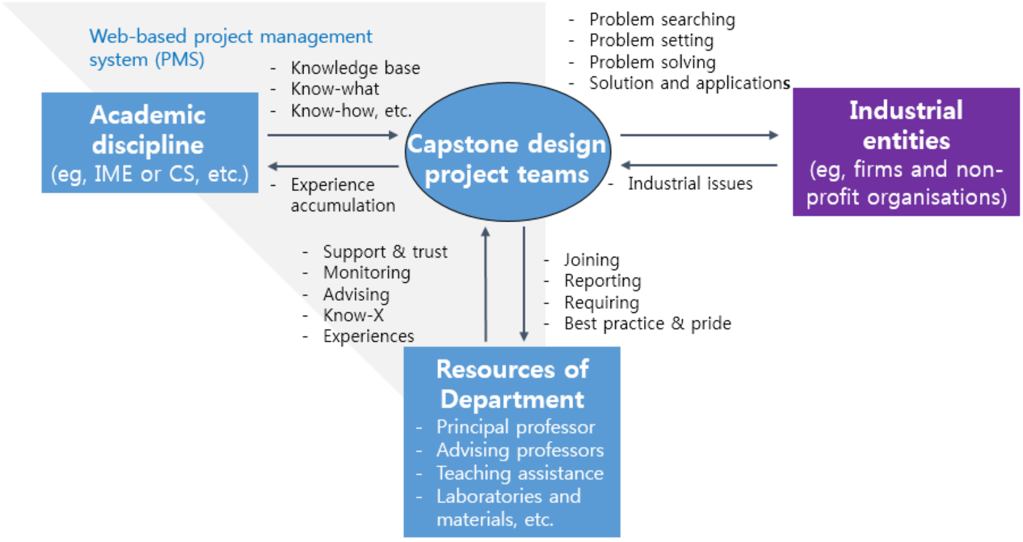

Figure 3: The capstone design course system of the IME Department at HUFS.

The capstone design course operates for the first semester of the senior grade, as well as about 10 weeks before and after the semester. Therefore, the IME capstone design course has three components the pre-course; the class-course; and the post-course. The pre-course activities include organising the team, the search for a project and the preliminary study associated with the project. Furthermore, in this period student teams can be consulted by faculty members and have access to the Web-based project management system [13] for searching existing capstone project results and references. The main work in the pre-course is preparing a proposal and a presentation in the first week of the class-course.

The class-course begins with oral presentations and submitting proposals by all teams on Saturday of the first week. The mid-term evaluation with oral presentation and interim report to decide to go/no-go takes place on Saturday of the eighth week. The final-term evaluation, with oral presentation and final report, to decide pass/fail of the team project is on Saturday of the 16th week.

Formal project execution is initiated upon appointment of a dedicated faculty member to each project team who is the advisor-to-team, as well as the determination of the final subject of each project. The Department usually has assigned a professor as an advisor to one or two project teams for 16 weeks. During the semester, each project team must provide to the class a biweekly presentation of the progress of their project and informal project activities are facilitated by weekly meeting with the advisor-to-team. Further, through frequent visits to, and meetings with industrial clients, the project team can learn about real industrial issues and explore methods of coping with such issues.

Outcomes of the project team activities are assessed during the final presentation; all project teams must submit final reports and project outcomes (e.g. prototypes, programs, information systems, business models, results of analysis). The academic score of each project team and members (students) is determined by three evaluations, i.e. peer review, firm's feedback on the quality of the project output and the advisor's opinion.

A departmental support system provides for post-course exploitation of the outcomes of each project after completion of the capstone course. Exploitation of project outcomes, such as subscribing to external competitions, patent applications, contributions to journals, software registration, or industrialisation of developed or established technologies, has been encouraged by providing pertinent information, expenses and labour resources. Teams usually carry out such activities autonomously during the summer vacation after course completion.

Shown in Figure 4 is the number of enrolled students and teams in the IMF capstone design course and the pass or fail results of team projects, from 2011 to 2017. For seven years, on average 54 senior students have enrolled in the capstone class with 12 project teams. While the average pass rate for the capstone course is 68.7%, the failure rate is 31.3%.

However, most students who have gone through the capstone design course mention that they have gained or experienced the advantages of PBL. In particular, they pointed out that the greatest experience in dealing with the real problems of industry and solving them through team collaborative study is the greatest confidence builder in working life after graduation. In addition to the educational effects of the capstone design coure, diverse external outcomes have been achieved. Top prizes in various external project contests and several articles in international conferences and refereed journals are good examples. Among the results of the capstone design course have been patent applications and programme registrations.

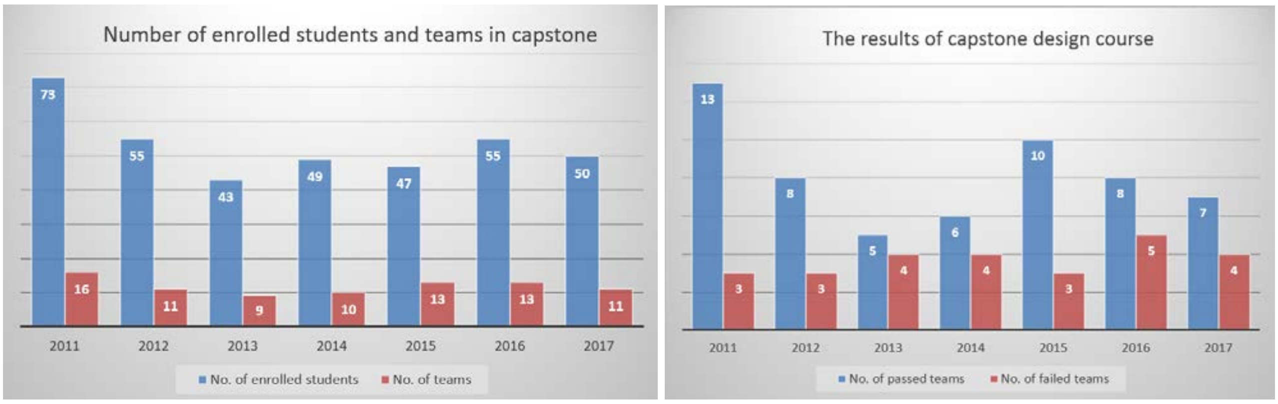

Figure 4: Capstone design status and results, from 2011 to 2017.

CAPSTONE DESIGN CASE STUDY: NEW PRODUCT DEVELOPMENT WITH A 3D PRINTER

Case Team

Fifty-one senior students of the IME Department enrolled on the capstone design course and formed 13 teams, for projects in 2015. Ten teams passed the course. The case team consisted of three females and one male student, all of whom majored in IME. The team's goal, derived from an industrial issue, is to develop a new knee orthosis using a 3D printer, reflecting the customer's needs and the firm's technical requirements and to verify its business feasibility. The project title was *New Knee Orthosis (NKO) Development by 3D Printer and its Business Feasibility*. Their client company was ORTEC (launched in 1999) with 26 employees and sales of 3.8 billion Korean Won, ranked second in 2014 in the Korean lower body orthosis market.

The company wanted to develop a new knee orthosis using auto-production including 3D printing instead of the existing labour-intensive system, as well as to verify the economic validity of it. Since the team members had discussed the problems several times with the client company and the faculty members during the pre-course period, they understood it would require several multidisciplinary knowledge streams, such as 3D printing technology including design skills, new product development (NPD) methodology, as well as economic analysis. The IME Department provided a 3D printer with fused deposition modelling (FDM) including design software (SolidWorks 3D) and 3D-related materials, computers and expendables. They nominated them a No Knock Out (NKO) team. The NKO team ranked in second position on the course. They delivered to the client company several prototypes developed by 3D printer and a business feasibility report.

NKO Team Project Execution and Outcomes

The NKO team carried out the project based on close internal interaction with team members and the advisor-to-team, as well as external interaction with the client company, from the initial stage. They made execution and detailed plans, including assigning tasks to each member, taking into account project goals, internal and external facilities, multidisciplinary knowledge and methodologies required. For example, the project manager, A (female student) has carried out the process management; the regular contact with the advisor; the NPD work included applying the house of quality (HoQ) analysis tool as part of the quality function deployment (QFD) technique. There was a review of numerical control processing prototypes; effect analysis of the prototype (β test) and market and financial feasibility analysis.

Team member B (female student) carried out NPD applying QFD (HoQ construction); a review of several 3D printers; a manufacturing prototype produced by 3D printer; and an effect analysis of the prototype (α test). Team member C (female student) fulfilled a main designer role including a review of domestic and overseas orthosis designs; prototype modelling and design with SolidWorks; a manufacturing prototype made by 3D printer; regular contact with the client; and technology feasibility analysis. Meanwhile, the only male member, D, primarily was responsible for business feasibility analysis for a new knee orthosis, including supporting prototype modelling and design with SolidWorks. A key feature of their detailed assignment was a system of *shooter* and *associate shooter*, one is responsible with support from the other. Although this improves the project execution by non-experts, who do not yet have professional knowledge and skills, strong teamwork is also required.

The NKO team split the execution into two steps that are partially parallel; a development step for a new knee orthosis using a 3D printer and an economic feasibility step to verify a new production system for the new knee orthosis. The first step for developing a knee orthosis consisted of two sequential sub-steps, i.e. the QFD step to identify critical factors for the new product and prototype development step using a 3D printer based on the critical factors. The second economic feasibility step was to test the economic benefit of the developed knee orthosis for the client company through integration of market, technology and financial feasibility.

Shown in Figure 5 is the QFD procedure of the first step to find the critical factors for the new product development. It synthesises two reviews: customer perspective and manufacturing perspective. While the NKO team identified 12 important customer requirements from the customer interviews (voice of customer or VoC), they found the six engineering characteristics (EC) from interviews of the client company's designers and technicians. Then, the critical factors for the quality of new product were identified from constructing the HoQ that is a matrix mapping VoC and EC.

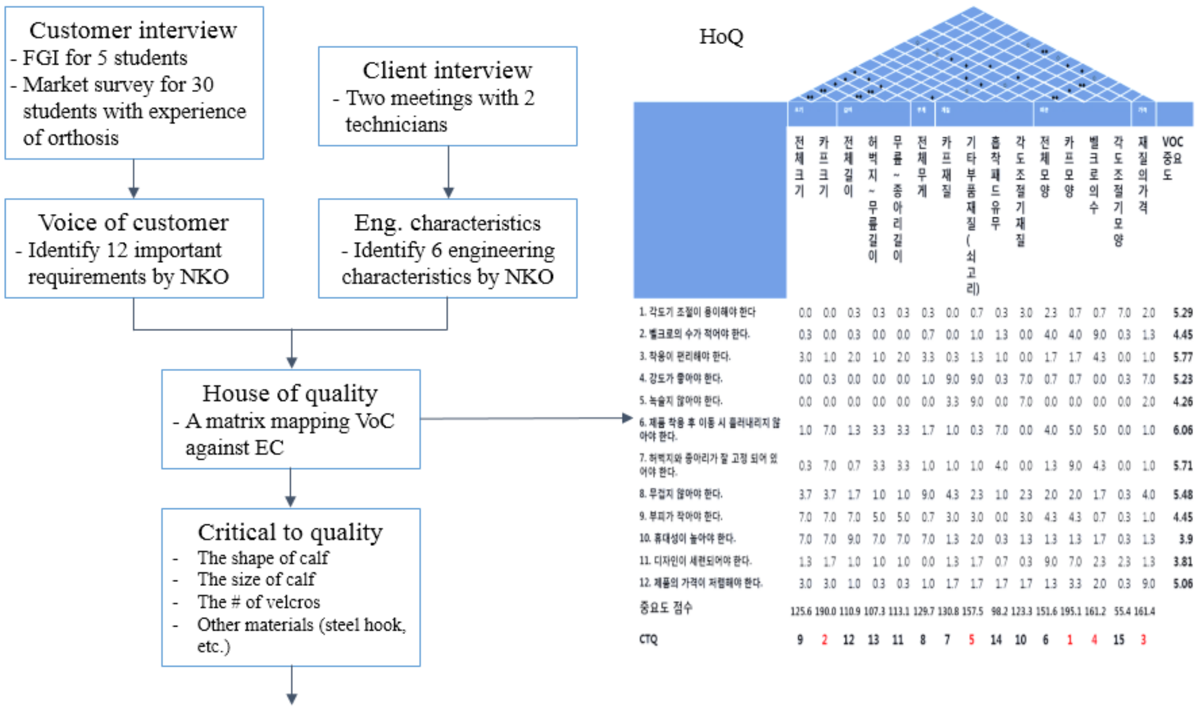

Figure 5: QFD procedure to identify critical factors for the new knee orthosis.

Shown in Figure 6 is the development procedure of a prototype of the new knee orthosis. Important development factors of new products for customers and companies should be reflected in the design and manufacturing process. Especially, a 3D printer enables the design of new knee orthoses, as well as their efficient manufacturing. Furthermore, whenever QFD changes, a 3D printer can be appropriately adapted. The final prototype was completed through α testing by the client company and β testing by the potential customers.

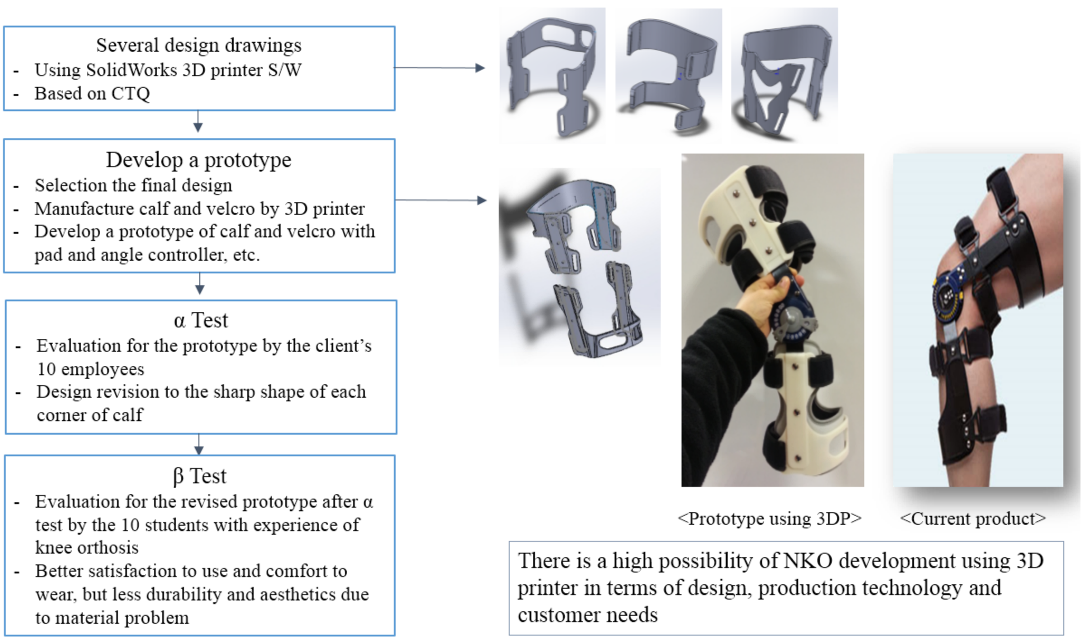

Figure 6: Developing a prototype by 3D printer.

The final stage of the NKO project was an economic feasibility study to verify the new production system using 3D printers for the new knee orthosis, as shown in Figure 7. The NKO team progressed the first steps (market and technology feasibility) with the costings obtained after the technology feasibility step. Sales and total cost for the new production system were estimated for the next three years.

Lastly, a Financial Feasibility analysis was performed to establish that producing 10% of the existing production with a 3D printer was the most economically feasible by both criteria of internal rate of return (IRR) and net present value (NPV). Meanwhile, the team indicated that, although the raw data and estimates of the feasibility test are based on frequent communication between the NKO team and the client, the result was highly sensitive to the current 3D printer price and demand, so if the price drops in the near future, more 3D printer production may be a better decision. The client company, ORTEC, has deeply considered the NKO team's prototype and feasibility test results and decided to introduce the 3D printers to design and develop the new product, as well as to adapt the NKO team's methodology to test the new product [14].

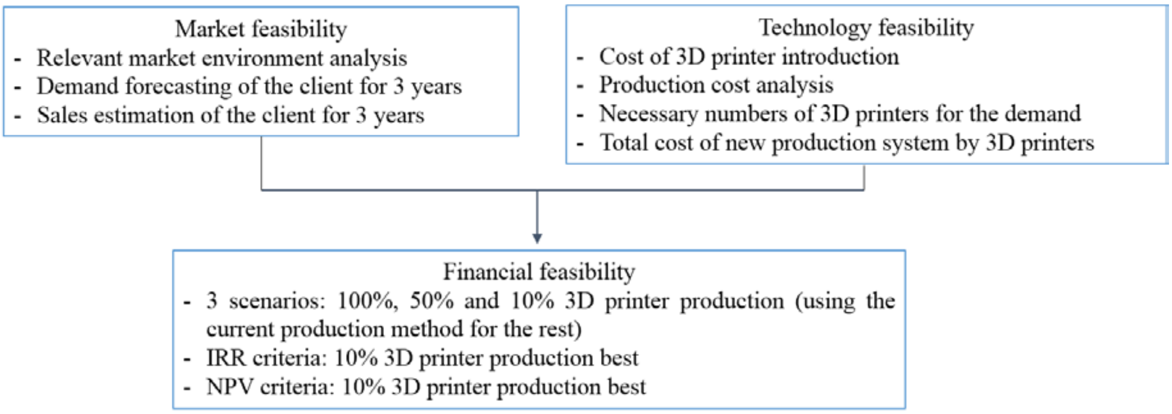

Figure 7: Feasibility test to verify a new production system of 3D printers for a new knee orthosis.

Review of the NKO Team

An advisor-to-team is a separate role from that of a principal professor of the capstone design course who could not handle all details of 13 teams. The advisor-to-team does not provide solutions and instructions to a team, but does play a critical role throughout the execution of the project, including conflict resolution between team members, monitoring execution, consulting on team-specific project solutions, and communication between teams and the Department to support equipment and supplies. As an advisor to the NKO team, the author believes that the most important element of the NKO success is teamwork and enthusiasm. The author has found that in more than 10 years of experience, the most important reason for team project failures was conflict among team members, caused for example by loafing, free riding and irresponsibility toward assignments.

In this regard, all NKO team members did their best for the assigned task, and especially in the case of disputes between team members, the team solved the problem through many conversations and discussions. In addition, team members were not afraid to challenge the learning of a new area, such as 3D printers, and they effectively sought solutions through some sort of backup system (assignment of a shooter and an associate shooter to the important task) for major activities. They gained an understanding of the knee orthosis market and industry through many on- and off-line discussions with the client company and, based on this, they were able to thoroughly conduct market research and analysis of production technology.

They were lucky, because the client company provided design and production information, as well as supported several working face-to-face meetings between students and designers and technicians. The NKO team project is a typical best practice, where the four elements of the IME Department capstone design system worked effectively, as shown in Figure 3.

The client of the NKO team was a small company that cannot afford management consulting on changes in production and equipment replacement. The CEO initially was sceptical as to whether the student project team could offer a solution to the development of a new knee orthosis and the feasibility of a production system using a 3D printer. But, he received the students' proposal at no cost and was impressed with the students' serious and enthusiastic attitudes, as well as their systematic and analytical work during the project period.

Although the company is located in Busan city which is about 500 km from the University, the student team carried out their work based on an understanding of the design and production process of the knee orthosis through several face-to-face meetings and on-line meetings by short messaging service (SMS) with designer and production department members within the company. In addition, a review of the intermediate outputs and feedback was performed. The CEO realised the usefulness for the company business.

The final outcome of the various methodologies in the analysis process will be very important references for the future product development and production process improvement for the company. After completing the project, the CEO noted that a variety of problems arise during development and production by small business. Although these problems can be greatly helped by students' capstone design projects, such companies do not have any methods to find such capable students. Therefore, it would be desirable to have a way to easily connect to the capstone design project team, to help solve the problems that occur in small and medium enterprises (SMEs). It would be good for small- and medium-sized businesses to find new and creative ways to solve problems and for students to have opportunities and the experience of solving the problems of real industries.

As shown in the appendix of the NKO team members' project reviews, all four team members opine that the most important element of their success was teamwork. All teams inevitably have conflicts and disputes among themselves, while on the capstone course. There is a need for the teams themselves to resolve these conflicts. The NKO team also encountered various forms of conflict and disputes, and had attempted to resolve them as soon as possible through frequent casual conversations among members using mealtime and irregular counselling with the advisor. In addition, major tasks were to assign two members to eliminate conflicts over the possibility of incompleteness and of free riding.

The four team members believed they had many benefits, which are exactly the same as the advantages of PBL, as mentioned in the previous section. During their semester, they gained confidence in collaboration, multidisciplinary knowledge and experience to solve real-world problems in industry through project-based and collaborative team-based learning.

DISCUSSION: LESSONS AND CHALLENGES FROM THE IME CAPSTONE DESIGN AND CASE STUDY

The capstone course has been considered one of the most important educational courses in most engineering schools. The IME Department at HUFS is proud of the capstone design course for the senior year because the staff have managed it with the commitment of faculty and teaching staff, as well as many pedagogical achievements over 20 years. The IME capstone design course in Figure 3 consisted of four elements with interactions among them. It was designed to help students construct teams, search and select projects and manage their project execution.

From the experiences of the IME capstone course, as shown in Table 1, although there are still several challenges, where the course can be improved, there are positive lessons from the course which provide a good reference from the four perspectives: university, department, faculty and students.

Table 1: Lesson vs challenges of the IME capstone design course.

Element	Lessons	Challenges
University	- Support for the capstone curriculum - Exclusive use of facilities	- Budget limit for facilities of capstone - Regulation of good grades of students enrolled on the capstone
Department	- Consistent management for systematic execution of the capstone course as a department-specific tradition - Investment for new facilities, such as robots, 3D printers, drone and related S/W - Providing an information system for efficient management of student projects, such as Web-based PMS, KUS and TSS (see below in the text for definitions)	- Obsolescence of the existing facilities - Limited number of experimental assistants due to the decrease of graduate students - Continuous maintenance and updating of the information system to support project execution
Faculty and staff	- Voluntary commitment and self-participation in the capstone class - Interest in project-related issues for student projects - Utilisation of the outputs from capstone projects	- Aging of the current faculty members - Burden of participating on Saturdays and week-based meetings of teams
Students	- High acceptance and incentive of students for the capstone course - Team ownership of projects - Confidence from achievement of the capstone course	- Free riding and social loafing problems - The difficulty of forming the team - The scarcity of company-based subjects - Various complaints for the capstones

Academic staff at Hankuk University of Foreign Studies have recognised that the capstone course has important advantages for students of engineering schools. Therefore, university support has been given to the capstone curriculum with flexible degree regulations, such as five-credit classes, and course management linked to the graduation thesis for the students' Bachelor degree and the exclusive use of a large conference room for public oral presentations on a Saturday. The support of the University for the course is a prerequisite for course management. The limitation of budget for facilities and the restriction rule for *A* grades for students enrolled on the capstone course are still main issues.

The Department has a critical role in assisting student teams by providing facilities related to projects. The IME Department has provided students with a systematic execution procedure and managerial tools for the capstone design course. These include a web-based project management system (PMS) to manage team projects, a knowledge utilisation system (KUS) to search for information and methodologies related to student projects [13], and a team-building support system (TSS) to search for a new member and construct teams [15].

Recognising the importance of capstone design is a necessary lesson for all department members and future members. However, there are many challenges yet in improving the capstone course, such as obsolescence of the existing facilities and limits to their substitution because of budget constraints; and the limited number of experimental assistants due to a decrease in the number of graduate students. As mentioned in several studies [10], the creation of a stable source of funding to ensure the Department has the resources necessary to cover the needs of student project teams is important. Furthermore, although Web-based PMS, KUS and TSS support the execution of students' projects and project-based learning courses, continuous maintenance and updating of those systems are necessary.

The principal professor and the advisors-to-teams have long been involved in the capstone design course, and are proud of the IME capstone. They have been deeply involved in the scoping, selection and execution of student projects from the pre-course and class-course to the post-course, including efforts to submit applications on project outputs to patent, academic papers and external competitions. But, as time goes by, the aging of faculty members is inevitable, guiding and advising student teams, including Saturday assessments and weekly team meetings, is increasingly burdensome.

The capstone design course is *for* students and *by* students. The success of the capstone design course eventually depends on the students. The IME students have heard many times about the course since their freshman years and were able to observe the three public presentations of the capstone design course. In addition, they have understood the advantages of project-based learning. Therefore, they have recognised the capstone design course as an IME Department tradition. They have high incentive to form an autonomous team for their project much earlier in the capstone semester.

Furthermore, the project teams usually hold strong ownership of their project and try for solid teamwork. Especially, regardless of the pass or fail of the final presentation, most of the teams have felt a sense of accomplishment from the project execution. However, not all students had the same feelings and perceptions. There were episodes of free riding and social loafing by some students in team activities that caused conflicts among members and even team breakdown. In recent years, some students have asked that courses are opened at the first or second semester to enable time to prepare for employment, and many have complained about credit evaluation. In addition, many challenges exist for students in building teams and exploring project topics with external client companies. The faculty members have recognised these situations and requirements as challenges to be solved by all members of the Department.

CONCLUSIONS

The Hankuk University of Foreign Studies Industrial and Management Engineering capstone design course was the focus of the study outlined in this article. The university staff experience running the course over the past few years was examined, and the findings are presented in an overview of a successful student-owned project with a 3D printer to solve a real problem of the medical support instruments industry as a best-practice case of the design and development projects in the capstone course. From the recent experiences and the case, the lessons and challenges of the IME-HUFS capstone course are summarised and are a good reference for higher education institutions, regardless of discipline. This is especially so, as methodology to solve the challenges from the students' perspectives, such as difficulties of team formation and researching the project issues of real industrial problems. The extended information systems, such as the Web-based PMS, KUS and TSS were helpful.

Above all, the most important lesson is that the capstone design course has been established as an educational system based on the interests and efforts of the faculty, students and university authorities, and has consequently resulted in a department-specific culture. The project-based learning courses, including the capstone course in the engineering school, although it has required much effort of the department members and high costs for project execution, are one of the best learning models and teaching methods to educate students for a profession.

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BIOGRAPHY

Moon-Soo Kim is a Professor at the Department of Industrial and Management Engineering, Hankuk University of Foreign Studies (HUFS), in the Republic of Korea. He gained considerable experience as a project investigator at the Electronics and Telecommunications Research Institute (ETRI) in Korea, before joining the University. His research is focused on technology and service management, and its various applications, as well as engineering education concerning project-based learning and practice with various techniques. He has published papers in several international journals, such as the *Global Journal of Engineering Education, World Transactions on Engineering and Technology Education, International Journal of Engineering Education*, *Journal of Engineering Education Research* and in a number of journals on technology and service management.

Student A (project manager, female): I have been given the greatest sense of responsibility during my four years of school life. It was difficult but enjoyable for me to make something with a very unfamiliar subject. I had thought there was a limit to the ability of an individual to improve our graduation project (students usually say the capstone design course is a graduation project). Nevertheless, we did it. I think our team has perfect teamwork that cannot be found in any other teams. Since December of last year, we were able to trust each other, while struggling with the project because each was a priority. I have heard that the IME graduation projects are not easy, so I cannot say it is fun, but I can feel all the joy and happiness and I have learned a lot through project execution so far. We proved that our efforts were not in vain, and were happy. I hope this project will be a good memory for all of our team members; further I really believe that our project will be a good foundation for doing other things in future.

Student B (female): our team started a little bit faster than the other teams, but our progress was slower than any other team. We had to spend three months on the project subject in the pre-course that we did not know what to do using a 3D printer. At the time, the idea of a *3D printer theme was not suitable for us* hung in our heads. But I thought that it would be a good chance and I wanted to use the novelty of the 3D printer. The flow of the project was too different. We shook a lot before the proposal and we repeated revisions of the proposal several times. Since the proposal we have really started and have faithfully fulfilled our roles. As I was really eager to work, I had a lot of heated debates with team members. The other teams said that it seemed that we were fighting each other. We used to discuss the project as we would fight that way. After a discussion like a loud fight, during the meal we returned as close friends and think this is the greatest advantage of our team. Also, this seems to have been the driving force of our team. In my opinion, through the ongoing communication between our four-team members, we shared our roles and helped each other. Without this teamwork, the project would end in failure. The unfamiliar topic of 3D printers affected problem-solving from the start, and I learned a lot through several meetings with the client company ORTEC staff and many references. At first, I thought our Department had no project subjects for a 3D printer, but now I think there are lots of opportunities for capstone design projects using a 3D printer. I wish my juniors would make a 3D theme project more interesting in the future. Before the start of the project, I saw several reviews from other seniors who had a very touching team. I thought it would be nice to write it down later, but now I was really impressed with what I wrote down. I got and learned a lot from my graduation project. Long live the IME graduation project!

Student C (female): the graduation project or the *flower* of Industrial Management Engineering is finally over. I have been struggling since I first dealt with SolidWorks 3D printer software. While I am confused whether it is mechanical engineering or industrial design, I would like to compliment myself on the fact that I have modelled more than half of my graduation project and have made a new knee orthosis. Also, thanks to NKO team members who came together last December, I finished responsibly in my own role and by the end of the project, our team work was perfect. Through this project, we learned how to handle work, including communication skills among team members and with the client; how to set up a process, to get results, starting with getting data. Later, I will be a great engineer when I join a company and use what I have learned from the project; and I will become a career woman who can work efficiently with the attitude of industrial engineering.

Student D (male): before the fourth year, the words *graduation project* itself felt scary and only difficult to me. But when I bumped into it, I had fun and learned a lot. Although it was not possible to use 100 percent of the knowledge learned in my main major and dual major, it was a good time for me to realise somehow how to approach and solve problems. In particular, I learned that the new, innovative products, called 3D printers, in detail and learned the CAD of SolidWorks, so I think I am ahead of many engineering students. If it were not a graduation project, the word *3D printer* might have been a word that was not in my head. To carry out the project, we have had six months of constant discussions and solution alternatives, faithfully carrying out their roles, so I am very proud of the good work that has resulted.