GSTF Journal on Education (JED)
DOI: 10.5176/2345-7163_3.2.85
Print ISSN: 2345-7163, E-periodical: 2345-7171 ; Volume 3, Issue 2; 2016 pp. 75 - 78

An Effective Interdisciplinary Teaching and Learning Methodology through Crossed-Subjects Design Project

An Experience Sharing

T. Hui Teo
Engineering Product Development
Singapore University of Technology and Design
Singapore
tthui@sutd.edu.sg

***Abstract*—Engineering education requires reformation to address the drastically change of the industrial development in various product markets. Nowadays most product development involves not only different disciplines of engineering but also integration of design science. In this case, the engineering education must in-cooperate design science into the curriculum seamlessly to give quality teaching and learning experience for both faculties and students. This work shares the experience of integrating design science into the engineering courses by introducing crossed subjects design project and lesson plan, which results in effective teaching and learning.**

Keywords—crossed subjects, design project, design science, inter-disciplines, CDIO, teaching and learning;

I. Introduction

Engineering product are often not dependent purely on a single discipline but a combination of various disciplines such as electrical, mechanical, chemical, materials, software and etc. In such case, the multi-disciplinary requirement deviates from the conventional engineering education where a specific discipline is studied and it is separated from other discipline. For instance, an electrical engineering student focuses on electrical engineering without interaction to the mechanical engineering. However, the interaction between various related disciplines is required for any modern engineering product design and development. On the other hand, a design project has been used as a tool in teaching and learning to achieve in-depth understanding of various topics and reinforce the concept learnt in a certain discipline. Conventionally, students are only able to perform the design project during their final year project execution, which is toward the end of the study for their undergraduate study. This is in fact not an effective approach and reduce a lot of the interest of the students in engineering study. This is because the students can only appreciate the application of the theories learnt throughout the undergraduate study in their final year project.

This work was supported in part by the Education Department of Singapore University of Technology and Design under Pedagogy Research Fund, Reference Number: 2015-2016.

At the same time, most of the final year project focuses on a specific topic in a certain discipline only. There is lack of interdisciplinary experience for the students. The objective of this study is to propose and experiment interdisciplinary teaching and learning methodology.

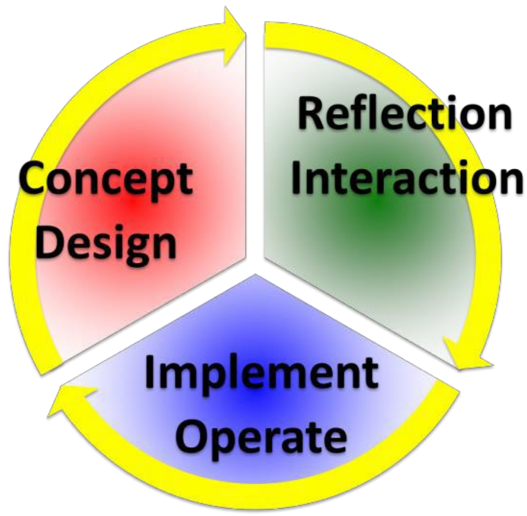


Figure 1. Components of CDIO-RI

The question now is how to implement the design project in the courses without losing the in-depth and focus of those courses. One of the implementation method is (Conceiving, Designing, Implementing & Operating) [1]. However, new method, CDIO-RI (Concept, Design, Implementation & Operation – Reflection & Interaction) is adopted in this work to achieve an effective teaching and learning methodology through crossed subjects design project. Unlike conventional CDIO, ‘C’ in the CDIO-RI represents the ‘Concept’ that is introduced in a course of study. This is where design science [2] is important in integrating various engineering disciplines in product design.

The flow and components of the CDIO-RI approach is depicted in **Figure 1**. The approach is described in general as the following. A specific topic is first introduced by the concept, and illustrated by a practical design in CD (Concept & Design) session. Feedback, problem solving, and discussion among students and instructors are carried out in the RI (Reflection and Interaction) session to further explore the concept that has been introduced and taught. The lesson plan for each lesson is JiTT (Just-in-Time Teaching) rather than structured lesson plan [3]. For engineering discipline, it is important to have hands-on, analysis, experiment, measurement, simulation, project and etc. to help the students to implement the concept learnt in practical design, and the relevant operation. These activities are carried out in IO (Implementation & Operation) session. After the first cycle, a new cycle of the CDIO-RI with deeper and more difficult concept is than introduced and continue the teaching and learning cycle. The crossed-subjects design project is implemented in IO session. The crossed-subjects design project is regarded as 2D (two dimensional) project in this context.

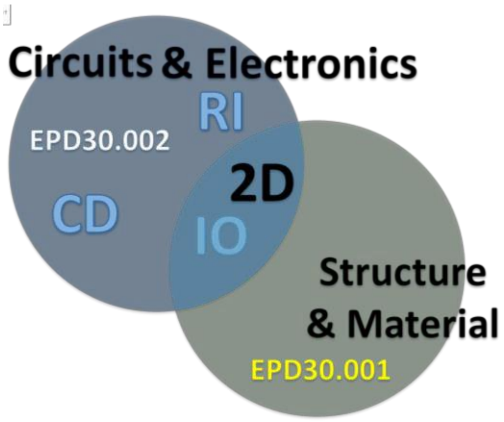


Figure 2. Subjects' interaction

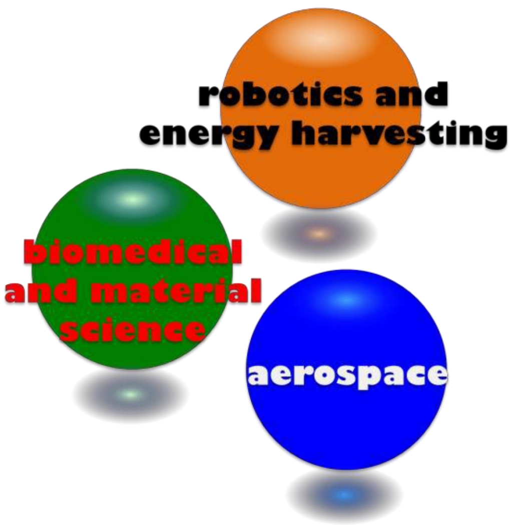


Figure 3. Focus of engineering product design

This paper is organized as follow. Section-II describes the implementation of the 2D project with practical design example. Section-III concludes the paper.

II. 2D DESIGN PROJECT

The objectives a crossed-subjects design project is to introduce inter-discipline engineering product design while provides an effective teaching and learning methodology. 2D projects in this case fills the gap for inter-disciplinary studies in engineering courses. The below text will describe the 2D projects organization and execution bases on the practical 2D projects that have been carried out in our institute.

2D projects in this contest is represented by a project that carried out by adopting knowledge learnt from different courses in the same academic term / semester. For instance, in term-4 (2th year) in this institute, the students are required to take Circuits & Electronics, and Structures & Materials. In this case the 2D project is related to these two courses, which are from electrical engineering and mechanical engineering disciplines respectively:

- Circuits & Electronics (Electrical & Electronics Engineering)
- Structure & Materials (Mechanical Engineering)

In order for the students to adopt the knowledge learnt from two different courses in the design project, the lesson plan for the two courses need to be carefully arranged and implemented. A common session for these two courses is also required to carry out the design project. IO session is used for the 2D project execution, where the lesson consists of three basic component, eg. CD, IO, RI, as shown in **Figure 1**. The interaction between the two relevant subjects is illustrated in Figure 2. It can be seen that there is an overlap for IO session for 2D in the diagram. It is also worth mentioned that follow the CDIO-RI methodology, the 2D project can be integrated effectively in the lesson plan and course delivery. These enhances the achievement of the Learning Objects (LOs), Measurable Outcomes (MOs) at course level, as well as Students Learning Outcomes (SLOs) at institution level, where the effectiveness of the teaching and learning is greatly improved in engineering education. LOs, MOs, and SLOs are achieved "Just-in-Time" the course is delivered.

In this 2D project execution, there are two 2D projects. The first project is partially guided for students to appreciate the process of interdisciplinary and system level design bases on the week-1 to week-4 content. The second project which is theme base design where students need to design a product for a specific application bases on the content of the courses for the whole term (week 1 to week 13). The two 2D projects are listed:

- Week 4 – Energy Harvesting (e.g. In House Wind Turbine)
- Week 1 to Week 13 – Theme Based-Biomedical and Materials Science (Design for Assistive & Rehabilitation)

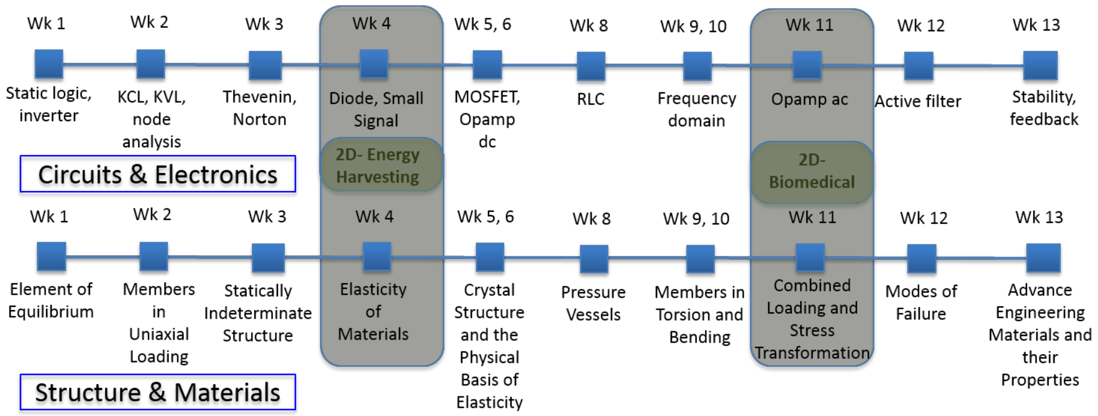


Figure 4. Lesson schedule

In the 2D project, there are different engineering products to be studied, such as in the area of robotics, energy harvesting, biomedical, materials science, and aerospace. The theme has to be confined to these engineering focus in line with the focus of the institution. The focus of the engineering product design category is depicted in **Figure 3**. The project scope has to be in line with the subjects' content, and confine to a certain level of achievement, thus it is manageable by the students for quality of learning experience.

The lesson schedule for the subjects that are involved in the 2D projects have to be aligned in time and content. Figure 4 shows the existing lesson plan in brief for the 2D project execution. The first 2D project in week-4 is a short one week design project where the students need to design an energy harvesting device, such as wind turbine making use of the knowledge learnt from week-1 to week-4. Basic instruction is given to guide the students in interdisciplinary design that involves electrical engineering and mechanical engineering knowledge.

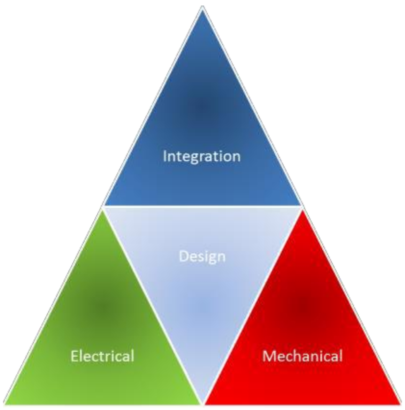
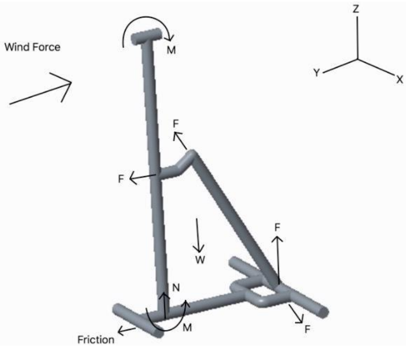


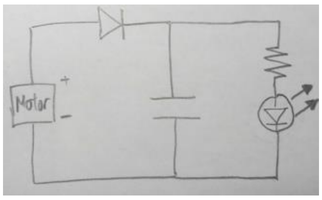
Figure 5. Interdisciplinary design hierarchy

In order to design the energy harvesting device, the students should have equipped with basic circuit analysis skill (e.g. KCL, KVL, node analysis, Thévenin's, Norton's equivalent circuit), electrical power concept, and non-linear device – diode. The circuitries have to be designed is a rectification circuit with capacitor as storage. The students also need to know how to perform simulation, analysis, and construction of the circuit besides knowing how to perform debugging using equipment such as multi-meter, oscilloscope, power supply, prototyping board and etc. Without a structure and prime mover to convert the wind energy to the electrical energy, the wind turbine cannot be implemented. In this case, mechanical structure design for the fan, stand with equilibrium, and loading consideration, is also required. Analytical skill involves free-body diagram, CAD (Computer Aided Design) drawing tool and hands-on skill in the structure construction are also inevitable. The design hierarchy for the 2D design is shown in **Figure 5**. It should be designed centric that is supported by both fundamental engineering disciplines (electrical engineering, and mechanical engineering in this case) as depicted in the figure. The ultimate goal of the project is to achieve the system integration towards the top of the hierarchy. At this introductory interdisciplinary design project, the students could appreciate the process of integration by adopting the various knowledge and skill learnt from two different subjects. The focus is not to deliver a final product by try and error but design the device systematically, and constructive. **Figure 6** shows one of the design by students in various parts and integration. This is different from the second 2D project which is very much application oriented and requires extensive active and independent learning.

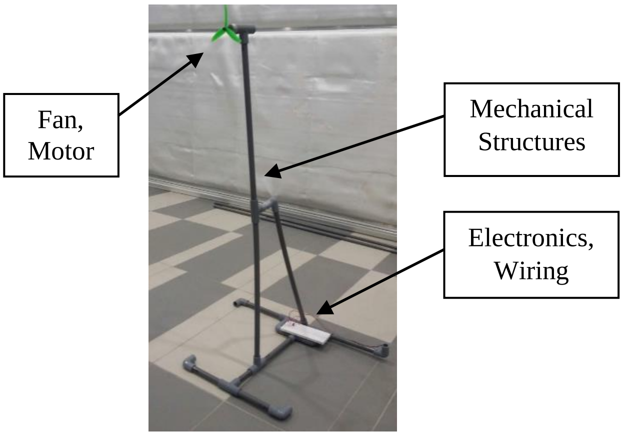
For the second 2D project, it has to be presented in week-11. However, the project is started in week-1 by project briefing and forming the project group. The students are required to propose the product to be design in week-4, and starts the project execution after the design review and evaluation by the instructors. The design process is again oriented around on CDIO-RI methodology. The focus is on biomedical and materials science, and the theme is "Design for Assistive and Rehabilitation". It is worth to mention that the students also approach external medical expert in finding the user needs. The external medical experts include medical doctor from hospital, specialist from medical center, as well as researcher in research institute. The resource planning for time, cost, materials, and etc. are very critical as the project execution period is only about eight weeks that need to cover a certain subjects of study which are running concurrently with the project execution. It can be seen from the classroom participation that the students are attentive to the topics of discussion and actively asking question and solution related their design projects. They could immediately implement the knowledge learnt from their lessons and try to relate new topics. These is basically the intended active learning attributes. One thing needs to cater for the project execution is the project space, materials, and technical consultation, which have to be ready almost 24-7 as the students are eagerly in carrying out the projects during their time outside the lesson.



(a) Mechanical structure design



(b) Electronics design



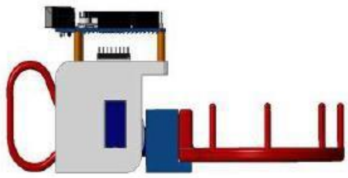
(c) Complete design

Figure 6. Introductory 2D project

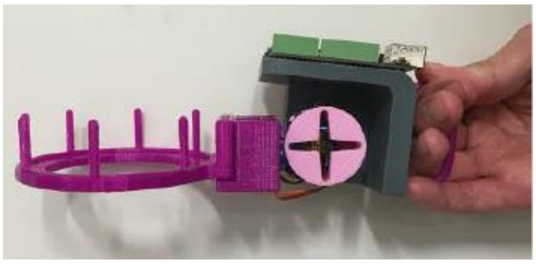
One of design prototype is shown in Figure 7, the design involves 3D modeling of the structure, implementation of the electronics, programing of the microcontroller, and finally the assembly and integration of the prototype. It is followed by prototype demonstration. It is an evaluation criteria that the design must be able to operate during the demonstration.

III. Conclusion

In a nutshell, the interdisciplinary teaching and learning can be achieved through crossed-subjects design projects in engineering education. The design projects give both the students and instructors a pleasure experience and quality of teaching and learning.



(a) 3D modeling



(b) Prototype demonstration

Figure 7. 2D project - an electronic gimbal

Acknowledgment

The author would like to thank the laboratory managers, Ms. Chu Wenjing, Mr. Nyan Lin Htat for their supports.

References

[1] http://www.cdio.org/

[2] V. Hubka, and W. E. Eder, *Design Science – Introduction to the Needs, Scope and Organizaiton of Enginering Design Knowledge*, Springer, 1996.

[3] T. Hui Teo, "Just-in-Time Teaching visual instruction for cohort base interactive learning-for engineering course," *GSTF Journal on Education (JEd)*, vol.3, no.1, 2015.

AUTHOR'S PROFILE

T. Hui Teo graduated with Master of Engineering and Ph.D. from National University of Singapore and Nanyang Technological Univsersity in 2000 and 2009 respectively in Electrical & Electronic Engineering. Since 1996, he was with Sharp, ST-Microelectronics, Intelligent Micro-Devices (Matsushita), and etc. as a senior Integrated Circuits (IC) designer, prior joining Institute of Microelectronics, Agency for Science, Technology and Research (A*STAR), Singapore as principle investigator in advanced IC design R&D. In 2010, he joined education sector for setting up both Analog and Digital IC design courses and laboratories for Technical University of Munich, Asia. He is currently with Singapore University of Technology and Design. His research interest are IC design, device characterization & modelling and design education. T. Hui is a Senior Member of IEEE, and Felow of IES (Institution of Engineers Singapore).