Make Design Training in Materials Engineering Education

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INTRODUCTION

The present study focuses on “make design training” for the students in the field of Materials Engineering. Advances technology of the future require innovations aimed at designing, developing and manufacturing materials with multiple functions and properties customized for desired performance requirements and applications. Materials science and engineering (MSE) programs at universities across the world face a challenge not only focusing on the research in materials but also the education of students in application of traditional and advanced materials in a wide spectrum of areas. However, preparing of succeeded materials scientists and engineers for the next generation requires more than teaching them knowledge of material properties and behaviours.

Learning to apply the design methods and process can be the key to understanding the merging of Materials Science with Engineering [1-3]. The subject of materials has its foundations in physics and chemistry and is usually regarded by many people as a science. It therefore tends to be taught with an emphasis on principles of materials science rather than how make materials, since the latter is much complicate to be taught in class. However, engineers may regard the subject in a more practical sense and may wish to know about engineering properties of materials for selection rather than only the science theory. It becomes a challenge for school to educate students in more practical way by the teacher with little practical experience. It can be good way by introducing design process through project-based learning activities to enable students to know how to merge the fundamental

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concepts of science to solve complex engineering problems. The traditional way used to overcome this situation is to have a capstone design course, usually in the final year of study, in which the students use all their knowledge to solve a design problem. However, this may not be enough to capture all the technical, economic, environmental and social (TEES) issues for Material education that arise in a real life design. The curriculum designed for the students should have them being aware of this broadness to tackle design from day one on their undergraduate degree [4]. It has been established that there are considerable advantages when design activities are integrated throughout the undergraduate learning experience [5-7]. The further challenge is to develop a systematic method to introduce design training with the process techniques for materials engineering students integrating as they progress through their undergraduate courses. In our work, we develop a manufacturing-based Maker Space, two design-based course modules and evaluation standards for both curriculum and equipment suitability.

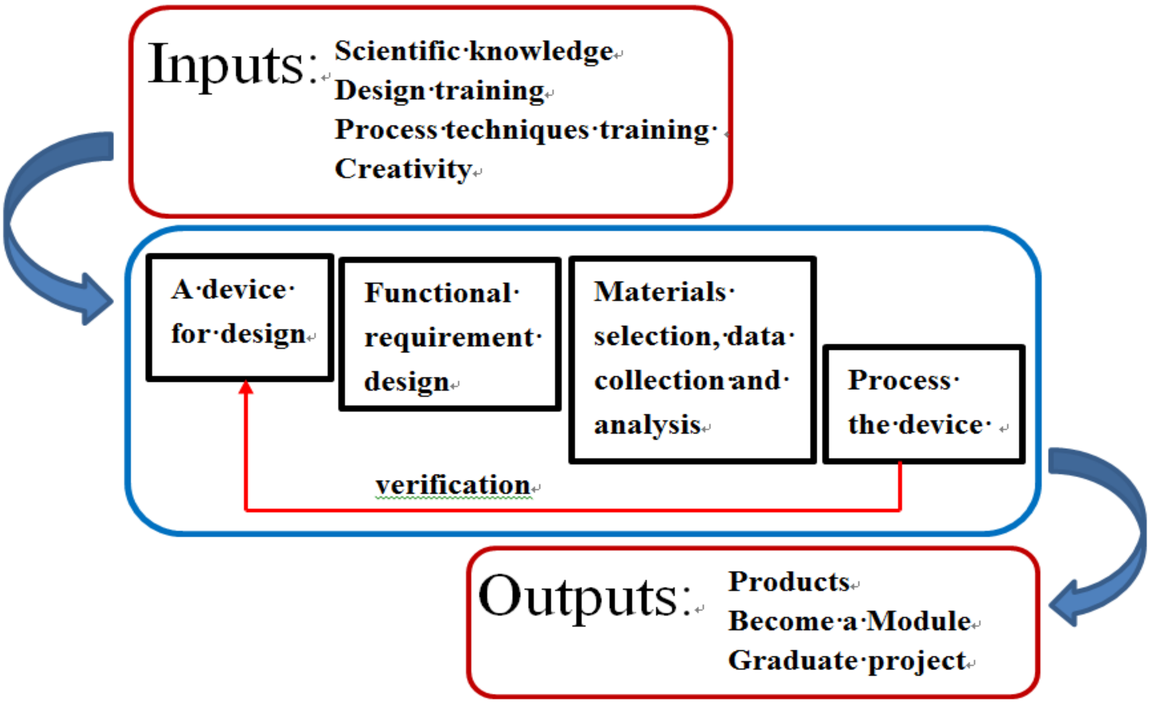

Fig. 1 Illustration of the make design training process as a system with inputs and outputs.

1 A SYSTEMS APPROACH TO DESIGN

This present program complies with the principle of "learning by doing" with design and process techniques training courses as "make design training". The "make design training" process as a system with inputs and outputs for the present study is shown in Fig.1. The program was conducted through a project-based pedagogy under several interactive-learning courses and training. As shown in Fig. 1, the make design training system includes inputs that are acted upon (processed) and produce outputs (results). For materials 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, the design thinking, process techniques, and creative problem-solving techniques should also be trained to the student in this project. Over their second and third years a design theme or an object will be provided for learning to apply the fundamental knowledge and in the fourth year it can be put into practice through their senior capstone project.

The interactive- learning courses and training for this program includes:

Instrumental Analysis Methods:

The specific experimental procedures for carrying out the tests and analysis of materials are introduced. (as seen in Fig. 2) The basic objective of these supplemental experiments is to give students the tool selection and hands-on experience in the third year.

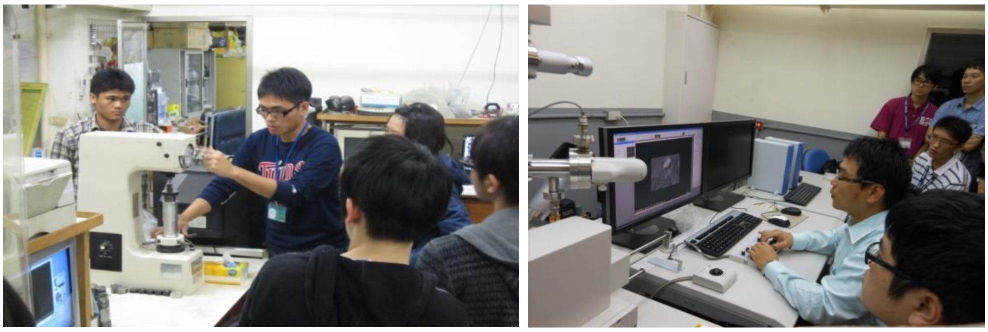

Fig. 2 The specific experimental procedures for carrying out the tests and analysis of materials is introduced. This includes mechanical properties tests, SEM, XRD, DTA, FTIR, Raman, etc.

Seminar on Journal Readings:

This course is designed for students to understanding the challenges and problems for the present materials technology.in the third year. The course is based on presentation on subjects by advisor and students with problems/cases interspersed throughout the classroom. The subjects are selected based on the issue of materials research through the various predicaments with materials.

The Project Laboratory (1):

This course is basically to help the students to finish a proposal for studying or applying the smart materials. Students are divided into several small groups and trained by different field of materials technology. 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 for improving students' learning skills and creative thinking by having small group discussions and frequent quizzes on laboratory exercises. A design-based course module is applied in this course and conducted in the manufacturing-based Maker Space. (as seen in Fig. 3)

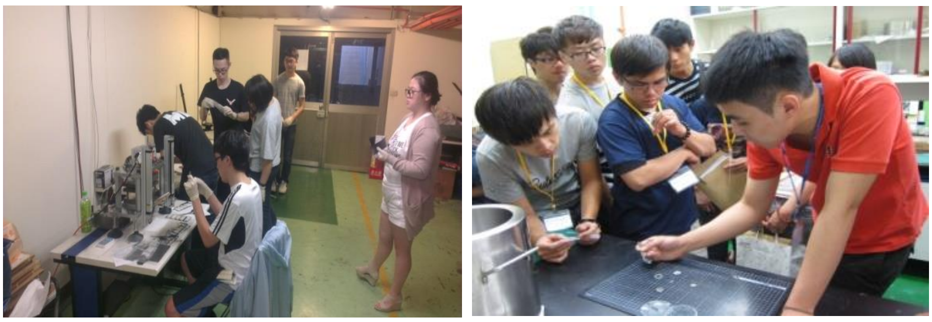

Fig. 3 Students did the laboratory exercises under a design-based course module in the manufacturing-based Maker Space.

Project Laboratory (2):

This course is designed to help students to process and complete the device or materials system proposed in Project Laboratory (1). This course is a capstone course providing opportunity for an integration of program coursework, knowledge, skills and experiential learning enabling the student to demonstrate achievement of the project. Students will focus on problem analysis, critical and creative thinking, and effective communication. Another design-based course module is applied in this course. Students will work on devices and materials systems in teams to collect, analyze, and interpret data. A team may include the students from the different fields such as materials engineering, mechanical engineering, art and design.

Course assessment for evaluating students' performance as well as for determining the effectiveness of the course is also conducted. These assessments help in regularly monitoring the course and then modify/improve the course as and when required. A list of core competencies and the inspection standards compiled from the capstone courses are shown in Table 1. Emphasis is given in the department curriculum to practices and assessment methods that are focused on these core competencies.

Table 1 A list of core competencies and the inspection standards for the program

The Core Competence of the Materials Engineering		Inspection standards
1	**Basic Engineering:** Being able to use science and principles of engineering in Materials system.	Applications of mathematic, physics, chemistry, and basic science
2	**Profession in materials**: integrative understanding the structure, properties, process, and performance of materials.	2.1 Process: more than one process of materials
		2.2 Structure analysis: for example OM/SEM/TEM /AFM/STM, Raman, FTIR, NMR, XRD, XPS, etc.
		2.3 Properties analysis: for example mechanical properties, electrical, magnetic, optical, thermal, chemical, etc.
		2.4 Discuss the relevance between structure, process, and properties of materials
3	**Data analysis**: have the ability of experiment, statistics, and analysis to solve the problems for the choice and design of materials.	3.1 Complete the proposal of the Project Laboratory (1) & (2) courses
		3.2 Have the ability to the data process (make table, figure, statistics, regression analysis, etc.) and analysis
4	**Understand the problem**: understanding the challenges and problems for present materials technology	The challenges and problems for present materials technology shall be discussed in the Introduction and Paper review sections of the report for the Project Laboratory (1) & (2) courses
5	**Continued learning**: to cultivate the habits and ability of continued learning.	Can continue to study the paper and get new knowledge related to the special subject experiment
6	**Communication and cooperation**: ability of effective communication and teamwork.	Effectively communicate and cooperate with the team member, advisor, and others, and promote the progress of the study
7	**Professional ethics**: understanding Professional ethics and Social Responsibility.	7.1 Participate the related course or activity for professional ethics.
		7.2 Sign the Academic Ethics Commitment

Final Report and Competition:

Final report of the program for a device or materials system should be held by the student at the end of the Project Laboratory (2) course. Students also need to show their achievements by the presentation in a workshop. A competition with awards will also take place in the workshop. (as seen in Fig. 4) 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.

Fig. 4 Students gave their final report and took the competition in a workshop.

2. INTEGRATING DESIGN INTO THE CURRICULUM

The term "Maker Movement" has recently been used to identify a class of people who are interested in developing new products through digital technology and innovation. The movement took off in 2005, inspired by the rise of 3D printing technology. This growing trend emphasizes creativity and a do-it-yourself ethos by sharing workspaces and equipment. It also stresses information sharing. This program complies with the principle of "learning by doing". It consists of development of a manufacturing-based Maker Space, two design-based course modules and evaluation standards for both curriculum and equipment suitability. Our Maker Space named FutureWard was built as shown in Fig.5. It is the largest maker space in Taipei located in a former industrial building at Tatung University. FutureWard develops on the strength of Tatung University's experience in the field of industrial design, but is also crafting new programs that have a wider resonance and deeper social and economic impact. Like other co-working maker spaces, FutureWard offers manufacturing, co-working, and social areas with a range of different machines and tools.

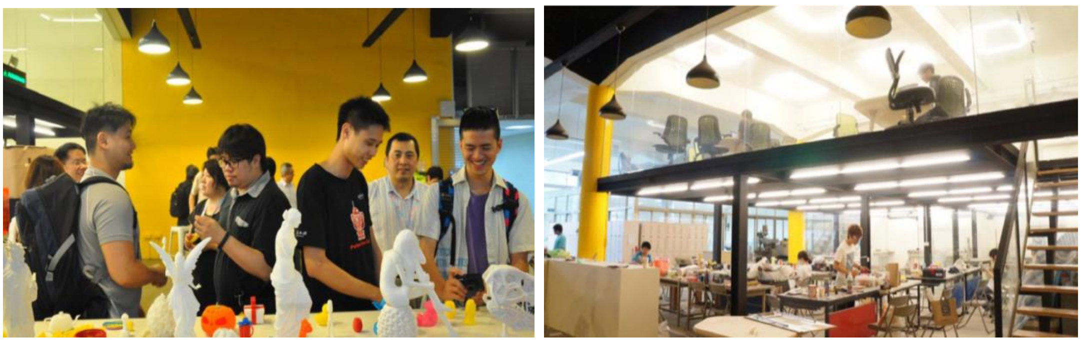

Fig. 5 The largest maker space in Taipei is Futureward, a non-profit organization established in 2014. The purpose of FutureWard is twofold: on the one hand working in education with students and teachers and on the other developing a sustainable ecosystem that makes full use of a network of small and medium factories of hardware and electronics existing in Taiwan as well as their supply chains, equipment and tools.

During the first six months, the curriculum and assistant training of “Experiential Manufacturing and Material Aesthetics” course module will be done. We commence the module in the following 6 months whereas the planning of “User-Centered Design-Problem Definition” module is started. Both modules are finished by a learning evaluation for further improvement for the second cycle. In the second round of the modules, we continuously enhance the quality of the module and start to introduce relevant competitions or activities to the students. This project contributes two course modules for application to relevant course, Project Laboratory (1) & (2). During the implementation of the projects, students, design assistants and teachers are inspired and interested academically and practically. Course modules are getting more comprehensive by multiple cycles of practice. Environment of Maker Space is diversified and the closer relationship between design and engineering school achieve the aim educating interdisciplinary human resource.

3. DISCUSSION AND IMPLICATIONS

Our assessment for this program involves use of the following tools: (1)one-on-one faculty interviews/advisement; (2)qualification for the professional program (upper division courses); (3)instructor assessment at the course level (including exams, quizzes, and homework that address specific competencies, student self-assessment, etc.); (4)standard university course evaluations; (5)student achievement portfolios. However, we will not discuss the way to use these tools to do the assessment in this manuscript. Instead, the outcomes reflect the effect of applying the “Experiential Manufacturing and Material Aesthetics” and “User-Centered Design-Problem Definition” course modules in the course curriculum will be discussed.

Students were assigned to evaluate course program in a specific group and their achievements were evaluated by themselves and advisors with guidelines at the end of the courses. In general, students were accepting of peer creativity evaluation and its inclusion into the final term grade. The core competence of the course was evaluated during the mid-semester period and also at the end of each semester to sustain optimum quality. Numeric values have been assigned to the various rating scales for the purpose of computing medians. The scale values are as follows: Excellent=5, Very Good=4, Good=3, Fair=2, Poor=1. The results of the assessment for the core competence were shown in Table 2. Fifty students participating in this program and divided into two groups based on with/without the design-based course module in the course training were under assessing. It was found that the assessment ranking of the group with Design-based course is higher than that without the module course in most items.

Table 2 Assessment ranking results of the core competence for this program

The Core Competence of the Materials Engineering		The group A (35 students) without design-based course module		The group B (15 students) with design-based course module	
		Assessment results (Teacher)	Self-assessment results (Student)	Assessment results (Teacher)	Self-assessment results (Student)
1	**Basic Engineering**	**3.5**	**3.8**	**3.9**	**4.5**
2	**Profession in materials**	**3.9**	**4.1**	**4.1**	**4.6**
3	**Data analysis**	**4.1**	**4.2**	**4.3**	**4.6**
4	**Understand the problem**	**4.0**	**4.3**	**4.3**	**4.6**

5	Continued learning	4.4	4.5	4.6	4.9
6	Communication and cooperation	4.2	4.5	4.8	4.9
7	Professional ethics	4.3	4.5	4.4	4.5

The ranking in the "Basic Engineering" item by teacher is much lower than by self-assessment for each group. 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 as the evaluation of teacher. In addition, the ranking of this item for group B is much higher than group A by self-assessment. This indicates that students become more confident to face and deal with the laboratory problems after the Design-based course. And students are more willing to discuss their research and work and share their ideas with team member and advisor. Their communication skill and understanding of problems are also promoted by introducing the training of design-based course. This is well agreement to the evaluated results with the higher ranking in "Communication and cooperation" item for group B students. On the other hand, there are 31 of the 35 students of group A completed the Project Laboratory (1) & (2).courses, whereas all students of group B completed the courses.

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 lack of correlation between creativity in design and report grade may show that creativity in design is unimportant within traditional evaluations of engineering design. However, the correlation between creativity in design and report grade is expected and become clear when the design-based course modules are introduced to the Engineering course curriculum. So the report grade for group A students reflects the correlation to Engineering design in usefulness other than creativity or innovation.

The process is used to define desired outcomes and to develop methods for helping students to achieve those outcomes. Many excellent achievements in practice research have been done at the end of the Project Laboratory (2).course. Figure 6 shows a team, in which students come from Materials Engineering and Design Engineering of Tatung University, won the first prize of the Light Metal Award in 2012. A device of battery made with magnesium metal is used for sea life jacket which can light LED in dark night. Figure 7 shows a team, in which students from Materials Engineering and Electrical Engineering won the first prize of the Nationwide competition in Innovation of Energy in 2014. They developed a fast charged method for Lithium batteries. These students were under design and process training in series courses developed by Materials Engineering. The courses are designed to help students developing skills as well as knowledge to be capable of realizing their ideas and adapting to new technologies and future challenges.

Fig. 6 A team of Tatung University won the first prize of The Awards for Innovative Design and Application of Light Metal held by the Ministry of Economic Affairs of Taiwan in 2012.

Fig. 7 A team of Tatung University won the first prize of Nationwide Competition in Innovation of Energy held by the Ministry of Education of Taiwan in 2014

4. CONCLUSIONS AND FUTURE WORKS

We have shown that successful implementation of design-based course modules into the curriculum in a meaningful and interesting way. Two design-based course modules were developed for materials engineering curricula. These courses were carried on in the manufacturing-based Maker Space complied with the principle of "learning by doing". To make a real designed specimen in the Maker Space becomes a spectrum and continuum of experiences in the innovation skill set and mindset of students. We have shown that students become more confident to face and deal with the laboratory problems after with the design-based course training. However, a question arises what are suitable methods for evaluating the creativity with the design-based course module training? This project proposes following three future works for the inspiration of creativity:

(1) To find the factors for the correlation between the practical environment and creativity.
(2) To understand how to evaluate and grade creativity.
(3) To establish and analyze the creativity from the student's study portfolio and assessment of the course.

5. ACKNOWLEDGMENTS

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REFERENCES

[1] Richard1 N. Savage2 (2006), "The Role of Design in Materials Science and Engineering," Int. J. Engng Ed.,Vol. 22, pp. 917-924.

[2] Cardella3 M., Atman4 C., Turns5 J., and Adams6 R. S. (2008),"Students with

differing design processes as freshmen: Case studies on change," International Journal of Engineering Education, Vol. 24, pp. 246-259.

[3] Silva A7, Faria8 L. (2012),"Two approaches to design teaching in a mechanical engineering curriculum," Int. J. of Engineering Education Vol. 28, pp.474-483.

[4] Silva A., Fontul9 M (2015),"Teaching design in the first years of a traditional mechanical engineering degree: methods, issues and future perspectives," European Journal of Engineering Education Vol. 40, pp. 1-13.

[5] Chaplin10 C. R. (November 1989), Creativity in engineering design: The educational function, UK Fellowship of Engineering Report No. FE4, 2 Little Smith Street, Westminster, London SWIP 3DL.

[6] Richard11 N. S., Chen12 K. C., Vanasupa13 L. (2007)," Integrating Project-based Learning throughout the Undergraduate Engineering Curriculum," Journal of STEM Education Vol. 8, pp 15-27.

[7] Malnarich14 G. and Lardner15 E. Decker (2003),"Designing Integrated Learning for Students: A Heuristic for Teaching, Assessment and Curriculum Design," Washington Center Occasional Paper Winter, No.1, pp. 1-8.