A DESIGN COURSE COMBINING AESTHETICS AND ENGINEERING KNOWLEDGE IN PBL STYLE

Chang, Hsiang-Tang
National Kaohsiung First University of Science and Technology, Taiwan, Republic of China

Abstract

This paper is to display the effect of a PBL (Project Based Learning) style design course, which was constructed by the author, and combined aesthetics and engineering knowledge. The author considered that current Taiwanese industrial design collegiate students are not strong in engineering design, and they often emphasize appearance of product but ignore function; therefore, the author tried to develop pedagogy which involves the above-mentioned idea to lead students to develop buckle design and fabricate it. Through the experimental project in the course, most of the students were satisfied with the learning style and find the fulfillment in engineering design.

Keywords: Aesthetics, Engineering knowledge, Project Based Learning, Buckle, Design learning

Contact:
Prof. Dr.-Ing. Hsiang-Tang Chang
National Kaohsiung First University of Science and Technology
Department of Innovation Design Engineering
Taiwan, Republic of China
htchang@nkfust.edu.tw

Please cite this paper as:
Surnames, Initials: *Title of paper*. In: Proceedings of the 20th International Conference on Engineering Design (ICED15), Vol. nn: Title of Volume, Milan, Italy, 27.-30.07.2015

1 INTRODUCTION

In Taiwan, earlier college-level industrial design program were derived from art program and engineering program; after about 50-year development, the industrial design program gradually integrated many different fields and formed its own unique style. Design college students are often partial to imagination and aesthetic matters, and the students are willing to spend much time to make their works more beautiful and amazing. For most professional industrial design or product design, however, engineering knowledge is necessary and that means the students have to comprehend it when they would like to make their ideas become real creations even products.

As the above-mentioned, some courses of industrial design program involve various categories of fundamental engineering knowledge, such as mechanics, materials science, electronics, etc. In fact, the industrial design students only need to learn the basic part of the above-mentioned engineering knowledge, nevertheless, in Taiwan, most of the industrial design students are afraid of the engineering courses because they consider that the courses always are full of mathematical equations and complicated calculations. Therefore, some of the important engineering courses are removed from the programs of the most Taiwanese industrial design departments. This change seems to make the program easy and friendly to the students, but it also reduces the ability of the students to resolve problems and realize their ideas.

The author and his research team has spent several years on systematic problem-solving (Chang and Chen, 2004; Chang and Ko, 2006; Chang and Chang, 2013) and design imagination (Chang *et al.,* 2103; Chang and Lin, 2013), and they consider that the engineering knowledge is the pillar of industrial design, and the design students should learn enough engineering knowledge for their design works.

The author's department, innovation design engineering, was founded in 2012, and the first freshmen were recruited in autumn 2013. The department is in the category of industrial design of Taiwanese higher education institution. Different from other industrial design department in Taiwan, the program of the department of innovation design engineering was combined aesthetics and engineering, several required and elective courses were arranged to support core design courses (they also are required) which are the most important in each semester. (Each semester involves one core design course generally, including Fundamental Design I/II, Product Concept Design I/II, Product Design I/II, and Monographic Product Design I/II.)

For the purpose of increasing the students' engineering accomplishments and introducing current hot 3D print technique, the author tried to improve a course to lead the students make product design through PBL (Project Based Learning) approach combining engineering knowledge and CAD/CAM skills. This paper will show how the author tried to lead the students run a project for product design and manufacture by 6 weeks in a required course, and reveal an idea for inter-schools collaboration on the issue of design imagination and engineering problem solving.

2 COURSE ARRANGEMENT, TEACHING MATERIALS AND PROCESS

The trial course is "Fundamental Design Engineering," which is a required course in the second year with 2 credits and 2 hours per week (the course was started in September 2014 and finished in January 2015). The author would like to introduce basic structural mechanics, mechanism theory, and several advanced popular manufacture techniques into specific corresponding product design projects. One of the projects is buckle design, and this is the second project of the course. In this project, first, the author would like to deliver basic buckle design guidelines, which involves criteria about geometric relationships and constraints of cantilever beams, to the students. The students should make their own elaborate design ideas of buckle under acceptable engineering performance through several one-by-one discussions with the author. Next, the author also instructed the students to realize the design ideas, *i.e.* to fabricate it. Because all of the students took another required course, named "Computer Aided Design" in the same semester, they should learn how to construct complete 3D models following their own design ideas of buckle. Furthermore, 3D printing technique is more and more popular, and it is conducive to making sample products, even finished product. The author planned to lead the students fabricate their own buckles through the 3D printer. During the process of 3D printing, the students had to comprehend the limitation of performance of the printer, and find out the know-how to print perfect buckle product.

2.1 Beginning by a scenario in a PBL style

As other PBL courses, the project of the course needs a good scenario to arouse interests of the students. In the first part of the project, each the student were supposed a younger design student who is always love to make new product with his/her own style. One day a buckle of his/her backpack was broken, and he/she decided to design and fabricate a new one. For the purpose, he/she would survey several existent buckle products with special style or function. The products could be his/her important references to new product development. Therefore, at the beginning the students were assigned to collect at least three different buckle products and explain what their features (outline and function) respectively are.

2.2 Introducing engineering design criteria

Most of the students know that the general geometry of buckle, usually an arrow-shaped head component and a seat component; however, they often do not know how to set suitable dimension for good connect and disconnect performance. For this reason, the students have to be inculcated the criteria of buckle design and they also need to keep the criteria in mind. In the second part of the project, and the students were anticipated to spend more time to comprehend on it. The author considers that this part is more difficult to the students. The students often can not blend harmoniously and grasp thoroughly, so that their new designed buckle could be fascinating in good outline but short on connecting/disconnecting performance. The general design criteria instruction in teaching materials is shown as Figure 1 (written in Chinese Traditional).

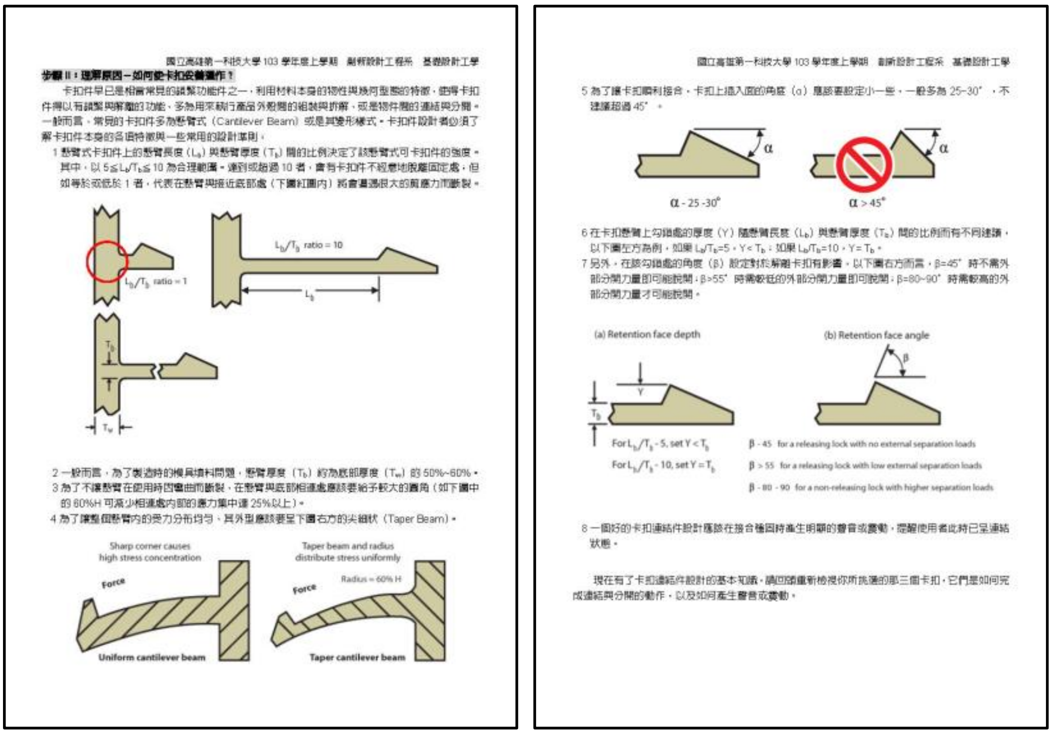


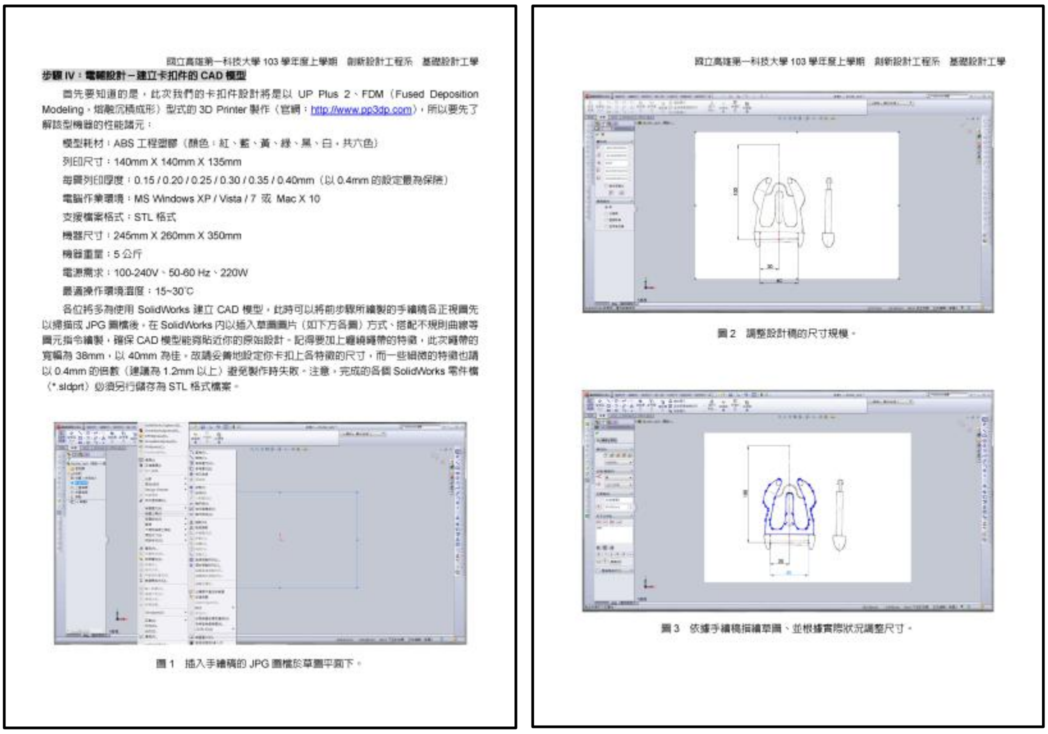
Figure 1. General criteria for buckle design (partly, and written in Chinese Traditional)

2.3 Thinking, sketching, discussion and modifying

After comprehending the engineering knowledge, the students would think the outline of their each new buckle and sketch it. The more sketches were encouraged and the students also need to discuss the sketches with the author. Initially, most of the students did their buckle sketches which were good-looking (freely depended on the student and without any constraint) but without practicality, the common problems involved (1) the dimension of their buckles did not satisfy some criteria, (2) their buckles could not provide convenient operation, (3) the head part and the seat part of their buckles could not cause an obvious "click" sound when connecting, (4) the head part could not be pushed out from the seat part when disconnecting. The author would give the students feasible suggestions for modifying. The author considers that this part is the most important and spends a lot of time because most of the students cannot completely comprehend the general criteria for buckle design. Therefore, the final sketches of the students were come out after three or four discussions. (Each discussion by one student was about 10 minutes, totally 40 students in this class; all the discussion were proceeded after class or in the author's office hours.)

2.4 Modeling for 3D printing

3D printing technique is becoming more and more popular recently. It is considered so conducive to industrial design students. In fact, 3D printing technique is derived from rapid prototyping technique, FDM (Fused Deposition Modeling), one of the modeling approaches, is the maturest approach, and many machine tools were launched by equipment companies. In the course, the author would like to teach the students to use the machine tool, which is named "Plus 2" and made by the company "UP 3D USA," to make their own buckle products. The machine tool is convenient and easy to operate; however, some skills and tricks of CAD modeling are necessary for good finished products. The author and a teaching assistant spent much time to check the CAD models of the students even though the students has learned the CAD course. Generally, the most difficult was how to avoid or reduce support parts, which were automatically generated by the software of 3D printer. The author and the teaching assistant delivered their experience to the students; therefore most of the students' buckles were successfully printed. Some skills and tricks of CAD modeling were collected and then collected in the teaching materials, which is shown as Figure 2 (also written in Chinese Traditional).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步驟 IV：電腦設計－建立卡扣件的 CAD 模型

首先要知道的是，此次我們的卡扣件設計將是以 UP Plus 2、FDM（Fused Deposition Modeling，熔融沉積成形）型式的 3D Printer 製作（官網：http://www.pp3dp.com），所以要先了解該型機器的性能諸元：

模型耗材：ABS 工程塑膠（顏色：紅、藍、黃、綠、黑、白，共六色）

列印尺寸：140mm X 140mm X 135mm

每層列印厚度：0.15 / 0.20 / 0.25 / 0.30 / 0.35 / 0.40mm（以 0.4mm 的設定最為保險）

電腦作業環境：MS Windows XP / Vista / 7 或 Mac X 10

支援檔案格式：STL 格式

機器尺寸：245mm X 260mm X 350mm

機器重量：5 公斤

電源需求：100-240V、50-60 Hz、220W

最適操作環境溫度：15~30˚C

各位將多為使用 SolidWorks 建立 CAD 模型，此時可以將前步驟所繪製的手繪稿各正視圖先以掃描成 JPG 圖檔後，在 SolidWorks 內以插入草圖圖片（如下方各圖）方式、搭配不規則曲線等圖元指令繪製，確保 CAD 模型能夠貼近你的原始設計。記得要加上繼續繩帶的特徵，此次繩帶的寬幅為 38mm，以 40mm 為佳。故請妥善地設定你卡扣上各特徵的尺寸，而一些細微的特徵也請以 0.4mm 的倍數（建議為 1.2mm 以上）避免製作時失敗。注意，完成的各個 SolidWorks 零件檔（*.sldprt）必須另行儲存為 STL 格式檔案。

圖 1　插入手繪稿的 JPG 圖檔於草圖平面下。

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圖 2　調整設計稿的尺寸規模。

圖 3　依據手繪稿描繪草圖、並根據實際狀況調整尺寸。

Figure 2. Skills and tricks of CAD modeling (partly, and written in Chinese Traditional)

2.5 3D printing, trimming and judging

This was the end part of the project. Two 3D printing machine tools printed 40 buckle products in over 120 hours. For the each student, it was very exciting to take his/her new buckle product. After receiving their buckle products, the students were taught to trim the buckle products, such as removing the residual support parts, and amending defects by chemical solvent (in the project, acetone was the solvent because the major material for 3D printing was ABS). Figure 3 and Figure 4 show that the author and the teaching assistant directed the students how to set up the 3D printer and trim their buckle products respectively. As for the judging, the author and the teaching assistant checked if the each buckle product satisfied the above-mentioned general design criteria. The author found several of the students were imaginative and creative, their buckle products were special despite they could not reach one or two of the criteria. The author considered that those buckle products will be better after little modification.

Figure 3. Author and teaching assistant showed how to set the 3D printer

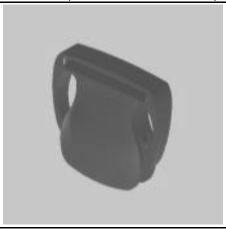
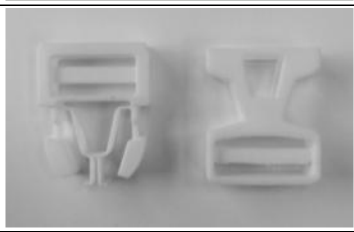
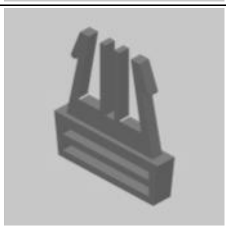
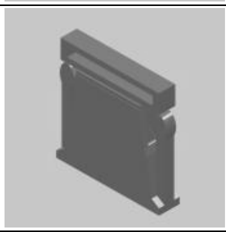
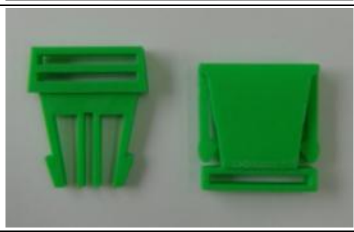
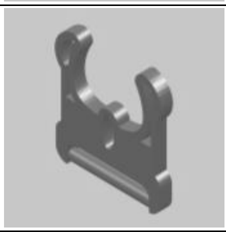
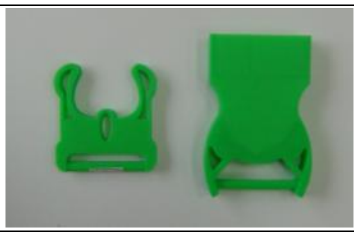
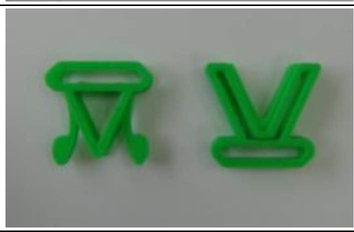
Figure 4. Author and teaching assistant showed how to trim buckle products

3 STUDENTS' ACHIEVEMENTS, PROJECT'S SELF-EVALUATION, AND DISCUSSION ON IMAGINATION ISSUE

3.1 Students' achievements

The course Table 1 shows part of the students' buckle products. Most of the students were the first time to design and manufacture a "real product" although the each product only has two parts. In fact, 18 students asked to re-print because they considered that their buckle products were not good. The students compared their own buckle products to each other's own, and some of them expected that their buckle product could be unique and would have good performance. Most of important, the author found that the students paid attention to the engineering problems and tried to solve through asking for advice from the author, teaching assistant and classmates. That demonstrated the arrangement of the project is indeed feasible for the course and conducive to the students.

Table 1. Students' CAD models and products in buckle design project (partly)

No	Head (CAD model)	Seat (CAD model)	Product by 3D printing	Feature
1				To push the ears of the seat to act on the head for disconnecting.
2				The outline is like a shell when the head and the seat connecting.
3				The head and the seat have two-way connecting function.
4				Making obvious "click" sound when connecting.
5				Another one to push the ears of the seat to act on the head for disconnecting
6				Central guide is longer as one of the head's characteristic.
7				The ear part of head is hollow style.
8				Special triangle shape.

3.2 Project's self-evaluation

The author and the teaching assistant made an investigation in the discussion with the students. The students returned responses to the design project in the course through a brief questionnaire, and the result is shown as Table 2. By the result, most of the students were satisfied with the pedagogy, the project and the course.

Table 2. Students' responses to the design project in the experimental course

Question		Strongly disagree	Disagree	Undecided	Agree	Strongly agree
1	I like the pedagogy.	0	0	3	9	28
2	I learned engineering design skills in this project.	0	0	2	17	21
3	I consider that my original design is aesthetic.	0	2	8	15	15
4	I consider that my original design is workable.	0	0	0	12	28
5	I consider that I need teacher's advice.	0	0	4	3	33
6	I followed the teacher's advice to modify my design.	0	0	0	27	13
7	I consider that the teacher's advice is useful.	0	0	0	29	11
8	I like the outline of my design after modification.	0	0	5	23	12
9	I often discussed my idea and new design with my friends or classmates.	0	0	4	22	14
10	I got fulfilment in the project.	0	0	5	26	9

3.3 Discussion on imagination issue

As the above-mentioned, the author and his research team are working for design imagination issue, and they were interesting in the relation between students' engineering design performance and their design imaginative performance. Some achievements (Charlesworth, 2008; Chu, 2012; De Cruz and De Smedt, 2010; Donnelly, 2004; Folkmann, 2014; Karwowski and Soszynski, 2008; Liang *et al.* 2012) gave the author some hints to investigate the imagination development in higher design education. However, the investigation needs long-term data collection. In fact, all the students in "Fundamental Design Engineering" were asked to join the teaching experiment course "Fundamental Design II" in their first year of university. The course "Fundamental Design II" is a required course in the first year with 3 credits and 4 hours per week, and the course is advised and judged by two teachers. Following the former experience (Chang and Lin, 2013), the author and his research team have collected their imaginative performance data in the course during February 2014 to June 2014.
Here the author would like to find the answer to the issue "if a student cannot have both good engineering design performance and imaginative performance during his/her school life?" By the reorganizing the data, as shown in Figure 5, the each students were located in the diagram depending on his/her engineering design performance and imaginative performance. The engineering design performance was made by a fraction, which is the score judged by the teacher (also the author) divided by the maximum score (100). The imaginative performance was also made by another fraction, which is the score judged by the teachers divided by the maximum score (75). In fact, the score of imaginative performance was judged according to a specific questionnaire (Chang and Lin, 2013), the teachers gave their opinions and then rated by Likert's 5-point scale.

Fortunately and exhilaratingly, some of the students had good performance in both engineering design and imagination (4 students, in Figure 5). Those students came from general high school (#1), and vocational high schools (#17, #35, and #38). The author also consider that the engineering design performance and imaginative performance of the students can be inspired by good course plan and style.

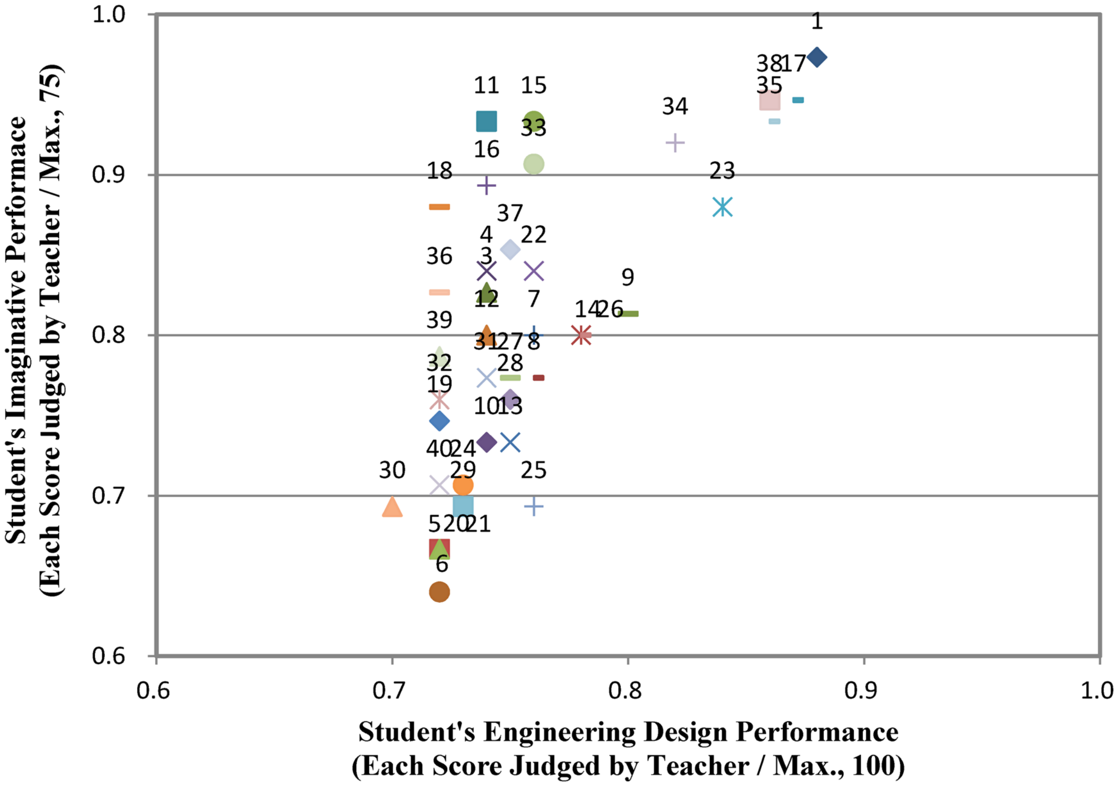


Figure 5. Students' engineering design performances corresponding to their imaginative performances

4 CONCLUSION AND FUTURE WORK

The experimental project may be said successful and conducive to the students. The course combining aesthetics and engineering knowledge in PBL style seems to be effective to Taiwanese industrial design students. They would not afraid to learn engineering problem-solving skills (for engineering design) and like to discuss their ideas (especially generated by imagination) and new design with the author and their friends. Most important, the students would obtain the fulfilment and it would drive them to develop other product design by applying other engineering knowledge.

After the experimental project, the author and other Taiwanese imaginational education study team will try to make an international research project (currently the project application is still under reviewing by Taiwanese Ministry of Science and Technology) with Prof. Hannele Niemi, University of Helsinki, also the project investigator of FINNABLE 2020 (http://www.finnable.fi/). The author wishes that this pedagogy can be mixed other learning tool (such as MoViE of FINNABLE 2020) and extended to other Taiwanese design colleges and even other countries.

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ACKNOWLEDGMENTS

This work is supported by the Ministry of Science and Technology, Taiwan. under grant number: 103-2221-E-327-036.