Integration of Industrial Design Method in Engineering Innovative Course

JIABEI JIANG† Member, DING ZHOU† Non-member
YUQING ZOU† Non-member

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Abstract: At present, engineering education is faced with a lot of problems. It focuses on cultivating students’ ability of product manufacturing and industrial innovation. However, it lacks communications with other fields. Industrial design education offers fantastic thinking and logical methods. As a result, many universities have opened the multi-disciplinary course about product design engineering. According to settings of the course, it is found that its main idea is innovative design thinking which reflects the industrial design method. This paper discusses the feasibility of integrating the industrial design method into engineering education, aiming to inspire the design thinking of the students. The authors attended the Summer Program for Innovative Engineering Design (SPIED) for two years, and gained some experience in teaching the engineering students during this program. In this paper, the project and needs of engineering students were analyzed with the course in SPIED 2015 as an example. The authors used industrial design to guide the students to find the possible innovative points. During the course, a questionnaire survey was conducted to evaluate the teaching effect. The survey result shows that innovative thinking training was the most popular method for students. The design thinking course in the SPIED gave the students some new thinking modes. The industrial design course motivated interest of the students.

Keywords: innovative thinking, engineering education, design thinking, SPIED, multi-disciplinary course,

1. Introduction

With the development of manufacturing industry, higher requirements have been put forward for the traditional engineering education, and the integration of research with practices has become a large challenge. The engineering education circle still pays the most attention to research and product development. However, linkage with the market is neglected. Hence, engineering education is faced with a lot of problems, needing to be improved [1]:

1). A shift to learning and social-behavioral sciences research.

2). A shift to emphasizing engineering design.

3). A shift to integrating other field.

On the other side, the education of industrial design [2] is closely correlated with manufacture. It mainly focuses on the research of market and user needs, but researches on technology development are insufficient. Accordingly, many universities have set up the discipline of product design engineering [3], which integrates the advantages of the above-mentioned two disciplines. It is found in comparison of the course settings at these universities, that “design thinking” [4] is the core idea in these courses [5][6]. This paper discusses how to apply design thinking in general engineering courses in order to practice innovative design. An experiment was performed in an international engineering design education program. A method was presented to help the engineering students find the possible innovative points during the project implementation.

This international engineering design education program is a two-week workshop. The students came from China, Japan and South Korea. The majors of engineering, medical and industrial design from each country. Many schools have tried the interdisciplinary corporation. However, they rarely gathered different majors and different countries’ students to join the innovative engineering design course. The program aims to make innovative design and thus solve the actual problems in this age or in the future. Most students and professors participating in this program came from the engineering field, and focused on “making” rather than “thinking”. In fact, the innovation ran through the whole design of the project, not on some special steps. The engineering students usually ignored this fact. They did not know why the “thinking” is important and how to think during the design process. Therefore, by virtue of the exercise chances in the classroom, the authors tried to guide the students to find the possible innovative points through industrial design and help them build the design thinking consciousness. As a result, the students became more interested in the innovative thinking training. The user research and the course could significantly improve their innovative thinking.
2. Industrial design and method for innovation

2.1 Industrial design The first period of the industrial design started from the middle 19th century, wherein the handicraft industry was transformed into the mechanical industry; in the 20th century, the Bauhaus proposed the principle that form follows function, namely a problem should be solved in a systemic and logical way, symbolizing the beginning of the second period of industrial design; and in 1981, with the development of manufacturing industry, the International Council of Societies of Industrial Design (ICSID)[6] defined industrial design as the design of products to be manufactured by techniques of mass production.

Since the beginning of the 21st century, with the arrival of immaterial era, the disciplines of the industrial design have been further extended. Recently, at the 29th ICSID[7], General Assembly in Gwangju, South Korea, the Professor Practise Committee re-defined industrial design: “Industrial Design is a strategic problem-solving process that drives innovation, builds business success and leads to higher quality of life through innovative products, systems, services and experiences.”

Despite its short history, the industry design field still plays an important role: it offers the approaches to find problems, realizing problem settlement based on combination of various resources and innovative thinking. The industrial design focuses on the method and aims to explore the real needs of users so as to provide better experience for the users. The user experience is defined as “a person’s perceptions and responses generated from the use or anticipated use of a product, system or service” by the international standard on ergonomics of human system interaction. A good understanding of users allows a designer to find the specific innovation points. However, engineering students can hardly identify user needs due to the lack of experience.

2.2 Method for innovative thinking Innovative thinking reflects the design method, which is implemented during design. This is the core part of the industrial design innovation. Selection and implementation of the method reflect the innovative thinking mode. As shown in Table 1, the traditional design method, as a rational and scientific method, emphasizes: problem finding and definition, date research and analysis, and manufacture. In this table, we take the “rice with spinach” recipe as a reference material.

In the 20th century, design thinking meant the exploration and integration of design methodology. Design thinking was first defined and advocated by Rolf Faste - a teacher at Stanford University. Afterwards, his colleague David M Kelley used it in commercial activities in the 80s and 90s. Peter Rowe used this term in 1987 in his book[9] in order to provide a practical problem-solving system for designers and city planners. Richard Buchanan published an article[10] to explain design thinking in 1995, since when design thinking had begun playing a more and more influential role in handling thorny issues.

In 2004, Professor David Kelley from the Department of Mechanical Engineering of Stanford University founded the Institute of Design (D. School) [11] at Stanford, and set up a design thinking course. Design thinking, now the most popular design method, is generated from integration of the traditional design method into social development. Table 2 shows the steps of the design thinking and its relationship with the industrial design method.

With this design thinking method, D. School has successfully accomplished a lot of projects. The Embrace-warmer [12] showed in Fig.1 is one of its proud products. This product was specially designed for warming premature infants. In poor areas of some developing countries, many preterm infants died in the hospital due to the decline of body temperature, wherein 98% of the premature mortality was caused by this. The students in D. School developed the product of Embrace Warmer based on design thinking, managing to help many families. This design thinking is revolutionary, and aims to balance the settlement of social problems and commercial operations.

The design thinking in the modern times emphasizes[13] user research. The design thinking drives the innovation, which is generated from user research and relevant technologies.

3. Case study: SPIED 2015

3.1 Profile of SPIED SPIED [14] was started in 2013 at Yamaguchi University. This annual program has been held for three times. SPIED is a two-week industrial in-
Table 2: Design thinking

<table>
<thead>
<tr>
<th>Step</th>
<th>Design Thinking (D. School)</th>
<th>Industrial Design Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Empathizing: Learning about the users, namely the target of your design.</td>
<td>1. Problem</td>
</tr>
<tr>
<td></td>
<td>Defining: Redefining and focusing on your question based on your insights gained from the empathizing step.</td>
<td>2. Problem definition</td>
</tr>
<tr>
<td>2</td>
<td>Ideating: Brainstorming and coming up with creative solutions.</td>
<td>3. Factors in the problem</td>
</tr>
<tr>
<td>3</td>
<td>Prototyping: Presenting one or more of your ideas to others.</td>
<td>4. Date collection</td>
</tr>
<tr>
<td>4</td>
<td>Testing: Returning to your original user group and testing your ideas for feedback.</td>
<td>5. Data analysis</td>
</tr>
<tr>
<td></td>
<td>6. Creation</td>
<td>6. Creation</td>
</tr>
<tr>
<td></td>
<td>7. Material and technique</td>
<td>7. Material and technique</td>
</tr>
<tr>
<td></td>
<td>8. Experimentation</td>
<td>8. Experimentation</td>
</tr>
<tr>
<td></td>
<td>10. Verification</td>
<td>10. Verification</td>
</tr>
<tr>
<td></td>
<td>11. Design and construction</td>
<td>11. Design and construction</td>
</tr>
<tr>
<td></td>
<td>12. Solution</td>
<td>12. Solution</td>
</tr>
</tbody>
</table>

Figure 1: Embrace Warmer

These innovation workshops, which involve students and teachers from different countries (China, Japan, and South Korea), different universities, and different disciplines. The first participants majored in engineering, involving knowledge of mechanical, electronic, and information technologies. From 2014, industrial design students were also involved in this program. In this program, there are two classes: a beginner class for beginners and an advanced class for senior learners. This program mainly aims to "make things". Students gather together and share their knowledge and experiences through international team activities so as to learn how to create new ideas and products. Meanwhile, the teachers, also from different fields and universities, guide and inspire these students. Most students came from the engineering discipline, so the industrial design course should firstly let them put forward their own views. This case study involved the SPIED 2015 in Kunsan National University in South Korea.

3.2 Setting of industrial design course in SPIED

SPIED 2014, which was the second SPIED, began with a lecture which introduced the industrial design course in the advanced class. Before the lecture, the students had started working on the subject without the design thinking process so as to develop the technology merely. For example, a group of students developed a foul-smell removal system, as shown in Fig.2. The project obeyed the following principles: firstly, using the smell sensor and camera to locate the foul smell; secondly, using the robot to automatically remove the foul smell. The students performed the project by sequential procedures including problem discovery, technique research, system establishment, and product development. The simulation was successful. From the engineering perspective, the project was accomplished. However, this project, which was an application of the technology, was unfinished from the perspective of industrial designers. Based on the same theme, an industrial designer will ask:

1). Who needs this product?
2). Why do they need this product?

3). Where will they use this product?

These user-centered questions will expand the concept of the product. Through investigation of these questions, the students may find out more possible innovative points.

There are different thinking modes between the engineering students and the design ones during handling of the same project. The engineering students mainly attached importance to technological realization, and rarely took into account commercialization, users and production feasibility, whereas these factors required prior consideration. Actually, the concept of this smell sensor could have been expanded in many directions if the designers had combined their thinking with the research of users during the design. They had missed many chances for innovation.

It was in the third SPIED program, namely SPIED2015, that industrial design was included in the program as a thinking training course [15]-[17]. This time, in order to avoid the previous problem, the authors revealed the theme in the class. The authors tried to improve the design thinking of the students through industrial design. During the exercise, the students needed to find the possible innovative points. This time, the course was also implemented in the advanced class.

Based on the purpose of the SPIED, the ability of the students and the D. school’s design thinking are shown in Table 2. The contents of the new design thinking course in the SPIED 2015 are shown in Table 3:

1). Mind-map: diffuse the thinking from a word related to the theme.

2). Research work:
   2.1 Marketing: research on the demand of the market; competition against other products and brands; life style; production plan.
   2.2 User: research on the user classification; personas creation; and action map.
   2.3 Technique: summarize the previous research, and study related technique.
   2.4 Product life cycle: consider the manufacturing, sales, use, and recycling of the product before the production.

   In this step, the persona is a tool used in user experience. After the user classification, we will create a group of the user as a fiction user, this call persona.

3). Design brief: review the previous work and plan for the next stage after finishing the research and defining the idea.

   We changed the order of design method for SPIED because:

1). Most students came from other majors such as engineering and medical. We wanted to use a familiar tool to start the innovative thinking, so we started from the Mind-map.

2). The empathizing was a research work. After they defined the theme specific, it was easy to start the research work.

After the class-exercise, a questionnaire survey was conducted to evaluate effects of the industrial design course. We set 13 questions in the questionnaire survey. Purposes of the questions: 1) learned about whether the students could understand the design thinking method in the course; 2) learned about whether the students could use the design thinking method during design innovation; 3) learned about whether the students had some questions about the design thinking method; 4) learned about which part of the design thinking method was easy to learn and had been used by the students (not of the industrial design field). Results in the table describe the influences of the course on the students.

In this paper, we chose three useful questions for the analysis, by which we could master the students’ thoughts about the course and obtained inspirations and advices to improve the course setting in the future. Results of the investigation of the useful part of the industrial design method (multiple choices) are shown in Fig.3 as follows:

- 87.5% of the students chose the first step mind-map, probably because this was a familiar tool for them.
- 63.3% of them chose the second step, namely research work. This part, especially the user research part, was unfamiliar to the students. Hence, they didn’t know how to carry out the research and accordingly find the possible innovative points. However, this was one of the most important parts in the process.
- 78% of them chose the third step - design brief. This part is superior to the second part. It was found that the students needed a break for reviewing the previous work and making the next-stage plan.

Figure 4 shows the result of an investigation of the useful part of user research. 50% of the students chose the action map. During formation of the action map, which was based on the analysis of user behaviors, the designer should put themselves in the position of the users. During this process, a lot of problems could be revealed. Sometimes, the solutions to these problems might be innovative points. In addition, both user classification and personas creation were chosen by 25% of the students.
Table 3: New design thinking course in SPIED2015

<table>
<thead>
<tr>
<th>Step</th>
<th>Design Thinking (D. School)</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mind-map</td>
<td>Ideate</td>
<td>Find the interesting points and diffuse the thinking.</td>
</tr>
<tr>
<td>2. Research work</td>
<td>Empathize</td>
<td>Sift the ideas proposed in the mind map and choose the final idea.</td>
</tr>
<tr>
<td>2.1. Marketing</td>
<td></td>
<td>The market characteristic is decided by the different cultures and policies. This also influences the user property.</td>
</tr>
<tr>
<td>2.2. User</td>
<td></td>
<td>Understand users, find their needs and discover new user experience.</td>
</tr>
<tr>
<td>2.3. Technique</td>
<td></td>
<td>Study the realization of the product.</td>
</tr>
<tr>
<td>2.4. Product life cycle</td>
<td></td>
<td>It is a required response to the needs at different design stages.</td>
</tr>
<tr>
<td>3. Design brief</td>
<td>Design brief</td>
<td>Clarify the project purpose, check the progress and plan for the next stage.</td>
</tr>
</tbody>
</table>

3.3 Idea of course

Firstly, design thinking was very unfamiliar for engineering students who hadn’t studied the industrial design course before. Considering that mind map had been used more commonly in engineering education, the authors firstly selected it as the starting point for the training.

Secondly, the students were guided to break through all the limitations and diffuse their thinking. At the final step, they could give play to the strong point - filtering the ideas. There was a “list” for selecting the suitable and final idea. The “list” was important, because it embodied the design methods. It was the research work in Table 3. Through combination of the design method with their familiar tools, the students could naturally understand and complete the procedure.

Finally, the design profile was written. Even for design students, the design profile was very important. According to the objective of the SPIED 2015, the authors created a list especially for the students:

1). Name of the product
2). Which market it is located
3). Who is the user
4). Action map of the user
5). Concept of the product (sketching)
6). Product property: technique application/material use/color
7). Cost research

This was a summary of the stage. After the first two steps, the students would usually feel confused about the original purpose. Based on this, they needed a break for putting all the things in order and checking the previous steps. After that, they were able to plan for the next progress.

4. Conclusions

The design thinking is based on the market needs, user needs and technical requirements. In this method, mind-map is usually the first step. It can start from any point of the view of the subject, and it is used to open the mind. It will let students associate the subject with other fantastic ideas. This step is one of the most important parts during design thinking. Then the students can select the possible ideas with the design methods and develop the ideas.

During the development of products, students may quickly give up an idea sometimes just because the idea
seems to be similar with other existing ones. In fact, creativ-
ity is embodied in the details. A product similar with others
can also be deemed to be innovative if it can bring better
user experience. Educators shall not only teach students
methodology, but shall also check and guide their thinking
to make them focus on the research work part.

SPIED is an annual event, so the method of training still
needs continuous refinement and improvement. According
to the investigation of the SPIED 2015, 75% of the students
showed more interest in the user-need research and 87.5% of
them wanted demanded trainings on innovative thinking
(see Fig.5). Most of the students claimed that the action
map study provided them with a new research way; and in-
dustrial design course was useful for their current study and
their future work. These inspiring feedbacks revealed the
needs of the engineering students.

The research has two major purposes: 1) the result of
the questionnaire survey reflects the students thinking of
the course, and we hope the result can be useful for the future
course setting; 2) from the perspective of industrial design,
we want to know, in the interdisciplinary course SPIED,
what the design method can do, and how it works.

The result here is a summary of this multi-disciplinary
course. It indicates that the design method can better fit
with the students before they start developing a project and
satisfy the course requirements. It will be devised in the fu-
ture. For the future tasks, we hope we can 1) summarize
some standards to evaluate the useful method in the design
thinking of creative activities; 2) help the students from dif-
f erent majors implement the research in a wide view; 3) fa-
lidate the engineering education.

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References

Major Shifts in 100 Years of Engineering Education”, Proceed-
ing of the IEEE, Vol.100, pp.1344-1360, 2012. DOI:
10.1109/JPROC.2012.2190167

[2] Alain Findeli, “Rethinking Design Education for the
21st Century: Theoretical, Methodological and Eth-
ical Discussion”, Massachusetts Institute of Tech-
DOI:10.1162/07479360152103796

using international student teamwork-to comply with future
needs”, European Journal of Engineering Education, Vol.26,
pp.179-186, 2001. DOI:10.1080/03043790110034438

[4] Ian de Vera, Gavin Melles and Ajay Kapoor, “Product de-
sign engineering-global education trend in multidisciplinary
training for creative product design”, European Journal of
Engineering Education, Vol.35, No.1, pp.33-34, March
2010. DOI:10.1080/03043790903312154

uct design”, John Wiley & Sons, Chichester(fourth), 2008.
DOI:10.1023/A:1019201500438

Leifer, L.I., “Engineering Design Thinking, Teach-
ing, and Learning”, Journal of Engineering Education,
Vol.94, No.1, pp.103-120. 2005. DOI:10.1002/j.2168-
9830.2005.tb00832.x

[7] International Council of Societies of Industrial De-
sign(ICSID), http://www.icsid.org/about/about. htm

[8] Bruno Munari, “Da cosa nasce cosa”, Editore Laterza, pp.35-
63, 1981.


[10] Richard Buchanan and Victor Margolin, “Discovering De-
sign: Explorations in Design Studies”, University of Chicago


embraceglobal.org/embrace-warmer/

pp.1-10, 2008

[14] Summer Program for Innovative Engineering Design
(SPIED), http://ire-asia.org/ire/spied/

Ltd, London, 2006. 10.1016/0142-694X(82)90040-0

[16] Rivka Oxman, “Think-maps: teaching design thinking in de-
sign education”, Design Studies, Vol. 25, No. 1, pp.63-91,
2004. DOI : 10.1016/S0142-694X(03)00033-4

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Jiabei Jiang (Member) received her B.S. and
M.S. in Industrial design degree from Politec-
nico di Milano, Italy in 2012. From 2012 to now,
she was hired as a lecture by School of indus-
trial design at Nanjing university of the arts. Her
research interests include product design, design
thinking, and service design. Recently, her re-
search focuses on interdisciplinary course edu-
cation. She is a member of CIDA and IIAE.

Ding Zhou (Non-member) received his B.A.
in industrial design from Zhejiang Sci-Tech Uni-
versity in 2006. After his graduation with the
M.A. in industrial design from Shandong Univer-
sity in 2009, he was hired as a lecturer in indus-
trial design by the School of Industrial Design
at Nanjing University of the Arts. In 2012, he
was sponsored by Jiangsu province government
to work as a bilingual visiting staff at the University of Virginia,
US. Further, as a visiting scholar in industrial design with the Chi-
inese national scholarship, he worked at School of Design of Vic-
toria University of Wellington from 2014 to 2015 in New Zealand.
He currently dedicates to innovative design applications of additive
manufacturing. The tangible interaction design also is included in
his research interests. He is a member of CIDA.
Yuqing Zou (Non-member) received his B.A. in industrial design from Shenzhen University in 2003. After his graduation with the B.A., he was worked in Japan zero-one design co. ltd, Shenzhen office for one year. And received his M.A. in industrial design from Guangzhou Fine Arts Academy in 2009. From 2009 he was hired as a lecturer in industrial design by the School of Industrial Design at Nanjing University of the Arts. His current research interests include product engineering design and innovative design applications of additive manufacturing. He is a member of CIDA.