INTERNATIONAL DESIGN CONFERENCE - DESIGN 2014
Dubrovnik - Croatia, May 19 - 22, 2014.

# HOW TO TEACH 3D CAD TO PRODUCT DESIGN STUDENTS PROVIDING INTEGRATED DESIGN EXPERIENCE

K. M. Kim

*Keywords: CAD education, product design, industrial design*

## 1. Introduction

3D CAD has been essential in designing, modelling, simulating and tooling throughout the product development process [Hoffmann 1989], [Delchambre 1996]. It is everywhere in industry, especially in manufacturing companies. Industrial designers and engineers use it every day in their work. However, there have been conflicts and inefficiency in design processes related to CAD works. An industrial designer and engineering designer, with 13 years of industry experience using 3D CAD tools, and a background in industrial/product design, observed frequent time consumption between industrial designers and engineering designers because of different CAD tools and working styles. This designer's return to academia showed that the CAD training courses for industrial designers in higher education didn't appropriately reflect the actual industry situation. Although there have been good suggestions and recommendations for creating a better CAD training course, it seems that these courses in higher education spend too much time on how to use CAD tools rather than how to design with CAD tools. The ultimate goal of CAD training courses should be to raise competent designers and engineers who can improve efficiency in product design and development utilizing CAD tools. Thus CAD training courses need to be connected with the design process.

Then, how can future product designers be trained through CAD courses? How can existing problems related to CAD training be solved? With these questions, a CAD course for industrial/product design students has been designed, reflecting the experience of the product/engineering designer who was a power user of CAD tools in product design practice. The course was titled '3D CAD & Prototyping' and has been taught for 1st semester students of 2nd year or 3rd quarter students of 1st year in an industrial design major. It has been implemented four times so far since 2011 and the fifth time course is now running. It has been an elective course and will be changed to a required one for industrial design majors from 2014. Before taking this course, most students take basic design courses related to design elements and principles such as form giving and visual design language.

This article aims to introduce a newly developed CAD training course, including design rationales, course content and structure, as well as some pedagogical methods, and report the results of the four-time implementation with achievements throughout the course. It doesn't aim to show any experiment results or quantitative evidence on CAD education. Instead, it reports how this course has been developed and taught, by which design educators and researchers could have insight into a better CAD education, reflecting actual design practice.

## 2. CAD; Trends, problems and criticism

Education for CAD has followed the disciplinary-oriented development of CAD technologies. Design schools emphasize shape and appearance with production of aesthetic and photorealistic images, whereas engineering schools focus more on mathematical principle, FEM and simulation [Ye et al. 2004]. These differences have caused problems because there has been little sharing between the disciplines, even though they have to share their data and tasks in actual product design practice. This section briefly reviews the developmental trends of 3D CAD tools and their characteristics, CAD-related problems in industry, and the educational situation of CAD.

## 2.1 CAID vs. CAD; industrial designers' tool vs. engineering designers' tool

The development of commercial 3D CAD tools mirrors the product development process, in which different tools are used for different design stages. With a simple categorization, there are 3D CAD tools for industrial design work, usually called CAID tools (e.g. [Associates 2012], [Autodesk 2013], [Autodesk 2013]), and tools for engineering or engineering design work (e.g. [PTC 2013], [Siemens 2013], [Systems 2013]).

The characteristics of CAID tools can be explained with surface modelling and photorealistic rendering functions. Designers have freedom to handle surface features, and can produce flashy images of 3D CAD models. However, CAID generally doesn't have functions for dimensioning, tolerance control, assembling and imposing physical parameters, as industrial designers focus on the aesthetics and rarely pay attention to dimension and scale. When they create a 3D CAD model, they pay more attention to creating detailed surfaces for certain features than figuring out relationships between volumes. That seems to happen due to the limited choices that designers must take within surface modelling. This doesn't accord with the designerly way of form giving in the physical world. In industrial design school, students usually study form giving in their first year. Its essence is on building relationships among dominant, subdominant, and subordinate forms [Hannah 2002]. They are trained to handle forms as connections of volumes with forces rather than surfaces that compose a volume. However, commercial CAID tools don't appropriately adopt this kind of concept, because of the surface modelling method. This forces industrial designers to adapt themselves to a different way of the form giving process from what they do in the physical world. Thus, CAID doesn't do well at supporting tasks in product development, except presenting visual images of design concepts.

3D CAD tools for engineering designers have different aspects. Contrasting to CAID tools, they are solid modellers. They have been developed to support detail design and manufacturing in product development. They are necessary for simulation. Interference checks, mechanical motion studies, stress analyses, and so on, can be performed. Comparing the material properties of a CAID tool that only provides visual appearance of a specific material, a CAD tool provides physical properties such as weight, density and etc. The tools have two different modes. Part modelling constructs pieces which can then be used in the assembly model to build a complete product or system. This can go on to be tested in terms of assembling, disassembling, kinematic study, and so on. Engineering drawing functions for communication and manufacturing processes after detail design are also provided.

To sum up, CAID tools have been developed to represent the industrial designer's visual concept of a product effectively, with freeform building and photorealistic functions, whereas CAD tools equipped with solid modelling and simulation functions have been developed for supporting product development, including the detail design, testing and manufacturing phases.

While the data compatibility between the two has increased, in many cases, their working flows are not well lined-up in industry, when industrial designers and engineering designers use different tools. As CAID tools focus on visualization of design concept, industrial designers' work frequently loses the sense of reality, and rarely considers the components structural relationships. The models produced have a lack of information related to tolerance, dimensions, assembling and manufacturing, and don't much consider the following design engineering phases. Because of this, most surface modelling data that industrial designers produced cannot be directly used by engineering designers in a detail design phase. They regenerate the outside shape with their own tools, causing extra time consumption and conflicts between the two groups. These conflicts happen frequently, as during the design phase there can be modifications to the outside shape due to the rearrangement of inside components. The solid model data that engineering designers generate should be sent back to the industrial designers for modifications, who often cannot handle it. The resending of surface and solid model data happens repetitively through common exchange file format such as IGES [Smith and Wellington 1986], and

Step [ISO 2012]. Even though they can share the data, this process itself causes conflicts and inefficiency.

### 2.2 Educational issues on CAD training

3D CAD training programs in higher education cannot avoid the responsibility in this current situation. Most art-based design schools instruct the surface modelling techniques [Unver 2006], although some design schools have started to teach solid modelling [Aldoy and Evans 2011] The fact that one is very knowledgeable on a CAD tool and its commands doesn't mean that one knows how to design or do design engineering with it. Most CAD reference books contain how to use the tools and commands rather than touch on the strategies for designing or doing design engineering with them.

To look at the cause from another perspective; education with lack of practical experience limits the utilization of computer technology [Coyne et al. 2002]. CAD instructors who have less experience in actual product design practice with CAD tools could hardly teach highly procedural knowledge on the design practices supported by these tools. They could not help teaching more declarative knowledge such as mathematic principles on CAD. The procedural knowledge they could teach would be limited to how to use commands, rather than strategies and approaches to designing with them. As a result, students in higher education could not utilize enough the possibilities of 3D digital tools [Aldoy and Evans 2011].

### 2.3 Criticism to new approaches

Some proposed ideas by researchers also seem to be lacking the holistic view of product design and product development procedures. Reverse engineering attempts to have precise modelling data by digitizing an original physical model have been made [Lee and Woo 2000], [Benko wt al. 2002], [Fisher 2004]. However, adopting reverse engineering technology in the industrial design phase is time consuming, especially when a new design project is undergoing, thus a new shape needs to be created. Reverse engineering technology is mostly useful in the industrial design phase when they want to replicate existing products, such as competitors' products whose data is not affordable, and to regenerate 3D data from existing products when they lost the original data or the original data is 2D. Thus, the idea of adopting reverse engineering technology in the concept design phase fails to reflect the actual design process in practice.

While it has been sometimes needed in the automotive industry, rarely does a product design process require an accurate physical model in the concept design phase. The initial form created by industrial designers undergoes iterative change through later procedures. As most industrial designers are trained to differentiate aesthetic shape, either of physical or digital model making, they directly generate a digital form with 3D CAD tools at first, and then fabricate a physical model utilizing digitalized machining tools to review their design concept with a tangible object. This is an opposite procedure to what reverse engineering advocates propose.

### 2.4 CAD in industry

Product design cannot be explained with either industrial design or engineering design, but needs a holistic and integrated approach of both [Roozenburg and Eekels 1995], [Cross 2008]. Engineering designers sometime view industrial design as artistic design [Pahl et al. 2007], [Eder 2012], as industrial designers in the automotive industry, called 'car stylists', focus much on aesthetic value. However, most mid-complex engineered consumer product domains, where the majority of industrial designers engage, require their contribution throughout the product development process [Ulrich and Eppinger 2012]. This implies the overlapping and sharing of tasks and data between industrial designers and engineering designers.

Leading companies in this field have started to use the same tool for the concept design and detail design phases. According to a recent study on the actual design process, and the interaction between industrial designers and engineering designers, three out of six leading companies in consumer electronic products in Korea have adopted the same 3D CAD tool policy between the two groups [Kim and Lee 2014]. All tools are feature-based parametric solid modellers. This change is attributed to the companies' endeavour to overcome the conflicts and time consumption caused by different CAD tools and working styles that they experienced.

Considering the old concurrent engineering principle, it is very natural that companies start to adopt the common CAD platform policy. It has been more or less believed that industrial design is not a topic for concurrent engineering. Nowadays state-of-the-art solid modelling CAD software has surface modelling functions, and the interface has been enhanced to the extent that industrial designers easily adapt themselves from CAID tools. Moreover a rendering engine is also provided as add-in software [Systems 2013] and independent rendering software has high compatibility with various 3D CAD tools [Luxion 2013]. This makes industrial designers free to select a modeller.

## 3. Course design and execution

The course is named '3D CAD and Prototyping' and is designed to teach industrial design students integrated knowledge on product design and development. The intended students are those who have completed the entry level of an industrial design major. Thus, it is designed to be offered for 1st semester students in 2nd year or 3rd quarter students in the1st year in their major. It has been offered five times so far, through which the contents and course structure have been gradually improved. It this section, the principles and rationales of the course design, the course content, structure and schedule, and the execution results are presented.

### 3.1 Course design direction

The course design direction can be summarized in three parts; 1) providing a holistic and integrated experience in product development, 2) adopting a designerly way of the form giving principle and 3) employing top-down & bottom-up modelling strategies.

#### *3.1.1 Providing a holistic and integrated CAD experience in product development process*

Industrial designers need to understand basic engineering design concepts in order to avoid problems [Field 2004]. A CAD training course should provide industrial design students with the experience of designing both the outside form and inside structure. In other words, a provision of the overall experience of the product development process, in which students can design products composed of multiple components, generate assembled models and engineering drawings, and fabricate physical models utilizing CAD tools [Ye et al. 2004]. Through this experience, industrial designers can understand how their designing activity is connected and influenced to the design engineering and manufacturing phases. Therefore, this course was designed to provide a process-oriented sequence [Asperl 2005] of product development, starting from outside design, and ending with prototyping. Figure 1. shows the product development process framework used to design the course. Students go through from concept design to testing and prototyping throughout the course.

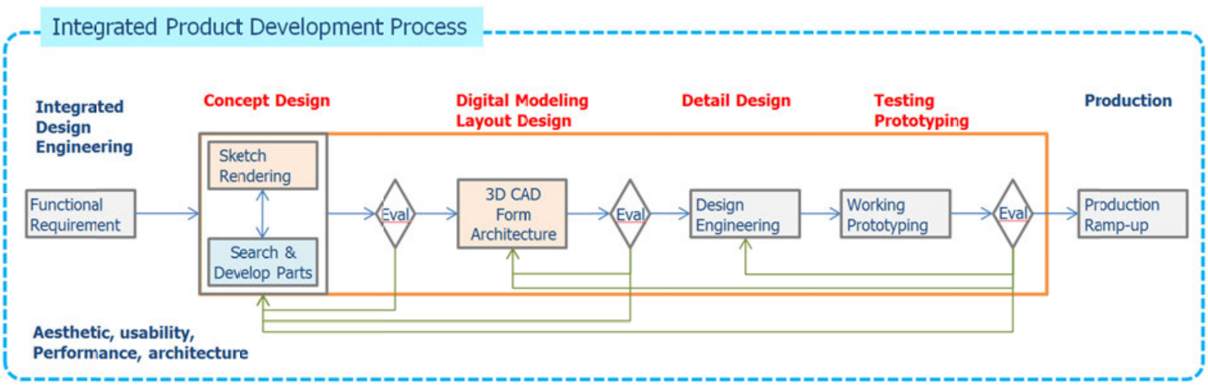


**Figure 1. Integrated produce development process framework**

*3.1.2 Adopting a designerly way of the form giving principles*

As already mentioned, current CAID use is not well matched with industrial designers' way of form giving for the physical world. If students can adopt the form giving principles that they learn from another course on basic principles of design, they can more easily adapt themselves to CAD tools. Thus, when students start to build a form, they need to identify positive and negative volumes, and their connection and transformation. This is the first stage to define an overall shape of a product.

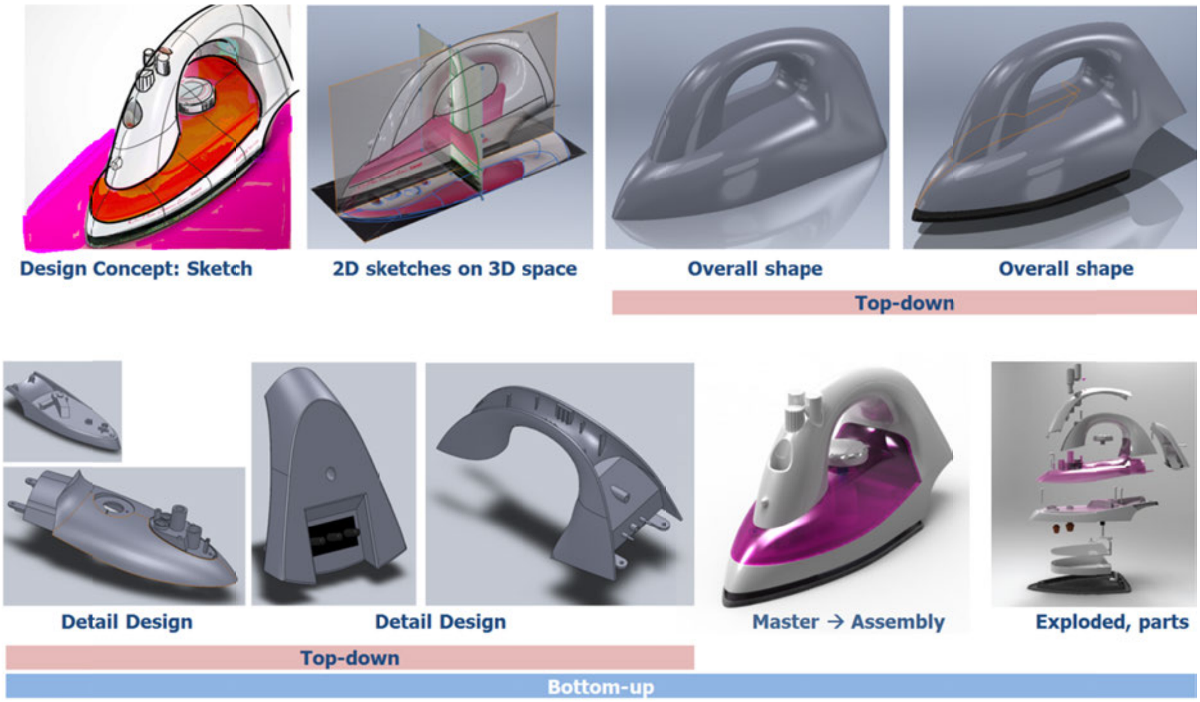


**Figure 2. Top-down and bottom-up modelling approach**

*3.1.3 Employing Top-down & Bottom-up modelling strategies*

The product design process can be viewed as a developmental process of outside form and inside layout [Hubka and Eder 1996], [Pahl et al. 2007], which are closely linked and influence each other. When the outside shape is defined, the layout should be considered, and the connection structure between them should be determined under careful consideration of both. Regarding the importance of the two parts and their roles, students need to experience the development of form and layout together. A top-down modelling strategy is employed, where designers create a big volume first, which is again divided into small parts to be elaborated as functional components [Ye et al. 2004]. Through this approach, students can determine the overall shape first, and the connection of compositional parts next. As the detail parts are driven from the overall or bigger shape, there is little risk of overlapping or discrepancy among components. The final outcome of top-down modelling is a complete part model composed of all necessary components. This model is called a *'master model'* which plays a role as a basic definition of a product, and will be used in further operation for modification and building an assembly model. The assembly model can be easily generated from the master models with a bottom-up modelling approach. All components are extracted from the master model and saved independently, and assembled again in an assembly modelling mode. Then, the final assembled model can be used for simulation such as interference check, assembling check, motion study, etc. (Figure 2).

### 3.2 Teaching approach and course scheduling

SolidWorks has been used for this course because it provides enough necessary functions for running the course effectively; a user-friendly interface, part modelling, assembly modelling, engineering.

**Table 1. Course schedule and contents**

| Week | Approach | Contents |
|---|---|---|
| Week 1 | Understanding<br>(1.5 weeks) | <Course overview><br>Relationship between CAD & design process |
| | | <Basic principles of 3D modelling><br>- Characteristics of feature-based parametric modelling<br>- Relations between elements and degree of freedom |
| Week 2 | | <Basic modelling concept><br>- Extrude, revolve, sweep, loft<br>- Virtual modelling training with pen-paper method |
| | Analysis<br>(2.5 weeks) | <Simple object modelling><br>- Analysing and copying professor's modelling procedure: USB stick & MP3 player / - Modelling students' own USB stick and MP3 player |
| Week 3 | | <Advanced modelling><br>- Advanced modelling tips & knowhow / - Top-down modelling<br>- Analysing and copying professor's modelling procedure : two chairs |
| | | <Advanced modelling><br>- Different modelling approaches to a same product<br>- Analysing and copying professor's modelling procedure : three mice |
| Week 4 | | <Assembly & motion><br>- Relationship between a part model and an assembly model<br>- Assembling model with USB stick and mouse<br>- Mechanical motion study / - Simulation: interference check |
| | | <Engineering Drawing & Rendering><br>- Types of engineering drawings / - Rendering method |
| Week 5 | Application<br>(3.5 weeks) | <Project I: Modelling an existing product><br>- Product selection criteria: composed of more than 20 different parts<br>- Well balanced with prismatic & curvy shapes<br>- Complete all steps: part modelling, assembling modelling, rendering, engineering drawing |
| Week 6 | | |
| Week 7 | | |
| Week 8 | | |
| | Project I Presentation | |
| Week 9 | Understand<br>(2 weeks) | <Introduction to prototyping><br>- Overview of the later part of the course<br>- Basic electronics: types of electrical/electronic components, soldering techniques |
| | | <laser cutting><br>- Basic principle of laser cutting and relationship with 3D CAD data<br>- laser cutting exercise |
| Week 10 | | <Machining><br>- Basic principle of CNC milling and relationship between 3D CAD data<br>- CNC milling exercise |
| | | <Rapid Prototyping><br>- Basic principle of Rapid Prototyping and relationship between 3D CAD data<br>- Rapid Prototyping exercise |
| Week 11 | Creation<br>(5.5 weeks) | <Project II: designing and prototyping a product><br>Goal: Making a working prototype utilizing the knowledge learned so far<br>Criteria: the prototyped product should<br>- be mechanical as well as electrical,<br>- have more than 20 components,<br>- be creative, interesting and attractive,<br>- be functioning, assembling and dissembling<br>- be perfect on surface finishing<br>** Not considering utility and usability of the product* |
| Week 12 | | |
| Week 13 | | |
| Week 14 | | |
| Week 15 | | |
| Week 16 | | |
| | Demonstration and presentation | |

drawing, simulation, and rendering functions. To train students effectively, two strategies have been employed. The one is to teach procedural knowledge by a *'strategy-copying approach.'* After a related lecture was delivered in each class, sample 3D model data related to the teaching was provided, with which students analysed procedural sequences taken by the instructor, and regenerated the same models through copying the instructor's strategies. In this way, they learn procedural strategy to build a form rather than command knowledge. The other strategy is to have them apply what they learned to create their own models, once independently and the next time collaboratively in a team [Chester 2008]. Thus, the whole course is divided into two phases; 1) design and design engineering training with CAD, and 2) developing a working prototype utilizing design and design engineering knowledge. Eight weeks, or a half semester, are assigned to each phase. One week has two classes with 100 minutes per class.

*3.2.1 Design and design engineering training with 3D CAD*

The first eight weeks are composed of three learning stages: learning through understanding, learning through analysis, and learning through application (see Table 1). The detailed descriptions are below.

Learning through understanding (1.5 weeks): The purpose of this stage is to make students understand how CAD works in the design process, and to teach them what concepts are applied and what procedures are needed for CAD modelling before starting with a real CAD tool. Therefore, basic knowledge about CAD, the design process and their relationship are firstly dealt with. Then, how parametric modelling works is taught, and related exercises are executed. These include 'degree of freedom' of elements and imposing relations onto elements. After understanding the basic elements of CAD and the design process, four basic modelling concepts – extrude, revolve, sweep and loft – and basic modelling procedures for simple objects are taught. A *'virtual modelling training with pen-paper method'* is adopted, with which students think out how objects around them can be built with a combination of the modelling concepts and procedures, and then draw out the sequence of modelling procedures on papers instead of utilizing a computer (see Figure 3.).


**Figure 3. Virtual modelling training with pen-paper method: a student work in 2012**

As most feature-based parametric modellers have similar modelling concepts and procedures, the virtual modelling training without an actual CAD tool is useful to teach students procedural knowledge on modelling itself.

Learning through analysis (2.5 weeks): From this stage, students start to use a computer to extend their knowledge. It is composed of four sections; simple object modelling, advanced modelling, assembly & motion, and engineering drawing & rendering. Each section introduces related commands briefly, and then teaches procedural sequences, utilizing them to generate particular models. Thus, half lecture and half exercise are the main teaching format. Also, the top-down modelling concept is delivered by showing that objects around us can be expressed with a manipulation of positive and negative volumes. Instead of attention on teaching how to use commands, modelling sequences with one or two example models are demonstrated. The method using 2D sketches as references for building 3D models, how to start with scale and dimension, and the top-down modelling process are covered. For the exercise and home assignment, teacher-generated models are provided, and students are asked to analyse the modelling strategies and copy them. This analysing process helps the students to quickly acquire knowledge developed by an expert. The models provided in the first section are a USB memory stick and an MP3 player (Figure 4). They are simple, as they can be built with fewer than thirty steps in the history list. In the advanced modelling section, five complex 3D models are provided; two chairs and three mice. They include curvy shapes and have long history lists (Figure 5). Two very similar solid mice are provided, one generated mainly with solid modelling commands and the other with mainly surface modelling commands. They both have a few inside components. Analysing and copying the modelling procedures of the two, students can naturally understand that there are various approaches to building the same model. At each section, completing the copy modelling is a home assignment.


**Figure 4. Sample models for simple part modelling**

**Figure 5. Sample models for advanced part modelling**

The other two sections are assembly and motion, and engineering drawing and rendering. When *'a master model'* is completed, assembly modelling and engineering drawing data can be easily constructed from it. Thus, the relationship among them is emphasized. The USB stick and mouse part-model data are used to explain this. An interference check is also demonstrated with the USB stick and mouse assembly models. How to draw out different types of engineering drawings; part, assembly, and exploded drawings, is also demonstrated. Students are asked to produce assembly models and engineering drawings as assignments. As part of a simulation, motion study is taught. Different types of motions are shown with five mechanical models (Figure 6). Finally, rendering techniques are taught using Photoview360 [Systems 2013], a SolidWorks' add-in software, and Keyshot [Luxion 2013].

*Learning through application (4 weeks):* No more lectures are delivered in this stage. Instead, the course continues on a tutorial basis, while each student carries out his/her own project. The goal of this section is for students to apply and utilize the knowledge they learned to generate a 3D CAD model by themselves. They are asked to select a real product composed of more than 20 components, which is neither too simple nor too complex, but includes balanced prismatic and curvy shapes. Most of them select consumer products around us. The final outcomes are a master part model, assembly model, engineering drawings, and rendering images. Every class, tutorials are given according to student progress. Emphasis is repeatedly given to the identification of positive and negative volumes from the products, and top-down modelling strategy overall. Students are asked to plan a sequential strategy for modelling the overall shape, as they did with the pen-paper method in the early phase. When they have it, they take pictures of the products from at least three views; front, side, and top views, which will be used as reference images to define the overall outside shape in 3D CAD. The 2D images taken are regarded as designers' sketches or renderings on papers in actual design practice. Sometimes, students adjust the 2D product images with image processing software such as Photoshop [Adobe 2013].

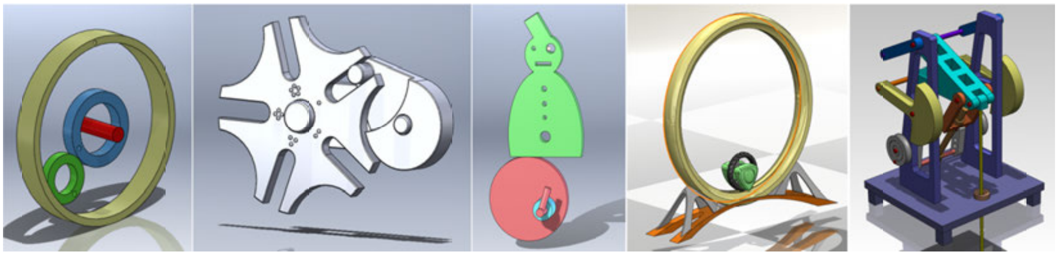

**Figure 6. Sample models for mechanical motion study**

After that, they dissemble all components and measure their important dimensions. These dimensions are used later to define the shape in 3D CAD space. When students stick to accurate dimensions and are in trouble because of conflicts among these, they are told the dimensions were determined by other designers and can be re-determined by themselves; the important thing is to keep the structural relationship among components. In this process, students assimilate the knowledge they acquired and raise application ability.

**Figure 7. Student works**

*3.2.2 Developing a working prototype utilizing design and design engineering knowledge*

The other eight weeks are designed to provide students with the integrated product design experience, fully utilizing CAD and the design related knowledge they learned. It consists of two parts; learning through understanding, and creation. The first two weeks cover knowledge about manufacturing with digital data. During the next five and a half weeks, student teams of two to three members develop working prototypes, which should be demonstrated on the final class day.

*Learning through understanding (2 weeks):* Manufacturing procedures utilizing 3D CAD data and related knowledge, including what file formats are needed for a particular manufacturing tool and how to transfer them, are taught. Demonstrations of soldering electronic components, laser cutting, and rapid prototyping, are made. To help students become familiar with the machining tools and methods, technicians run a two-hour training course on general milling machines and both general and CNC lathes. Also, a small project utilizing a laser cutter is given to student teams.

*Learning through creation (5.5 weeks):* This is the final stage of the course in which each two to three member student team carries out a product development project. They should build a working prototype passing through the idea generation, 3D CAD modeling, detail design and manufacturing processes. To this end, they should fully utilize the knowledge that they have learned, and devise their own approaches and strategies. Furthermore, teamwork is emphasized [Chester 2008] because the actual design process in industry is always collaborative. The project brief is as follows:

- Goals
  - To develop a creative product from idea generation to prototyping
  - To learn teamwork in product development
- Criteria for the product
  - To be both mechanical and electrical
  - To be composed of more than 20 components
  - To be creative, interesting and attractive
  - To be functioning, assembling and dissembling
  - To be perfect on the surface finishing
  - Not to consider utility and usability

The class runs on a tutorial basis. Even though every class requires giving student teams feedback on their progress, each team's work is self-regulated. On the final day, each team is asked to make a demonstration of the prototype's functionality, assembling and dissembling.

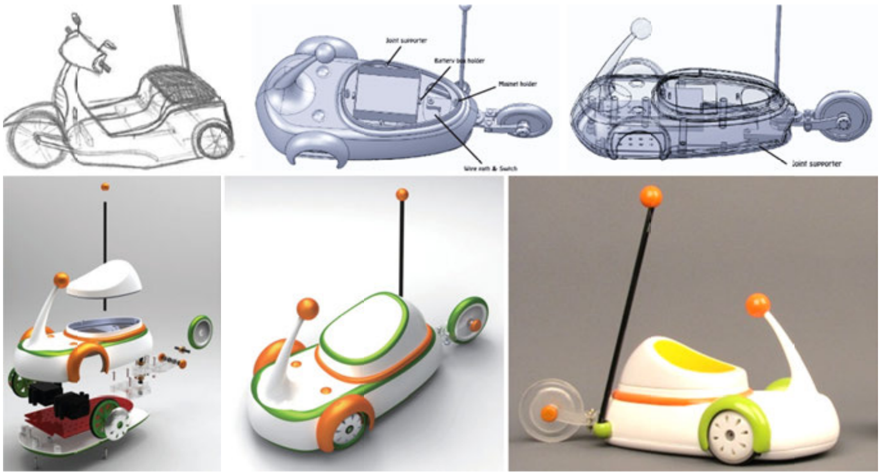

**Figure 8. 'Toy car' in 2011: from concept design to working prototype**

**Figure 9. A working prototype of 'Lotus light' in 2012**

## 4. Reflection and discussion

A newly developed CAD training course has been introduced at the author's institution. During the four times it has been implemented, the contents and teaching methods have been elaborated. One very noticeable phenomenon is that enrolment has increased, from six in the first two courses, to thirteen, twenty six and then now to thirty eight. Some students have personally asked the instructor if they could take this course. Some students who took this course have made remarkable achievements. One student won the first prize and another placed third at the 13th National CAD Modelling Competition in 2012, as a maiden entry from this institution. Another student placed first again in 2013. Some other students from this course have also won awards in other competitions. Some students taking this course have had remarkable performances in other design studio and project-oriented courses. They have played a key role in team projects. In addition to academic achievement, a few students have been involved in actual product development projects.

Since the fourth implementation of this course, students have been surveyed on their first and last day for their reasons for taking it, and on what they achieved throughout the course, respectively. Most mentioned that they wanted to be competent on CAD and product design, and that they had heard this course was tough but rewarding. Their responses to the achievement throughout this course were positive. Most of them mentioned that they have learned how to implement the design idea in their mind.

So far, CAD tools have been developed in a task-based and disciplinary-oriented direction. Many thought that one type of tools were good for industrial designers and the other for engineering designers. Most CAD training courses in higher education have also not considered the integrated approach. Design schools emphasized on the production of photorealistic images, whereas engineering focused more on mathematical principles and simulation, but both have somehow failed to reflect the actual CAD related design practice. With the awareness of these problems a new CAD training course for product design students, has been developed and implemented, based on industry experience and researchers' recommendations. Three principles were applied as follows; 1) providing a holistic and integrated experience in product development, 2) adopting a designerly way of using the form giving principle and 3) employing top-down & bottom-up modelling strategies.

It seems that CAD related courses are not easy to teach because the contents require highly procedural knowledge from product design and development practice. Without practical experience, the teaching would rely on the command knowledge or mathematical principles behind the operation, as these can be acquired without practical experience. Designers often use CAD tools in limited ways in practice, and have to relearn practical knowledge on CAD again for their first and second year in companies.

The dichotomized CAD education between industrial design and mechanical engineering is problematic. We rarely see industrial design departments teach how to construct inside components and build functional prototypes, or see mechanical engineering departments educate on how to design and determine overall shape, and produce rendering images. Considering product design and development proceed under the interaction between and contribution by both industrial designers and engineering designers, CAD education should provide the holistic and integrated experience of product design. This article will give meaningful insight into the direction to CAD instructors and design researchers.

### Acknowledgement

This work was supported by the National Research Foundation of Korea Grant funded by the Korean Government (NRF-2012S1A5A8024274).

### References

*3DS MAX, http://www.autodesk.com/products/autodesk-3ds-max/overview, accessed at Dec. 4, 2013.*

*Aldoy, N., Evans, M., "A Review of Digital Industrial and Product Design Methods in UK Higher Education", The Design Journal, Vol. 14, No. 3, 2011, pp. 343-368.*

*Alias, http://www.autodesk.com/products/autodesk-alias-products/overview, accessed at Dec. 4, 2013.*

*Asperl, A., "How to teach CAD", Computer-Aided Design and Applications, Vol. 2, No. 1, 2005, pp. 459-468.*

*Benko, P., Kós, G., Várady, T., Andor, L., Martin, R., "Constrained fitting in reverse engineering", Computer Aided Geometric Design, Vol. 19, No. 3, 2002, pp. 173-205.*
*Coyne, R., Park, H., Wiszniewski, D., "Design devices: digital drawing and the pursuit of difference", Design studies, Vol.23, No. 3, 2002, pp. 263-286.*
*Cross, N., "Engineering design methods: strategies for product design", 2008.*
*Delchambre, A., "CAD Method for Industrial Assembly: Concurrent Design of Products, Equipments, and Control Systems", John Wiley & Sons, Inc., 1996.*
*Eder, W. E., "Engineering Design Vs. Artistic Design–A Discussion", Proceedings of the Canadian Engineering Education Association, 2012, pp. 1-7.*
*Field, D. A., "Education and training for CAD in the auto industry", Computer-Aided Design, Vol. 36, No. 14. 2004, pp. 1431-1437.*
*Fisher, R. B., "Applying knowledge to reverse engineering problems", Computer-Aided Design, Vol. 36, No. 6. 2004, pp. 501-510.*
*Hannah, G. G., "Elements of design: Rowena Reed Kostellow and the structure of visual relationships", Princeton Architectural Press, 2002.*
*Hoffmann, C. M., "Geometric and solid modeling: an introduction", Morgan Kaufmann Publishers Inc., 1989.*
*Hubka, V. and Eder, W. E., "Design science: introduction to needs, scope and organization of engineering design knowledge", 1996.*
*ISO 10303-233:2012 Industrial automation systems and integration - Product data representation and exchange - Part 233: Application protocol: Systems engineering, International Organization for Standardization, 2012.*
*Kim, K. and Lee, K.-p., "Don't Make Art, Do Industrial Design: A Voice from Industry", DMI Review, (in press), 2014.*
*Lee, K. and Woo, H., "Development of an efficient method for interfacing reverse engineering and rapid prototyping", 2000, pp. 62-7.*
*Luxion, I., "KeyShot", 2013.*
*NX, http://www.plm.automation.siemens.com/en_us/products/nx/, accessed at Dec. 4, 2013.*
*Pahl, G., Wallace, K., Blessing, L., "Engineering design: a systematic approach", Springer, 2007.*
*Photoshop, http://www.adobe.com/, accessed at December 8, 2013.*
*PhotoView 360, http://www.solidworks.com/sw/products/3d-cad/photoview-360.htm accessed at*
*Pro/Engineer, http://www.ptc.com/products/proe/wildfire4/, accessed at Dec. 4, 2013.*
*Rhinoceros, http://www.rhino3d.com/, accessed at Dec. 4, 2013.*
*Roozenburg, N. F., Eekels, J., "Product design: fundamentals and methods", Wiley Chichester, 1995.*
*Smith, B., Wellington, J., "Initial graphics exchange specification (IGES), version 3.0", Society of Automotive Engineers, 1986.*
*SolidWorks, http://www.solidworks.com/, accessed at Dec. 4, 2013.*
*Ulrich, K. T., Eppinger, S. D., "Product design and development", McGraw-Hill/Irwin, 2012.*
*Unver, E., "Strategies for the transition to CAD based 3D design education", Computer-Aided Design and Applications, Vol. 3, No. 1-4. 2006, pp. 323-330.*
*Ye, X., Liu, H., Chen, L., Chen, Z., Pan, X., Zhang, S., "Reverse innovative design—an integrated product design methodology", Computer-Aided Design, Vol. 40, No. 7. 2008, pp. 812-827.*
*Ye, X., Peng, W., Chen, Z., Cai, Y.-Y., "Today's students, tomorrow's engineers: an industrial perspective on CAD education", Computer-Aided Design, Vol. 36, No. 14. 2004, pp. 1451-1460.*

KwanMyung Kim, Assistant Professor
Ulsan National Institute of Science and Technology
UNIST-gil 50, Banyeon, Yeonyang, Ulju, Ulsan 689-798, Republic of Korea
Telephone: +82-52-217-2714
Telefax: +82-52-217-2708
Email: kmyung@unist.ac.kr.
URL: http:// iidl@unist.ac.kr
http://youtube.com/user/kwanmyungkim