AN INTEGRATED APPROACH TO ENGINEERING AND DESIGN

Dr Linda Lee, Peter Lo and Lim Siew Kuan

School of Mechanical and Manufacturing Engineering, Singapore Polytechnic

ABSTRACT

This paper describes the approach to integrate engineering and design where students learn the practice and application of engineering skills and foundation design skills in year 1 of their study. The design knowledge and engineering skills acquired by the students equipped them in the generation of ideas and implementing these ideas through team project activities. As part of the CDIO implementation plan for this module, a workspace is created to provide students to gain simple Design-Build experiences. This workspace allows each project team to realise their creative designs and develop them into models.

The paper also explains how the contents of the two modules, "Introduction to Engineering" and "IDEA" (Innovative Design and Enterprise in Action) are integrated. An example in the form of project will be described in detail to show the CDIO skills learned and experienced by the students. Finally, a summary of the evaluation this programme has in delivering the intended aims and conclusions are also outlined.

KEYWORDS

CDIO, workspace, design-build and integration

INTRODUCTION

The School of Mechanical and Manufacturing Engineering offers five diploma courses, namely Diploma in Aeronautical Engineering, Diploma in Bioengineering, Diploma in Mechanical Engineering, Diploma in Mechatronics, and Diploma in Resort Facilities Services and Management. The five courses, which have about 600 students, share the same first year curriculum and the students continue with their respective course of study from the second year.

CDIO [conceive-design-implement-operate] was implemented for the all the diploma courses in the first year of study. The objectives of implementing CDIO are to achieve the following goals:

- Improve the quality of the courses.
- Provide significant learning experiences for students which are more than foundational knowledge acquisition.
- Enhance the local relevance of our program.
- Enhance international recognition for the excellence of our courses.

A comparison between the current syllabus design methodology and CDIO is given in Table 1 below.

Current	CDIO
1. Learning outcome: heavy on "what we think students are capable of doing"	1. Learning outcome is determined by what the graduates are expected to do, example of which is the job competency.
2. Modules are still largely "independent", that is compartmentalized learning. Disconnect between C-D-I-O, not integrative	2. Modules are integrated to support the job competency.
3. Assessment: heavy on testing knowledge	3. CDIO elements are assessed mainly on application of knowledge

Table 1. Some shortfalls in current syllabus design methodology and how CDIO framework can address them

In determining these learning outcomes, there has also been an integrating of the two modules, and a subsequent alignment of the assessment system to the new outcomes.

The CDIO framework[1] consists of 2 broad categories: the 'WHAT' which are the skillsets that students need to learn and the 'HOW' which determine the method of getting it done.

A "Gap Analysis" for the Diploma courses was conducted to determine the missing and necessary skillsets to be introduced to the students. "Introduction to Engineering", which is Standard 4 of the 'HOW' was then introduced in year 1 of the course. This module is integrated and conducted together with another module, "Innovation, Design and Enterprise in Action" (IDEA) to fulfil Standard 3. In "Introduction to Engineering" module, students are engaged in the practice and application of engineering skills and knowledge in the manufacturing of a product. The skills acquired for generating ideas for the product was taught in "IDEA". The integration between these modules is achieved through team project activities. Students were awarded credit on Personal and Interpersonal skills through oral and written presentation.

To engage students in an active learning environment, a CDIO workspace, Standard 8, was built for students to gain simple Deign-Built experiences.

MODULES DESCRIPTION AND INTEGRATION

Two modules, "Introduction to Engineering" which is engineering in nature and "IDEA" which is design based were integrated and conducted as one module.

The objectives of ''Introduction to Engineering" are to:

- introduce students to engineering
- motivate them for engineering studies
- provide real experiences of engineering work
- support the learning of CDIO skills

The module starts by introducing the students to the world of engineering, understand the engineering behind how stuff work, understand machining processes and their applications and finally experience a simple design-build project. Students also have to demonstrate their ability to work individually and in groups to encourage teamwork, personal and interpersonal communication skills.

The objectives of "IDEA" are to:

- develop an attitude and skills in basic design creativity through an understanding of the experience design process
- enable students to question preconceptions, see things from multiple perspectives, and generate new ideas.
- enable students to generate new ideas
- provide students with the ability to work with and communicate effectively with the others for good teamwork and collaboration

Although the two modules are integrative in nature, other skills such as computer-aided drafting and oral communication are also taught. The core discipline knowledge complemented these two modules. Figure 1 shows how the modules are integrated.

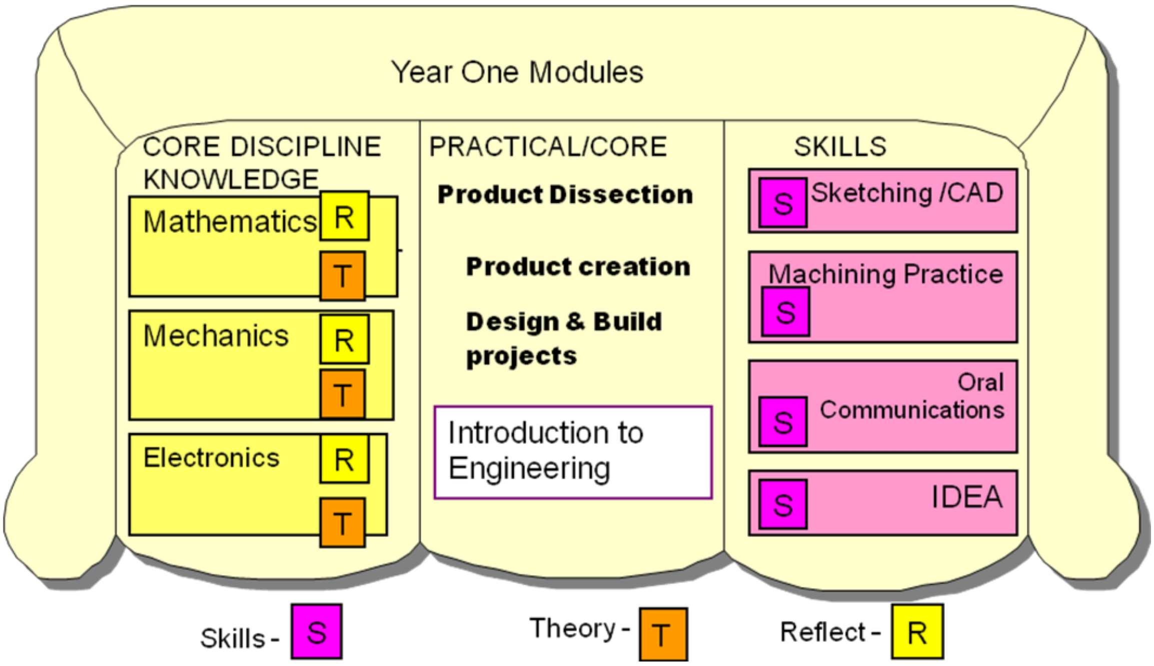

Figure 1. Integrated Curriculum

PROJECT DESCRIPTION

The design-build project is a Race Car comprises of two parts:

- Designing and modelling of the Race Car body which is conducted in "IDEA" module whereas
- Machining of the Race Car chassis is conducted under "Introduction to Engineering" module

Figure 2 shows how the two parts are assembled into a Race Car. Students complete the modules by participating in a CDIO Racing Challenge with the model racing cars that they have designed and produced.

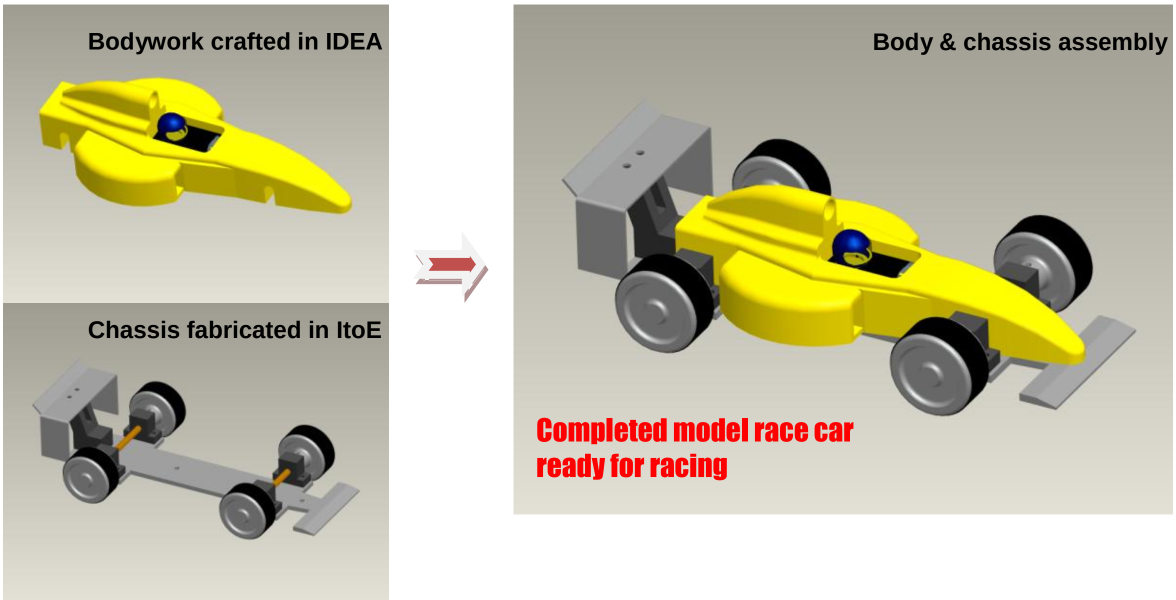

Figure 2. Design-Build Project

Figure 3 shows the detailed drawing of the chassis assembly.

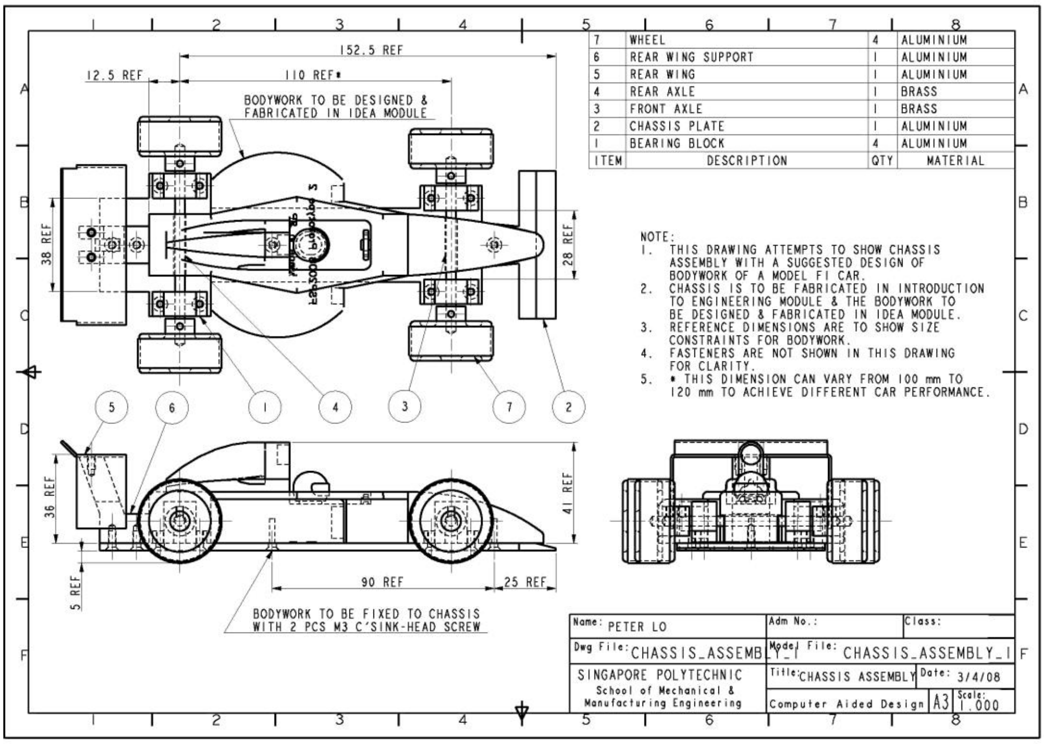

Figure 3. Chassis Assembly

Lecturers selected from each class two finalist cars (one to take part in the best performance category and the other in the most innovative design category).

Selection of the most innovative design cars was based on the following assessment criteria:

- form (innovative and functional)
- built quality, colour and decals

Selection of the best performance cars was based on time taken to race down the 6-metre long race track. In the 2nd CDIO Racing Challenge, as shown in Figure 4, the electronic timing readings ranged from 2.87 to 3.30 seconds among the 18 finalist cars.

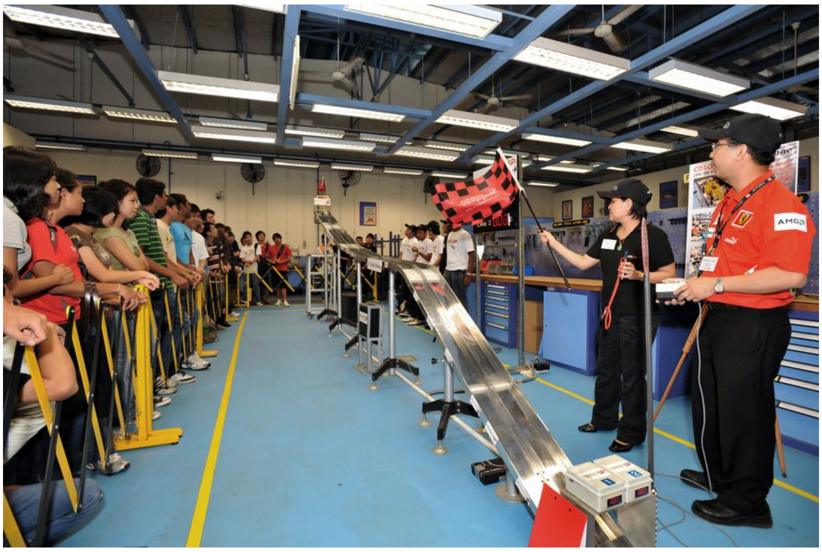

Figure 4. 2nd CDIO Racing Challenge

Figure 5 shows the winners of the most innovative design category and the best performance category.

Figure 5. Most Innovative Design and Best Performance Cars

WORKSPACE AND RESOURCES

The Instructions approaches for the two modules take place through a combination of tutorials and practical workshop. A CDIO Workspace, shown in Figure 6, was created for the students to design and produce their model race cars. Facilities such as foam cutter, saw and polishing machine were provided.

Figure 6. CDIO Workspace

A 6-metre long race track with two lanes and electronic timing system, as shown in Figure 7, was specially created for the CDIO Racing Challenge.

Figure 7. Race Track

MODE OF ASSESSMENT

The students were assessed on the process of designing and building the project. They are required to describe the various stages of team formation, select a project design from a collection of designs conceived during the "IDEA" design phase, manage the entire process of the project by appointing suitable members for the various tasks, apply machining skills to fabricate the parts and assemble the entire project and communicate group findings through a presentation.

The assessment consists of three components. The first component is on the design and modelling of the race car body which is conducted in "IDEA", the second is on the machining of the car chassis which is conducted in Introduction to Engineering and, the third is on the assembly, performance and presentation.

Students were assessed through critiques sessions on their ability to design and build their projects for the first two components. A rubric is designed for the assessment of the third component as shown in Table 2.

Grade **Criteria**	**Excellent**	**Good**	**Satisfactory**	**Needs improvement**
Final Assembly of Chassis and Car Body	Great effort was put into the assembly. The completed model is rigid and stable yet neat and attractive.	The completed model is technically sound and neat. All individual components are properly secured.	The final assembly were satisfactorily completed. But some details could have been refined to make it more presentable.	The final model appeared haphazardly assembled if not uncompleted. Many parts are still loose, not assembled properly and needed refinement.
Car Performance	Completed the race in the 95^{th} percentile.	Completed the race in the 90^{th} percentile.	Completed the race.	Unable to complete the race.
Presentation to Class	Clear, effective and well-organised, good visual aids. Displays excellent teamwork and good communication.	Good presentation with appropriate visual aids. Evidence of positive teamwork.	Satisfactory presentation with limited visual aids. Satisfactory cooperative work.	Presentation lacks effectiveness. Limited cooperation and communication.

Table 2. Rubric for the Final Assessment

MODULE EVALUATION

At the end of the semester, an evaluation was conducted to gather feedback on students experience, achievement and development of selected CDIO skills. A set of questions for interview was conducted for a selected group of about 103 students.

The evaluation is targeted at the students' ability to understand the skills and whether the skills help them in the tasks they were given. The following skills areas were evaluated:

- Thinking
- Managing your learning
- Communication
- Teamwork

A Rating scale of 1 to 5 is used where 1 being strongly disagreed to 5 being strongly agreed.

The % of Ratings of 3 or more were collected and the results of the evaluation are shown in Table 3.

Singapore Polytechnic **CDIO Evaluation Survey Results**	
Questions	% of Rating >=3
Q1a : I am aware that the following skills are being practised in my Introduction to Engineering lessons. (thinking)	98
Q1b : I am aware that the following skills are being practised in my Introduction to Engineering lessons. (teamwork)	96
Q1c : I am aware that the following skills are being practised in my Introduction to Engineering lessons. (communication)	95
Q2a : I understand the usefulness of these skills in my learning and development as a technologist. (thinking)	98
Q2b : I understand the usefulness of these skills in my learning and development as a technologist. (teamwork)	98
Q2c : I understand the usefulness of these skills in my learning and development as a technologist. (communication)	95
Q3 : The activities in my Introduction to Engineering module make my learning more interesting and motivate me to learn more about my course.	95
Q4 : I am participating more actively during my Introduction to Engineering lessons	95
Q5 : As a result of the activities in the Introduction to Engineering lessons, I am able to think more creatively and generate ideas.	93
Q6 : As a result of the activities in the Introduction to Engineering lessons, I am able to use a range of critical thinking skills more effectively in problem-solving (e.g. analyse, compare & contrast, evaluate).	94
Q7 : As a result of the activities in the Introduction to Engineering lessons, I am able to manage my learning effectively (e.g. keep to deadlines, organise notes and prioritise learning activities).	97
Q8 : In doing the project/s in the Introduction to Engineering module, I understand the importance of having initiative and the willingness to take thoughtful risks.	97
Q9 : The activities in the Introduction to Engineering module gave me a greater understanding of the importance of team roles and their impact on team performance.	95
Q10 : As a result of the activities in the Introduction to Engineering module, I am able to design and deliver more effective oral presentations	92
Q11 : I am able to see the linkages between the IDEA module and the Introduction to Engineering module.	93

Table 3. Results of Evaluation

CONCLUSIONS

The paper presented the integration between an engineering module, “Introduction to Engineering” and a design module “IDEA” and how the knowledge gained from one module is used culminating to the design and building of a Race Car,

Overall responses from the students were positive and majority felt that they have benefited from the integration of the two modules and the ability to understand and apply the CDIO skills effectively.

REFERENCES

[1] Rethinking Engineering Education, The CDIO Approach, Chapter 2 and 3.
Edward Crawley, Johan Malmqvist, Soren Ostlund and Doris Broseur. Springer

Biographical Information

Dr Linda Lee is the Deputy Director for the Product Engineering & Management Division. She is also the Course Chairman for the Diploma in Mechanical Engineering. She currently oversee the implementation of CDIO for the School of Mechanical & Manufacturing Engineering, Singapore Polytechnic. As Course chairman, she is responsible for the management of the course.

Dr Linda Lee
School of Mechanical & Manufacturing Engineering
Singapore Polytechnic
500 Dover Road
Singapore 139651
+65 67721457
LLeeMK@sp.edu.sg

Corresponding authors

Mr Peter Lo is a senior lecturer and section head of the Design Section. His teaching focuses on engineering design, computer-aided design, and new areas related to CIE (creativity-innovation-enterprise) and CDIO (conceive-design-implement-operate). He is the organising chairman of the Toy Design Competition for secondary school students since it was founded in 2006. Mr Lo is also the project developer of the CDIO design-build project and the organiser of the CDIO Racing Challenge events.

Mr Peter Lo
School of Mechanical & Manufacturing Engineering
Singapore Polytechnic
500 Dover Road
Singapore 139651
+65 67721552
PeterLo@sp.edu.sg

Mrs Lim Siew Kuan
Mrs Lim Siew Kuan is a senior lecturer and section head of the Drawing Section. His teaching focuses on engineering materials, computer-aided drafting, and new areas related to CIE (creativity-innovation-enterprise) and CDIO (conceive-design-implement-operate).

Mrs Lim Siew Kuan
School of Mechanical & Manufacturing Engineering
Singapore Polytechnic
500 Dover Road
Singapore 139651
+65 67721572
skuan@sp.edu.sg