AC 2007-918: DESIGN EDUCATION INNOVATION IN KOREA THROUGH CAPSTONE DESIGN EDUCATION PROGRAM

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Design Education Innovation In Korea Through Capstone Design Education Program

Abstract

In 2001 the Ministry of Commerce, Industry and Energy of Korea (MOCIE) launched new projects of human resource development programs to reconstruct the education system of the industrial workforce so as to increase its efficiency. The program was to educate engineering students with revised curriculums considering industrial demand and hands-on experience rather than to go through re-educating process of the industrial workforce after college degree. With the increasing importance of design programs which concentrates on practicality and creativity in college engineering education, the capstone design program has been developed at the Seoul National University of Technology and incorporated into the curriculum. Through this, students, professors, and industries have chances to cooperate in changing design education to fit the requirements of the today's market.

This program was a turning point in engineering education and human resource development in Korea. In particular, selecting practical topics considering industrial demands for their graduation thesis pushed students to seek industry's cooperation by themselves, which resulted in a new system of industry-academy cooperation. The practical engineering design education has been achieved in literal sense. This paper will discuss this newly established engineering education model and the results from the capstone design education of Seoul National University of Technology and its effects on design education in Korea.

1. Introduction

Mechanical system design is a process of devising parameters and working conditions that are needed in developing and manufacturing of a planned product. Being a comprehensive process in product development, it is a major factor in determining the competitiveness of a product. For this reason, design should not be considered as a method of imitating of past products and accumulating of the data, but as a database warehouse which creatively integrates all major areas of manufacturing know-hows in the product developing process. Design today includes not only the functional design, but also sensitive design, process design with super precision, and manufacturing planning. Design is a total solution for a new product.

As a way to create high-value added products and overcome national economic crisis, the

mechanical system design should transit from the imitation design to the information-based creative design. This requires the innovation of design infrastructure and increasing number of professionals specializing in design. Accordingly, design education in college engineering has become more important. And to make it more practical and creative, the capstone design education programs have been incorporated into the curriculum. Through this, students, professors, and industry have cooperated in modifying design education to meet the needs of the job market.

First, the efficiency of the existing human resource development programs of the MOCIE, whose purpose was to re-educate the work force of industry was reevaluated. It was decided that programs to give engineering students practical experience would be added to the existing programs. According to this decision, the MOCIE established the 'capstone design education model and human resources development program' at the Seoul National University of Technology in 2001. This newly revised programs marked a turning point in the programs of engineering education and human resource development by the MOCIE. In particular, by selecting industrial (or real market oriented) themes for graduation projects and inducing students to industry, new approaches of industry-academy cooperation and a practical engineering design education have been created. This paper will explain and discuss this newly established engineering design education model, results from the capstone design education, and its effects on design education.

2. Capstone Design Education

The level of domestic design technologies reaches only about 50%-70% of the top level of the world. When a new design technology is introduced, 5~20% of overall sales must be increased. [1] The domestic industry is especially lacking in system design technology (46.9%) and materials technology (28.8%). [1] Also, at least 2-3 years of field training and experience needed for graduates from college to design practical products in their job. The way to satisfy the needs of the industries and shorten the field training period is to set up professional education courses emphasizing real-life experience and to create attractive working environments suitable for the field design engineers in the university.

Design is the alpha and omega of mechanical engineering. Professors who teach design need to realize that design should not be taught as an independent course, but as a continuous learning process that advances according to the development of the student. Companies like Boeing Airlines and professional organizations like ASME and ABET require universities to hold high standards and great capability of design for engineering [2]. Understanding of mechanical engineering basics, insight in practical engineering, communication skills,

creative and critical thinking, ability to work independently or cooperatively, endless curiosity and unfaltering academic passion are only a few of the most important requirements. The education of such good engineers for the industries needs innovation of lecture-oriented classes and curriculums to cover new technologies. Policies to give more opportunities for students to have practical design experience and accumulate work capability through industry-academy cooperative education and motivate professors to participate in the program. Especially, professors themselves should increase their efforts in design to enhance the comprehensiveness of the capstone design education.[1,2]

In America, since the 70s, when the importance of design courses increased within the ABET[2], an engineering major has been required to take 17-18 credits which are related to design before graduation. Design education has changed from concentrating on analysis to combining synthesis. While the importance of engineering science has decreased, comprehensive engineering design has become more and more important.

By requiring a minimum of 6 credits of comprehensive design courses like capstone design, students can learn the responsibilities of engineers and optimal task management skills in the process of solving real-life, open-ended engineering tasks during the course. While performing projects and achieving goals, students would learn how to use electronic equipment and how to incorporate dynamic cooperation with members in the group. By working in teams, students would develop communication and presentation skills. Students will be able to experience and perform tasks by incorporating the resources of industries which would be otherwise unavailable to them. Through this, new opportunities for industry oriented education would be created for universities. For industries, there are new product developing chances and sometimes, new patents can be obtained by providing the creative students a little of industry, resources such as expertise, materials, or data.

3. Capstone Design Education Project of Seoul National University of Technology [3]

Starting in 2001, the Seoul National University of Technology, for the promotion of capstone design education in design education of Korea, has performed the project of 'Developing Capstone Design Education Model and Human Resources Development' and has played the central role of spreading and supporting practical design education programs throughout Korea. For this purpose, the Seoul National University of Technology has developed an information system to encompass information of technologies of design and manufacturing, and engineering education. By doing so, it has been able to meet the increased needs of mechanical system design technicians in industries. The Capstone Design Education project is becoming gateways to start new businesses and create of patents as shown in Fig. 1.

Through these projects, a new model in engineering education to train more capable engineers needed by industries has been established.

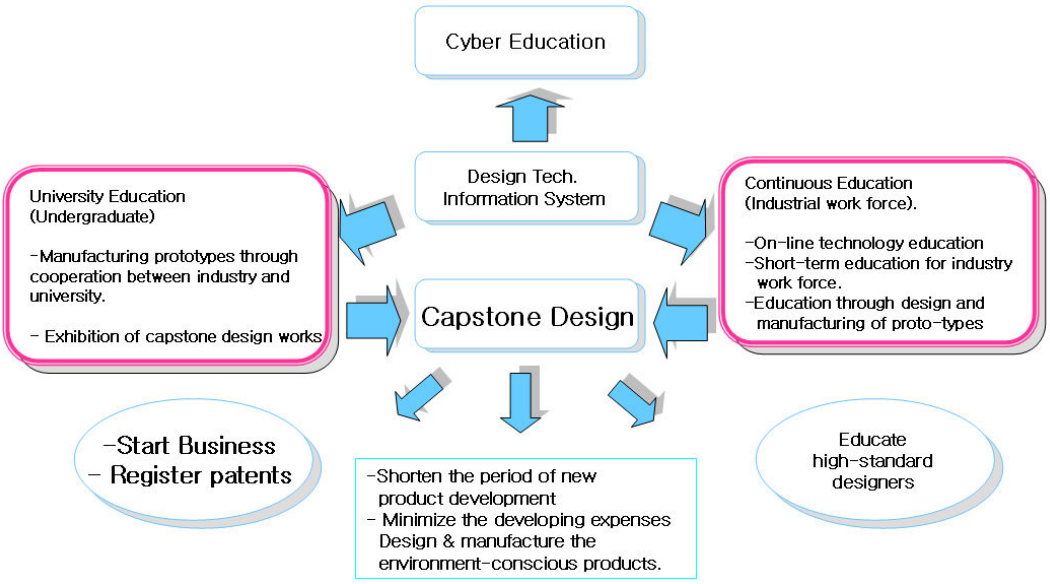


Fig 1 Industry –University Capstone Design Education Program [5]

Seoul National University of Technology has been executing the Comprehensive Graduation Design Projects as a required course for the graduation by Mechanical Design Department since 1994. Starting in 1998, by presenting and exhibiting graduation design works of students at the Korea Exhibition of Machinery, International Exhibition of Die and Mold Industries, and International Exhibition of Automation Systems and Precision Equipments, Seoul National University of Technology is credited for introducing a new model of engineering education and educating design engineers with practical experience (Fig. 1). From 1999 as a part of the Seoul National University of Technology education projects, it has been pursuing the construction of a design technology information system to support the design education program comprehensively. Based on these projects, starting from 2001, the university has been pursuing the following goals.

First, as a preliminary executive university of the Capstone Design Education, two Seoul National University of Technology's specific goals are establishing the Capstone Design Education model and expanding the reeducation program of industrial workforce. Engineering students, after learning system design, an interdisciplinary curriculum of design education, a design information system with a data base of various design techniques, design elements, and teaching materials are expected to grow out of the projects. The Seoul National University of Technology has hosted annual engineering education forums since 2001 and has recommended students of design engineering to participate in national and

international design contests.

Second, specific methods to spread capstone design education are as follows: formation of industry-academic cooperative system of design (Fig. 2), reeducation of industrial working people using capstone design based education system, development of a national network of capstone design education among universities and industries for the spread of the design education model, setting a strong relationship with ABEEK (Accreditation Board for Engineering Education of Korea), and foundation of Capstone Design Education Support Center.

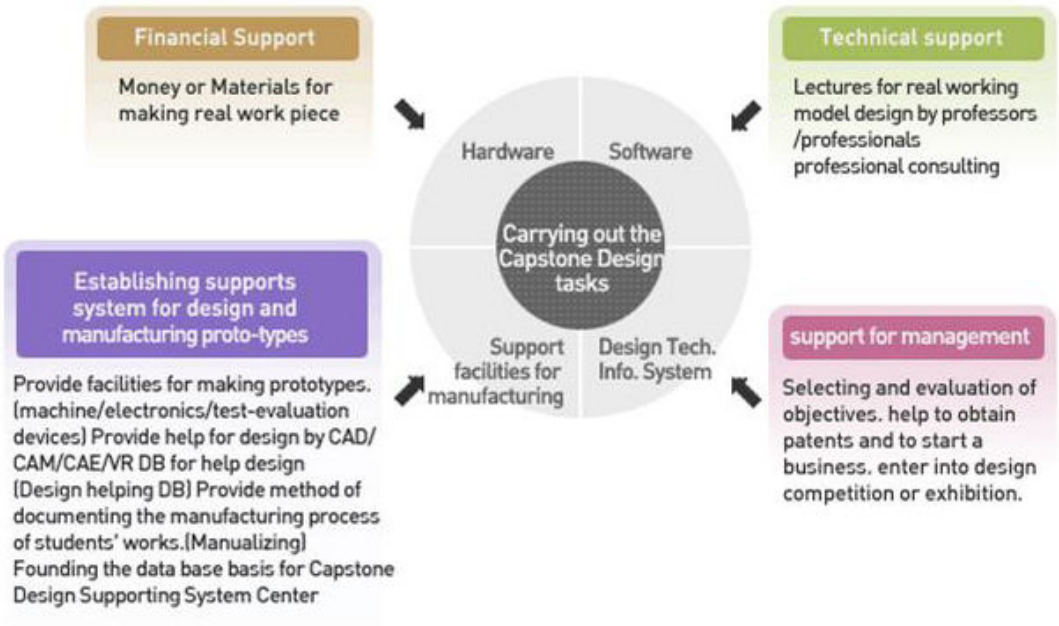


Fig 2 Supporting System of Capstone Design Education Project [5]

Third, with the construction of a web-based comprehensive information system of mechanical system design (Fig. 3), the followings are expected to achieve: exchange of information of design among universities and industries for solving bottleneck engineering problems: Data-Base of mechanical and electronic parts, design consultation using design professionals: and development of manuals of design and manufacturing process of mechanical and automatic systems.

Fourth, as ways to keep the capstone design education program a self supporting program after spending funds from the MOCIE, several plans are considered. These include a supporting system of patent creation and systematic consultation for system design and new product design for industry: support for starting of businesses using new products from capstone design projects: re-training program of industrial working people: and adoption of

membership payment system for Web-Based Comprehensive Information System of Mechanical System Design (Fig. 3), etc.

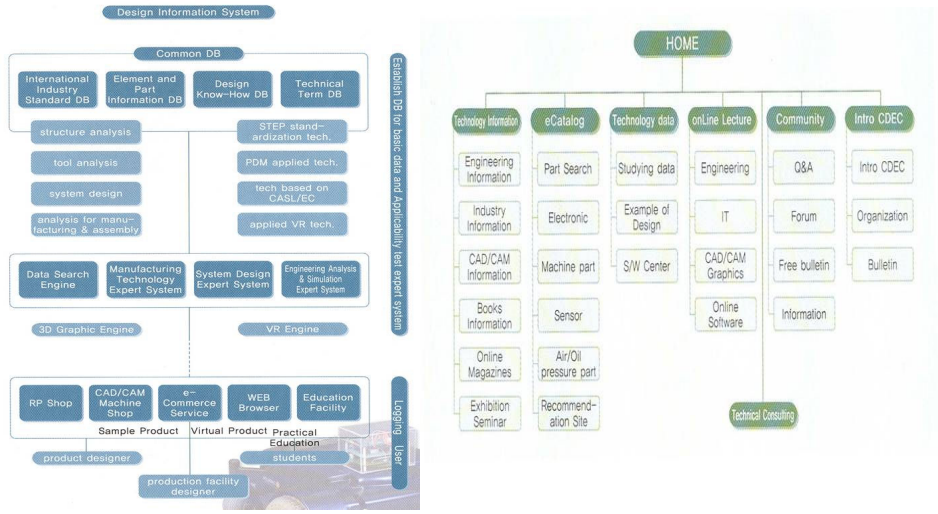


Fig 3 Web-Based Design Information System [4]

Capstone design education was started by three major departments (School of Mechanical Design and Automation Engineering, Department of Die and Mold Design and Department of Industrial and Information Systems Engineering) and was expanded and adopted by other departments of the College of Engineering of Seoul National University of Technology. Experience from the capstone design projects plays a major role after graduation in real-life work places, since most topics of the projects are given from industries and so are related to real industrial projects. In the grouping of teams, in order for design education and professionalism to be balanced, a member from a particular industry and students from many other departments are selected for a team. From this, interdisciplinary collaboration and learning are achieved. Themes provided every year by industries are given as the themes of projects. As seen in Table 1, the education curriculum has been changed to be oriented around practicality for more time in labs and experiments so that the seniors can perform projects easily in the lab. As in Table 2, for an evaluation of the progress of capstone design, monthly presentations are hosted which in turn will enhance presentation skills and allow objective evaluation of projects and progress of projects comparing with others. Projects are also presented in public exhibitions for more objective evaluation.

Table 1 Mechanical Engineering Curriculum Based on Capstone Design Education

Yr	Stage of Education Progress	Items for Education	Important Educational Direction
1	learning structure and principles of machines and electric circuits	- disassemble/assemble -operation of working model mechanism -basic electric/electronic circuits	-educate principle of operation of mechatronic system and its structure -encourage to learn basic mechanics and engineering analysis -instillation of engineering motivation and interests
2	Understanding elements and parts of machines and automation systems	- comprehensive integration of basic mechanics -digital/analog circuit theory and application -application of computer software and computing tool	-emphasis on cultivation of capability of basic mathematics and engineering analysis - educate real application of engineering techniques to the practical products based on industrial needs. -transformation engineering education philosophy from Teaching to Learning and from Faculty to Self - education based on laboratory and practice
3	Emphasizing system design of machine and automation	-engineering design and analysis, CAD/CAM -mechatroniocs 1,2 -fluid/pneumatic Power 1,2 -microprocessor control -labs and internship	- provision of advanced design tools of intelligent and automation system - emphasis on teaching of practical engineering tools of CAD/CAM, engineering analysis, mechatronics, digitalized mechanical system operation - conducting capstone project in summer and winter breaks
4	Application of capstone design of machine and automation	-Capstone Design 1 -Capstone Design 2 -Capstone Design products exhibition -optional class for Special engineering majors	-design/manufacturing of capstone design projects with industries for future jobs -completion of capability to apply engineering knowledge to real industrial design and manufacturing of products. -open various courses related to industrial design projects -supervision of students by university faculty and industrial faculty

Table 2 Schedule to Teach Capstone Design Projects

Semester	Month	Contents (activities)	Supports	Lectures/Events
Spring	1	grouping of design teams and idea presentation	industrial projects and provision of ideas by faculty	Lecture: creative design methodology
	2	design idea presentation (production cost estimation)	set up project objectives and guidance of projects	Lecture: machine element design
	3	evaluation of basic design idea	provision of mechanical characteristics and new ideas	Lecture: CAD/CAE
	4	evaluation of detailed design and assembly drawing	allocation of labs	Manufacturing parts &purchasing process (consultation by experts)
	5	purchase of parts and material, and fabrication of elements	purchase of parts and materials	Lecture: manufacturing process
	6	mechanical fabrication and design of control circuits	support for circuit fabrication	Lecture: mechatronics
	7	mechanical fabrication and design of control circuits		Lecture: PLC and microprocessor
Fall	8	preliminary assembly and test operation	fabrication of PCB boards	
	9	Correction and improvement of system performance		
	10	assembly, test operation, preparation for exhibition	preparation of patent application	
	11	exhibition and completion of report	display panel and pamphlet preparation	Lecture: technical writing of reports
	12	evaluation of report		collecting new ideas for following year projects

4. Results from Collaborative Industrial Capstone Design Projects [2,3]

As a way to keep the capstone design education program as a self supporting program after spending funds from the MOCIE, several industrial projects have been performed to establish the system of prototype product development for the industries. These projects were made from technology royalty and patents for the Capstone Design Education Center. Out of the 80 Capstone Design Projects every year, 10-15 projects are done as industry-academic cooperation projects (Fig. 1 & 2). The Capstone Design Education Center supports 40% and industries support 60 % of project cost for each industrial project. In most of these projects the ownership of the Capstone Design projects can be given to industries, but the patents arising through contracts belong to the college. There is also an option of giving the patent to the industries, but allowing free-usage to the college. Currently, every year 5-6 patents are being given to projects which are investment-worthy. Table 3 shows the current situation of patent licensing by year and Table 4 shows list of industrial capstone design projects.

Table 3 Capstone Design Patent Application

Yr	Application	cases
2002	request for R & D by industries	3
	patent and new design application	8
2003	patent	4
	patent on new device	2
2004	patent	3
2005	patent on new device	1
	patent	3

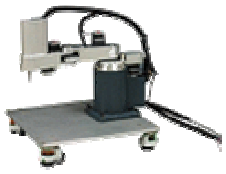
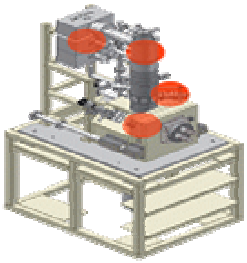
Table 4 Industrial Capstone Design Projects

Yr	Department	Project Title
2001	Mechanical Design and Automation	6 bar Robot, New Laundry, Shampoo Machine, Train Model, Internet Based Robot, Automobile Simulator, Remote Control Vacuum Cleaner, Multi-Purpose Electric Car, Undersea Robot, Internet Electric Boiler, MEER ROBOT, INFO ROBOT
	Die and Mold Design	Deep Drawing Process for Stainless Steel Cook Ware, Improvement of Die Design for DVD/Player housing & Tray Design of Three Dimensional Parts and Standardization of Chip Die Fluid Analysis of Large Forming for Automobile Optimal Operational Condition for Injection Stretch Blow Molding
	Industrial & Information Systems	Construction of Internet Shopping Mall based on Three Layer Structure Concept, Jewel Design Using CAD/CAM Technique Diary for Health Examination
2002	Mechanical Design and Automation	Ribbon Cutter, EA Wheel Chair, CVT Bicycle, Automation of Cement Molding, Drawer Style Automatic Parking System, Design of web-Based Data Base, Smoke Generation Device of Model Locomotive, Micro Reduction Gear Design, Torus Compressor Design and Manufacturing, Intelligent Suspension System, Horizontal Multi-Articulate Manipulator
	Die and Mold Design	Fluid Analysis of Large Forming for Automobile Development of Post-Processor of Micro-Bellow Analysis for Automotive Panel Forming , Optimal Operational Condition for Injection Stretch Blow Molding
	Industrial & Information Systems	Design of GUI and Wireless Remote Control Using CDMA 1X Network Design of 3 point Sensor
2003	Mechanical Design and Automation	Shear Die Feeding System, Two Wheel Driving Moving Supervision System, Flexible Automatic Control Device, Intelligent Automobile, Wafer Transporting Robot, Rubber Forming Machine, Scalar Robot Using Step Motor, Remote Controlled Balloon, Automobile Simulator, Emotional Toy
	Die and Mold Design	Analysis of Forming Shrinkage of Forming Products Micro Bellow Post-Processing Development
	Industrial & Information Systems	Measuring System with High Precision, Design of Automatic Control System for Air Purifier, Design of Air Cooler
2004	Mechanical Design and Automation	Automation of Wig Manufacturing System, Design of GPS of Human Robot, Design of MJPEG based IP Camera, Humanoid War Robot, Design of Propeller of Pleasure Boat, Humanoid Robots Using DSP
	Die and Mold Design	Residual Stress Measurement on forming Products, Micro Bellow Post-Processing Development Design of Die and Mold of Personal Mobile Phone Case with Self Defense Device
2005	Mechanical Design and Automation	Multi-Objective Motored Rowing Boat, Design of Electric Trike, Design of CVT of Automobile, Measurement of Distribution of Body Pressure, Various Humanoid Robot (Golden Titan)

Another effort is to provide an opportunity to experience entrepreneurship to students. School

enterprise called as Capstone Design Incorporate was founded using products from capstone design projects. The products of the company are shown in Table 5. The company provides internship to the students for the practice of learning the actual design and manufacturing processes of company. Additionally, the practice in the school enterprise can give students chances to learn the managing and administrating skills and systems of industries. This will give students positive attitude toward majoring in engineering, hand-on experience, self-confidence, and capability to adapt themselves easily to the industrial environment. The school enterprise will use creative ideas and technologies of students who are participating in the capstone design projects. The company will also look for aggressive students with entrepreneurship to use their creativity.

Table 5 Capstone Design Projects for School Enterprise

Title	Description	
Parallel Mechanism 1	One of parallel robot mechanism using servo units on the slope can be used to design a system to show an accurate position control mechanism. This unit can be used for educational purpose.	
Parallel Mechanism 2	This parallel robot can be used in the assembly line of factory automation by replacing industrial robot. Due to its small size and high rigidity, it can be applied to the assembly line of small space for highly accurate job.	
SCARA Robot using Step Motor	This robot is design for educational purpose and can be applied to the assembly line requiring high accuracy and high rigidity.	
Mini-Scanning Electron Microscope	This mini SEM is competitive to the SEMs imported from Japan, and USA, etc. It has magnification of 10,000 times despite its comparably low price. Since School Enterprise can support whole process of design and manufacturing, the company can support R & D to design hybrid equipment with SEM and other fabricating devices.	

5. Conclusion

The Capstone Design Education Project is in the 5th year. The good results until now are thanks to individual efforts of professors, supporting workforce, industries, and students. The Capstone Design Project was first started to give undergraduates a chance to put together and refine skills and knowledge obtained during their undergraduate courses through graduation projects of great practicality, close to real-life application. In the process, it was expected to give students a basis to succeed in real-life and have confidence in their field. Also, through the project, professors would be given a motivation to continuously conduct researches on technologies and acquire new skills.

As a result, while in school, students have acquired great knowledge and skills, as well as a high job acceptance, comparable to any other departments within the Seoul National University of Technology. Also, publicity, the rising recognition of the school, is a by-product of performing the project.

For the success of the project, professors are required to give ideas and industry-academic integrated themes and students are recommended to participate in national and international competitions. The setting and completion of specific goals in the projects give high self-satisfaction to the students and professors. Evaluation has shown that there is a very high satisfaction shown by students and professors alike.

Also, through industry-academic cooperation, in the form of technology usage fee, the burden of first-time research and development cost is separated from technology application cost and therefore lessen the burden on industries. This gives a fast and effective, economical solution to problems faced by industries.

As for the support system, for the systemization of this project and spread of technologies, capstone design project schedules, description, process, evaluation, information have been recorded, organized and stored on the web on the completed web-based comprehensive support system and is being managed by the staff of the Capstone Design Education Center. Cooperation with engineering certification projects for recognition nationally and internationally is being progressed simultaneously so that this project can become a regular, exemplary project of the university.

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