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DEVELOPMENT OF ENGINEERING EDUCATION COURSE FOR TRAINING CREATIVE ENGINEERS USING AXIOMATIC DESIGN

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ABSTRACT

Engineers who are trained by today's engineering education may become useful engineers for their school, but not for the society. And they also find it difficult to feel worth and happiness for themselves from their work as well as worth and happiness for their society. And they also find it difficult to feel worth and happiness for themselves from their work as well as worth and happiness for their society. This study is development of new engineering education course to cultivate engineers who can initiate new positive thinking and realize active creative activities. Especially this engineering education course was developed by using Axiomatic Design(AD) and Molecular Structure Design(MSD), and appropriateness of the developed engineering education method was examined by applying it to a mechanical engineering class called Creative Design Project 3. Also axiomatic design and molecular structure design were looked at from reversible and irreversible standpoints.

Keywords : Creativity, Intrinsic motivation, Axiomatic Design (AD), Molecular Structure Design(MSD), Education

1 INTRODUCTION

The biggest purpose of university engineering education is to train talented engineers who can create happiness and worth in life through creative activities, for the world as well as for society. However, today's university engineering education merely focuses on delivery of knowledge without actual application of the acquired knowledge. This mere delivery of knowledge deprives students of opportunities to develop important creativeness and creative thinking process. Thus today's students show many problems in utilizing and adapting the knowledge they learned. Therefore engineers who are trained by today's engineering education may become useful engineers for their school, but not for the society. And they also find it difficult to feel worth and happiness for themselves from their work as well as worth and happiness for their society. But now our society demands fusion talents who can incorporate expertise of more than one area, rather than those who have expertise in only one area or those who have knowledge in various areas but lack true expertise in one area. However, today's engineering education cultivates talents for school, who possess expert knowledge only, rather than cultivating fusion talents mentioned above. And this causes widening gap between school's engineering education and qualities of talents for companies, thus expanding the dissatisfaction and negative attitudes toward each other. In order to actively solve these emerging problems, it is necessary to look back the position of current engineering education, and grope for ways to motivate students based on the observation.

Purpose of this study is development of new engineering education course to cultivate engineers who can initiate new positive thinking and realize active creative activities. Especially this engineering education course was developed by using Axiomatic Design(AD) and Molecular Structure Design(MSD), and appropriateness of the developed engineering education method was examined by applying it to a mechanical engineering class called Creative Design Project 3. Also axiomatic design and molecular structure design were looked at from reversible and irreversible standpoints.

2 AXIOMATIC DESIGN AND MOLECULAR STRUCTURE DESIGN

2.1 AXIOMATIC DESIGN (AD)

Axiomatic Design is a design method that discovers problems that can arise in early design phase and evaluates them, by using Independence Axiom and Information Axiom – 2 axioms used in performing products or process design. Most important elements in this Axiomatic Design method are appropriate selection of FRs and DPs, by designer's experience and knowledge. Especially Axiomatic design helps make better design process by showing inter-relations between elements that arise in design phase.

2.2 MOLECULAR STRUCTURE DESIGN (MSD)

Molecular Structure Design is one of the imitation design methods that applied methods of axiomatic design to chemical molecular structure equation. It is a method that judges each design proposal reasonably and systematically by showing the design equation in independent axiom through chemical molecular structure equation and adapting the general phenomenon that appear in chemistry. It also selects the most suitable design by using design bonding force(bond energy) between each element that appears in design molecular structure,

in similar methods as information axiom. In other words, molecular structure design extracts WHO design structure that is a design molecular structure made up of design molecules W (What), H (How) and O (On-Solution). And the extracted design structure judges whether the design is feasible or not based on the chemical stability of molecules.

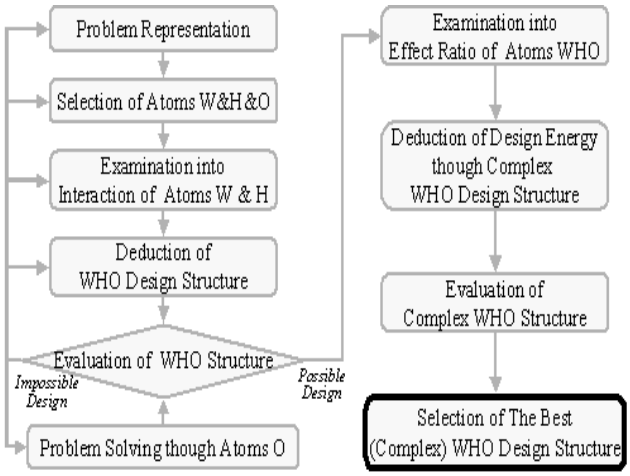

Figure 1. Example of MSD process

3 APPLICATION OF AD AND MSD

3.1 CULTIVATION OF CREATIVE ENGINEERS

Most important element in cultivating creative engineers is providing them intrinsic motivation for engineering. Students who have real intrinsic motivation can really like engineering and have high potential of putting real efforts for self realization through the study of engineering. Therefore for cultivation of creative engineers, research on engineering education that can give them intrinsic motivation toward engineering is essential.

Table 1. Cultivation of creative engineers

Cultivation of Creative Engineers	
Ultimate Object	Cultivating fusion talents by giving them intrinsic motivation toward study of engineering
Process	Development of new engineering education

3.2 APPLICATION OF AXIOMATIC DESIGN

For cultivation of talents appropriate for fusion technology age, a new education that can cultivate creative engineers is a must. This new engineering education should be able to give students interest in engineering, thinking, imagination, creativity and problem solving ability. Furthermore, it should cultivate not only research-minded talents but also field-first talents. For development of new engineering education that can satisfy these various demands, application of axiomatic design was attempted herein.

FRs and DPs for new engineering education are as follows.

Table 2. Cultivation of creative engineers

	FRs	DPs
1	Give interest in Engineering	Adjusted classes focusing on students
2	Develop creative thinking	Training on thinking and strengthening problem solving ability
3	Cultivate talents for corporations	Systematic understanding of product development process

3.2.1 PART 1 : CULTIVATION OF EXPERTISE-KNOWLEDGE TYPE TALENTS

If students can feel curiosity and interest in engineering, then they can have pride and challenging spirit about the engineering study they are undertaking, and this can be manifested by devotion and efforts into engineering study. When efforts and devotion are focused on one area, they can become top exerts with the expert knowledge that is second to none in the chosen field of study. Therefore adjusted class that center around students for cultivating the interests for engineering study can help develop expert-knowledge type talents.

3.2.2 PART 2: CULTIVATING VERSATILE-TYPE TALENTS

Creativity and imagination generated by active thinking are basis for all problem solving. When faced with various and complex problems, they can solve the problems flexibly by using their creativity and imagination they have learned through thinking training. Therefore cultivation of creative thinking can help develop versatile talents who can deal with problems in various areas as well as just engineering problems, with flexible attitudes.

3.2.3 PART 3: CULTIVATING FIELD-TYPE TALENTS

There is a huge difference between talents wanted by schools and talents wanted by corporations. Talents wanted by corporations should possess sociability and business ability that enable them to deal flexibly with various changes in technology and market. Therefore systematic understanding of product development process through team project helps attain the basic elements for corporation-type talents.

3.2.4 DESIGN EQUATION

Extracting Design equation by using FRs and DPs analyzed above is as in equation (1)

$$\begin{Bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{Bmatrix} = \begin{bmatrix} \times & 0 & 0 \\ \times & \times & 0 \\ \times & \times & \times \end{bmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{Bmatrix} \quad (1)$$

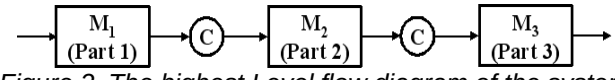

Figure 2. The highest Level flow diagram of the system

It can be found that the design of new education method is decoupled design, by using design matrix of the given design equation. In other words, when new engineering education satisfies FRs by using each DP in sequence of FR_1(Part 1) → FR_2(Part 2) → FR_3(Part 3), then cultivation of creative engineers we pursue ultimately is made possible.

3.3 APPLICATION OF MOLECULAR STRUCTURE DESIGN

Looking at the inter-relation between W atom and H sub-atom for application of molecular structure design is as follows

Table 3. Interrelationship W_S and H_S

Ws (FRs)	Hs (DPs)
W_1 (FR_1)	H_1 (DP_1)
W_2 (FR_2)	H_1 & H_2 (DP_1 & DP_2)
W_3 (FR_3)	H_1 & H_2 & H_3 (DP_1 & DP_2 & DP_3)

Therefore extracting WHO molecular structure based on the inter-relationship between atoms is as follows.

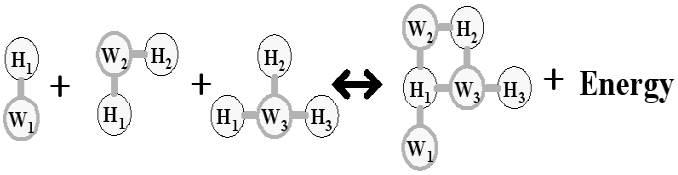

Figure 3. WHO design structure

Extracted WHO design structure goes through structure analysis, based on chemical stability. Designer's energy about the interested area is applied to the completed WHO structure analysis, then WHO molecular structure is atomized or molecularized by the applied energy. Whether design is feasible or not can be judged following these steps. Figure 4 shows the steps in which WHO molecular structure is atomized or molecularized. From this process, it is found that the design is feasible like axiomatic design.

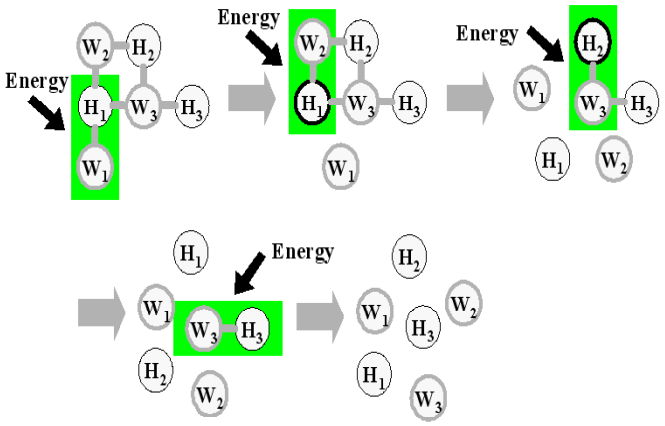

Figure 4. Analysis process of WHO design structure

3.4 REVERSIBLE DESIGN AND IRREVERSIBLE DESIGN

Reversibility and Irreversibility can be considered for design as well as chemical reaction. For example, if cutting of length is included in design process, then it has to be irreversible design. But reversibility of design can be applied to the design that has mental elements, like the above-mentioned engineering education. Axiomatic Design's perspective applies irreversible design's perspective that relies on paths as shown in decoupled design. On the other hand, molecular structure design looks at the design from reversible perspective since it is based on general chemical reaction.

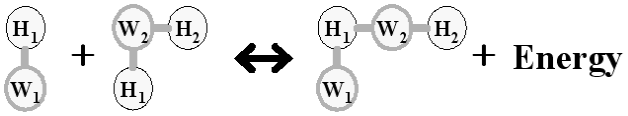

Figure 5. WHO design structure

Considering chemical stability of molecules, WHO design structure in Fig. 5 shows that molecularization occurs in sequence of W_1 → W_2. But if H_1-W_1 molecules are stable and H_1-W_2-H_2 molecules are stable, then WHO design structure also becomes unstable, so molecularization of H_1-W_2-H_2 molecules can occur first. At this time, molecularized W and H design molecules are converted into molecules of stable conditions, through 2nd chemical reaction. So unlike axiomatic design, reversible design is possible for molecular structure design.

3.5 AD AND MSD FOR NEW ENGINEERING EDUCATION

Suitability of new engineering education method was found through axiomatic design and molecular structure design. Also it was found that axiomatic design and molecular structure design have very similar analysis process of design, through examples of application. However, since design of new Engineering Education Course cannot help but include Design Factors that are related to people's minds, target values for design vary for every individual. Therefore in achieving the purpose of new engineering education course which is to cultivate fusion talents through cultivating internal motivation toward engineering study, many problems can arise. In order to overcome such problems, applying molecular structure design rather than axiomatic design looks a more reasonable choice. Especially since W and H atoms that are related to individual minds include instability of atoms themselves, it will be necessary to do design that considers reversibility, based one the assumption that WH molecules that make up Part1, 2, 3 are in instable condition in applying molecular structure.

4 APPLICATION OF NEW ENGINEERING EDUCATION COURSE

4.1 INTRODUCING CREATIVE DESIGN PROJECT 3

Currently New Engineering Education Course offered by School of Mechanical Engineering (Yonsei university) is a subject called Creative Design Project (CDP) 1, 2, 3. Creative Design Project 1 and 2 are related to problem-based learning and small project-based learning that solve the given problems in various

ways. This education course is a subject that focuses on Part 1(Expert-knowledge type talents) and Part 2(Versatile talents) exclusively. New Engineering Education Course that is designed by axiomatic design and molecular structure design as suggested in this study, is a education course called CDP 3, which is based on CDP 1, 2. This education course is differentiated from the previously operated classes, and is an education course that emphasizes Part 3(Field oriented talents) as well as Part 1 and Part 2.

4.2 APPLICATION OF NEW ENGINEERING EDUCATION COURSE

New Engineering Education Course must proceed in sequence of Part 1 → Part 2 → Part 3. Especially Part 1 → Part 2 is educated through the preceding subjects CDP 1, 2, and is covered in detail through CDP3. Eventually purpose of Part1, 2, 3 is achieved in overall through CDP 3. Education of Part 1 and Part 2 herein proceed with instability of WH molecules in each part in consideration (Reversible process occurs according to the degree of Part1 and Part2 target fulfillment). And the education targets to achieve the standard purpose (minimization of WH molecule instability) of each part. CDP 3 provides overall education of Part 1, 2, 3 for cultivation of creative engineers, which is the ultimate target. Instability of WH molecules can arise here too, and the instabilities that arise herein are instability between Part1&2 and Part3. However, since Instability of Part1&2 WH molecules is minimized through CDP1, 2 education course, CDP can operate education course that focuses solely on Part 3.

4.3 APPLICATION OF CREATIVE DESIGN PROJECT 3

New Engineering Education Course was applied to creative design project. Firstly, number of students was minimized to around 27 to make classes with active student participation and classes were run by 5 professors. There were 3 classes with 8~10 students per each, so the total number of classes was 8. With lower number of students per class, various types of creative thinking process and presentation could proceed, and variety of problems that students have to extract and solve themselves was also strengthened. Especially as part of the way to strengthen marketing and promotion fields, which are the first areas engineers find themselves involved, students were required to create advertisement images about products, to improve and test student's creative thinking ability. Also Project Design Studio was used as a space for practicing equipments such as shelf, milling, RP, vacuum modeling tool, and producing products. All the sequential steps of producing products were carried out in this space.

4.4 RESULT AND ANALYSIS OF CLASSES

Final outcome attained from classes consisted of 8 advertisement images and 8 products students have produced. Students have experienced many mistakes and errors throughout the course of project, but they have produced various products with creativity and originality. 8 products produced by students are in Table 4. Students have attempted various approaches based on creative thinking to produce products that best meet customers' demands, and for some products, companies have even approached for possibility of commercialization.

Table 4. 8 developed Products

Product Name	Brief description
Wootuli	Automatic dehydrator for umbrellas
Dryer Mate	Automatic dryer stand for pets
Butgeojo	Automatic shoes remover
To Your Face	TV stand with automatic view angle control
Weather forecaster	Home Weather forecast system
Hungry Frog	Living Environment friendly insect exterminator
Jeonabader	Wireless notifier for mobile phones
JI-1.01	Wheelchair container for automobiles

And most important thing for class is students' degree of satisfaction and whether it has satisfied the original purpose of class. Satisfaction of students could be found by using class-evaluation. For class evaluation of other classes in school of engineering, satisfaction of students was found to be 4.0/ 5.0. But satisfaction of creative design project 3 was found to be 4.5/5.0, showing higher degree of satisfaction. As for fulfilling the purpose of class, it was true that fulfillment of class purpose was somewhat short of what has been set out, due to some degree of trial and errors, as it is of a curriculum that is tried for the first time. But it will improve with time. As for the reaction of students to classes, although majority of them is positive, some dissatisfaction from students could be found. So based on these responses, grope for change in class curriculum might be necessary.

5 CONCLUSION

For cultivation of creative engineers, furthermore for cultivation of fusion talents through cultivation of internal motivation toward engineering study, New Engineering Education Course requires higher-level of creative thinking as a class that focuses on practical problem solving. Purpose of New Engineering Education Course is to give internal motivation to students, and to improve their problem solving ability, by strengthening positive thinking as well as creative thinking. Especially Creative Design Project 1,2,3 is the first class that is attempted to achieve the purpose of New Engineering Education Course, which is cultivation of expert-type talents, versatile-type talents and field-type talents. Among them CDP3 attempted more comprehensive application in new education course. By giving students practical situations where students need to extract problems they can solve, with the limited ability and surrounding environment, and students need to solve the problems within the limited time, students could gain big educational effects toward Part 3, as well as Part 1 and Part 2. Put in other words, it required more variable thinking from students, by asking them for problem solving not just from engineering perspective, but also from management perspective. From this, students could gain more than the shown results, by applying their creative thinking process. This will help students after their graduation better adapted to the actual fields. Their outcomes could cultivate in

students motivation toward engineering study and expansions of vision above engineering study. Through this, students could gain a great deal of satisfaction. When the problems that have been emerged from classes are supplemented in the future, then this creative design process will be able to play a big role as a replacement for the current engineering education. And this will also be able to cultivate more engineers who succeed in both society and life.

More researches on molecular structure design are necessary for axiomatic design and molecular structure design that are used for development of New Engineering Education Course. Application of more cases and support of more detailed theory will be necessary in proceeding with basic research.

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