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Course Modules Designed for Creativity Training in Materials Engineering Education

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Abstract

One of the challenges for us is to excite creativity and innovation in the Engineering education by emerging the design courses. The objectives of designing courses for engineering is to teach students the aesthetics and critical thinking with creativity. In this study, we merged two design-based courses modules into the original course curriculum to promote the creativity of students in the field of material engineering. The course module (I) “User-Centered Design-Problem Definition” was offered based on the product and user oriented design aspects. The other course module “Experiential Manufacturing and Material Aesthetics” was proceeded through project-based learning activities.

The two course modules were combined into relevant course, Project Laboratory (1) & (2), on the spring semester (2016) as an elective course to undergraduate students. Students should submit their research portfolios and final report of the program with a device or material system and they also needed to show their achievements by oral or poster presentation in a workshop. Summative assessments of student’s performance as well as the effectiveness determined for taking the Project Laboratory (1) & (2) courses was evaluated at the end of the semester. In this study, students’ creativity were assessed by means of a rubric adapted from the *Consensual Assessment Technique* (ITC).

There were 87 students taking the Project Laboratory (1) & (2) courses in the third and fourth years, respectively. Among them 29 students attended the project under guidance with the two course modules and achieved a higher average score (>3.0/4.0) in every assessed criterion than other students. “Motivation” seems to be the key for students to bring their potential into play. Students became more confident to face and deal with the laboratory problems after training with the two design-based course modules. It is widely accepted for students’ comment that introduction of the design-based courses make the course more lively and interesting. These course modules make them to think about the origin properties of materials and creativity in applications.

1. Introduction

Material engineers are expected to develop, process, and test materials used to create a range of products, from semiconductor chips and space shuttle to golf clubs and biomedical devices. Students of Material Engineering should study the properties and structures of all kinds of materials and other substances and learn to create new materials to meet certain requirements. These properties of materials are particularly important for commodity such as buildings, vehicles, appliances and clothing. Moreover, products related to human comfort, inspiration, and sensual satisfaction are also very important. The situation is very different for materials whose performance is not based solely on physical parameters, but also on sensual, tactile, aesthetic, and cultural properties. However, there exists no systematic methodology for the development of materials with such senso-aesthetic properties. The status in Materials education indicates that the course structures have not changed significantly over recent decades and remain content heavy. The other is that courses have in general become narrower in their technical focus as the depth of knowledge has developed. In addition, the cross-disciplinary content is often quite limited. To be a material engineer, one should not only focus on the science research in materials but also in application of traditional and advanced materials in a wide spectrum of areas. We all know that training Material engineers for the next generation requires more than teaching them knowledge of material science.

Learning to apply the design process as reported can be the key for students to understand the blending of Materials Science with humanity needs [1-3]. There are many ways to define "design" in different fields. Here we would like to use the definition of "design" as "the creation of a plan or convention for the construction of an object, system or measurable human interaction [from Wikipedia, the free encyclopedia, https://en.wikipedia.org/wiki/Design]." Designing usually needs to consider the aesthetic, functional, economic and societal dimensions of both the design object and design process. Learning the design methods and processes through project-based learning activities seems to be an important route for students to understanding the merging of materials science with engineering for future challenges as reported [4-6]. Introducing designing processes through project-based learning activities will enable students to see how the fundamental concepts of science and math can be applied to solving practical engineering problems. Currently, most schools try to overcome this situation by planning a design training in the capstone course, usually in the final year of study, in which the students use all their knowledge to solve a problem. The curriculum designed for the students should have them being aware of this broadness to tackle design from day one on their undergraduate degree [7]. There are considerable advantages when design activities are integrated throughout the undergraduate learning experiences as investigated [8-10]. The further challenge is to develop a systematic method to introduce design training with the process techniques for Material engineering students. In this study, we merged two design-based courses modules into the original course curriculum to promote the creativity of students in the field of Material engineering.

2. Designed Course Modules

The present program complies with the principle of “learning by doing” with design and process techniques training courses as “make design training”. This program was preceded through a project-based pedagogy under several interactive-learning courses and training. The make design training system includes inputs that are acted upon (processed) and produce outputs (results). For Material engineering, the inputs are the foundation for the math, chemistry, physics and materials science that students often take in the first and second years. In addition, we also need to train students with experimental techniques and creative problem-solving skills during the second year. Over their second and third years, a design theme or an object will be provided for study to apply the fundamental knowledge. In the fourth year, it can be put into practice through their senior capstone project in the course of “Project Laboratory “. The design-based courses modules were introduced into the original course curriculum to promote the creativity of students in the program during the third and fourth years.

Some of the courses will be proceeded in a manufacturing-based Maker Space. Our Maker Space was built as shown in Fig.1. This space develops on the strength of Tatung University’s experience in the field of industrial design, but also creates new programs that have a wider resonance and deeper social impact.

Fig. 1 The Makerspace in Tatung University, a non-profit organization established in 2014.

Two course modules, “Experiential Manufacturing and Material Aesthetics” and “User-Centered Design-Problem Definition”, were designed under the collaboration with the colleagues in the Department of Industrial Design. The content of “User-Centered Design-Problem Definition” module (I) is listed in Table 1. We adapted several skills in this module, including SET analysis, Product Opportunity Gap (POG) analysis and Value Opportunity Analysis (VOA). POG analysis is used effectively to discover the current shortcomings in the existing products and future needs of the customer. A Value Opportunity Analysis (VOA) is a method that creates a measurable way to evaluate the success or failure of a product by focusing on the user’s point of view. This course module is product and user oriented design training. This module can be merged into the Project Laboratory (1) course or other selected course. A device or a material system and the functional properties will be selected as the object for the study and design. More importantly, emphasis is given on improving students' learning skills and creative thinking by having small group discussions.

Table 1. The course module (I) of "User-Centered Design-Problem Definition"

unit	*Topics*	*content*	*Learning activity*
1	●Literature review ●market survey	SET analysis	As a team to investigate the Current Situation of manufacturer and products
2	●Field Observation ●Participatory Design	●POG analysis, ●VOA analysis	●To interact with the user in the field ●summarize literature ,market, field, and the opinions of users
3	Making specifications for Innovative materials	Design needed Card law	Using card law to confirm the best material properties for product and fabricate procedure
4~6	Try to make Innovative materials	Wrap-up presentation at last week	Finish making Innovative materials at Maker space

Fig. 2 (A) Some materials used in the course module based on a project, (B) Students were working on the project, and (C) Students were making "innovative materials" at Maker space.

The content of "Experiential Manufacturing and Material Aesthetics" module (II) is listed in Table 2. This module focuses on the aesthetic of product and 3D manufacturing techniques. Students were taught to sketch products beginning with a basic line drawing. Following with learning prospective principle and sketchily sculpturing geometric shape in which students are taught to calculate the ratio and change view angles. A prospective gridded cube is given to student to practice shape styling as seen in Fig. 3(A) for them to experience the real shape creation and explore what they might still unsure in sketch it out. Students were encouraged to observe the presentation of features in different prospects during sculpturing the models as seen in Fig. 3(B).

Table 2. The course module (II) of "Experiential Manufacturing and Material Aesthetics"

Unit	Topics	content	Learning activity
1	Aesthetic foundation	●Basic Aesthetic principles ●Design Thinking	●Functional product design ●Specifications developed
2	Products Design shaping	Usability testing	Clay modeling and test
3	Reverse Engineering	●3-D scanner Tutorial ●3-D Model repair	Scanning the shaped product in the 3-D software and repair the defects
4	Dewaxing mold /sand mold	Wax mold making procedure	●practice to make wax mold before class. ●practice the sand mold making
5~6	Try to make a product	Wrap-up presentation at last week	Finish making Innovative materials at Maker space

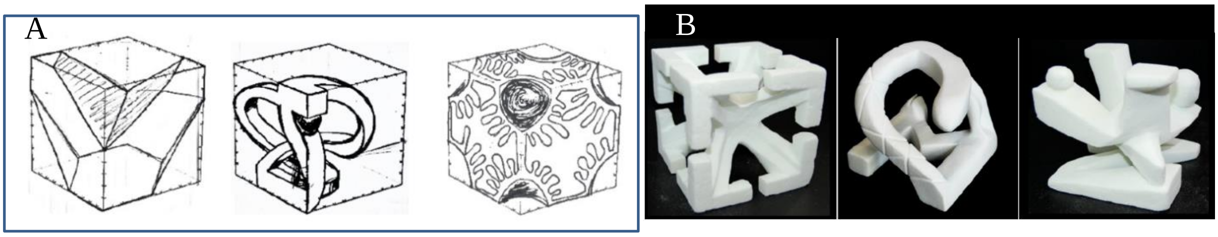

Fig. 3 Outcomes of the students' works. (A) Initial shape styling practice by sketching, (B) PU form models by sculpturing. (2016/3~2016/4)

This course module introduces students to the fundamental concepts and workflows for creating 3D models. Students were taught to explore how to create and modify both solid and surface models. Students would learn how to present their ideas and designs while they are still being created. Fig. 4 shows some products manufactured by the students attending the course module. Project Laboratory (2) is a capstone course designed to help students to process and complete the device or materials system proposed in Project Laboratory (1) with the knowledge of materials science. Students will work on devices and materials systems in teams to collect, analyze, and interpret data.

Fig. 4 Typical practical products made by students. (A) A visualized product under 3-D modeling training, (B) A moveable car with 3-D manufactured wheels, (C) A motor cycle

made with metals, (d) An "innovative material" made with cement and silicone for 3-D training. (2016/5~2016/06)

Students should hand in the final report of a device or material system by the end of the Project Laboratory (2) course. Students also need to show their achievements by oral or poster in a workshop. A competition with awards also took place in the workshop. It is hoped that this approach to the design project on a device or materials system will give students a realistic experience in engineering design and project management. Figure 5 shows the attendance of students in the workshop.

Fig. 5 (A) Students gave their final report with poster, and (B) some of them took the competition in a workshop. (2016/10~2017/01)

3. Assessment and Discussion

The course modules (I) and (II) were merged into relevant course, Project Laboratory (1) & (2), on the spring semester (2016) as an elective course to undergraduate students. In this study, there were 87 students taking the Project Laboratory (1) and (2) courses in the third and fourth years, respectively. Among them 29 students (as Group A) attended the project under guidance with the two course modules. Other students without course module training were placed in Group B.

The grade will be a composite of achievement in each of the two module courses. A specified minimum amount of work is expected of all students. The grading for the participating student needs to meet course requirements, complete the in-class projects and submit group project reports. On the other hand, the evaluation of the student's research outcomes in capstone course, Project Laboratory (2), is according to the following surveys: (1) communication, (2) analytical with materials science, and (3) integration. Table 3 shows the summary reports of the grade of the course modules and Project Laboratory (2). It can be found that the evaluation of the students' performance in Group A is obviously higher than that in Group B in "communication" and "integration". The percentage of the students with grade A in Group A was 48.3%, which is much higher than the 20.7% in Group B. There are so many factors affecting students' performance and needs to be further analyzed. The "positive attitude" seems to be the most influential of all factors on the results.

Table 3 Grades of the teams on the course module (I), (II) and Project Laboratory (2) for each groups. (A: good, B: fair, C: incomplete or fail)

	Number of students	Grade			Percentage of grade A students
		A	B	C	
Group A course module (I)	29	8	15	6	For reference
Group A course module (II)	26 (3 withdraw)	12	8	4	For reference
Group A Project Laboratory (2)	29	14	12	3	48.3%
Group B Project Laboratory (2)	58	12	32	14	20.7%

Course assessment for evaluating students' performance as well as for determining the effectiveness of the course were also conducted. These assessments help in regularly monitoring the course and then modify/improve the course as and when required. In this study, creativity assessment was applied on the *Consensual Assessment Technique* (ITC) [11-13], which is based on the idea that the best measure of creativity regardless of what is being evaluated. Figure 6 shows the results regarding the ITC Rubrics for the two groups with the Project Laboratory (2) course.

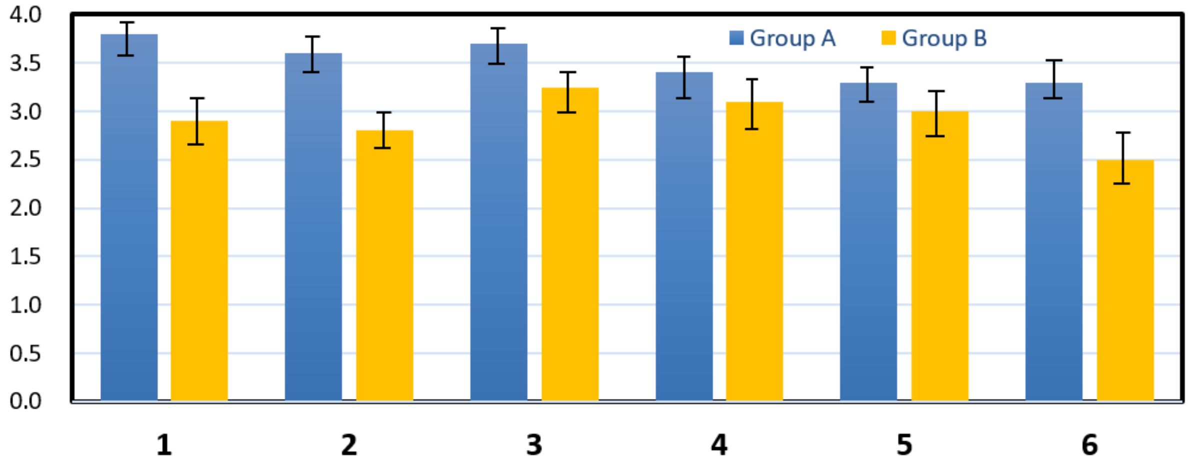

Figure 6. The average scores of six criteria for the two groups assessed by means of the *Investment Theory of Creativity Rubric* [14]. 1. motivation, 2. intellectual styles, 3. creative personality, 4. knowledge of domain, 5.intellectual processes, 6. creative product

As can be noticed from the obtained results, the group A achieved a high average score (>3.0/4.0) in every assessed criterion. There was a big gap between group A and B in "Motivation" (3.8 for group A and 2.9 for group B), "intellectual styles" (3.6 for group A and 2.8 for group B), and "creative product" (3.3 for group A and 2.5 for group B). "Motivation" is a good criterion to judge the characters of students, therefore the presentation of the students allowed to identify a high level of project pride and interest in task. Students (Group A) under the training with course modules showed much higher motivation than other students (Group B). "Intellectual processes" and the "creative product" were the lowest scored features for Group B students. In the case of the former, these lower grades are related to the lack of variety in their initial ideas. The most project topics for the Group B students were from their advisors with limited choice. Although they could properly utilize formal knowledge, they were not able to use more widely knowledge in order to look for more diverse examples. The course module (II) as though gave the students (Group A) opportunity to learn some informal processing techniques that might inspire their ideas.

The scores of "creative personality" and "intellectual processes" criteria were close for the two groups. This indicates that most students would like to take risk and tolerate for ambiguity. Most of them were able to analyze their experimental processes from different perspectives to explain and present in a professional manner. It seems well consistency that students with higher assessment scores in the six criteria have higher course grades. Some team members with lower performances were mainly due to not the adequate throughout project development, which was reflected on the quality of requested deliverables, including the final presentation. This means that students are lack of enough knowledge or have a wealth of disconnected knowledge and do not know how to build relationships among them.

Students become more confident to face and deal with the laboratory problems after training with the design-based course modules. In addition, students are more willing to discuss their research and work and share their ideas with team member and advisor. It is widely accepted for students' comment that introduction of the design-based courses make the course more lively and interesting. These course modules make them to think about the origin properties of materials and creativity in applications. The correlation between creativity assessment and report grade of course as expected to be intimately related and become distinct when the design-based course modules are introduced to the Engineering course curriculum.

4. Final remarks

It is well known that there is a wide difference between active and traditional learning environments. In our study, those students (Group A) willing to take training with design-based course module showed more active in learning. These students worked their product in the manufacturing-based Maker space complied with the principle of “learning by doing” that becomes a spectrum and continuum of experiences in skill ideas. The Maker space seems to be giving students a space to imagine and plane their goals. The vast majority of students in Group A attained final project expected outcomes at excellent level. Taking the course modules can help students to create a link between abstract knowledge and a real context and thus define desired outcomes.

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References

1. C. L. Dym, A. M. Agogino, O. Eris, D. D. Frey, L. J. Leifer 2005. Engineering Design Thinking,Teaching, and Learning. Journal of Engineering Education. 94(1), 104–120.
2. M. Lammi and K. Becker 2013. Engineering Design Thinking,” Journal of Technology Education, 24(2): 55-77.
3. I. Rauth, E. Köppen, B. Jobst, and C. Meinel 2010. Design Thinking: An Educational Model towards Creative Confidence. in Proceedings of the 1st International Conference on Design Creativity (ICDC2010), Kobe, Japan.
4. Richard N. Savage 2006. The Role of Design in Materials Science and Engineering,” Int. J. Engng Ed., 22(5):917-924.
5. M. Cardella, C. Atman, J. Turns, and R. S. Adams 2008. Students with differing design processes as freshmen: Case studies on change. International Journal of Engineering Education, 24(2):246-259.
6. A. Silva, L. Faria 2012. Two approaches to design teaching in a mechanical engineering curriculum. Int. J. of Engineering Education, 28(2):474-483.
7. A. Silva, M. Fontul 2015. Teaching design in the first years of a traditional mechanical engineering degree: methods, issues and future perspectives,” European Journal of Engineering Education, 40(1):1-13.
8. C. R. Chaplin 1989. Creativity in engineering design: The educational function. A Report published by Fellowship of Engineering.
9. N. S. Richard, K. C. Chen, L. Vanasupa 2007. Integrating Project-based Learning throughout the Undergraduate Engineering Curriculum,” Journal of STEM Education Vol. 8(3&4):15-27.
10. G. Malnarich and E. D. Lardner 2003. Designing Integrated Learning for Students: A

Heuristic for Teaching, Assessment and Curriculum Design," Washington Center Occasional Paper Winter, No.1:1-8.

11. T. M. Amabile 1982. Social Psychology of Creativity: A Consensual Assessment Technique. Journal of Personality and Social Psychology, 43:997-1013.
12. R. J. Sternberg, and T. I. Lubart 1993. Creative Giftedness: A Multivariate Approach Investment. Gifted Child Quarterly, 37:7-15.
13. R. J. Sternberg, T. I.Lubart , J. C.Kaufman and J. E. Prelz 2005. Creativity. In K. J. Holyoak and R. G. Morrison (Eds.) The Cambridge Handbook of Thinking and Reasoning (pp. 351-369). New York: Cambridge University Press.