Integrating CDIO skills and technical knowledge from different modules in a project

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ABSTRACT

As part of the Singapore Polytechnic's plan to adopt the CDIO framework, the second year curriculum of the Diploma in Electrical and Electronic Engineering (DEEE) programme has been redesigned to include a design-build project. This paper outlines the issues and challenges that arise during the implementation of this project. Three objectives for this project have been identified: to facilitate the conceive-design process but, at the same time, produce viable project ideas, integration of knowledge from different technical modules, and optimal use of curriculum time and resources.

To ensure viability of the project, a microcontroller kit set used in the laboratory of one of the technical modules is used as the main backbone for the project. Students are given the liberty to conceive and design solutions based on the kit. In this way, students' anxiety in fabricating the entire electronic system may be alleviated. Based on the students' ideas, they will only need to design and fabricate the hardware interface to the kit.

The scheduling of some topics in the technical modules is also modified to provide 'just-in-time' knowledge for the students as they embark on their project. Finally, in the later half of the semester, some curriculum time from two of the technical modules are 'donated' to the project so that students have sufficient time to complete their project.

A survey of the first group of students who have gone through the redesigned curriculum shows that more than 70% of them have understood the CDIO cycle, are confident of designing a product based on customers' needs and are able to see the connection between different technical modules.

KEYWORDS

Integrated curriculum, design-and-build projects, multi-disciplinary, just-in-time.

INTRODUCTION

The Singapore Polytechnic began experimenting with the CDIO methodology in its curriculum way back in 2003[1]. A small scale project-based learning project based heavily on the CDIO concept was piloted amongst a class of 20 second-year students in the Diploma in Electrical and Electronic Engineering (DEEE) course. The changing environment, as Singapore's economy matured, provided the main impetus to explore novel teaching and learning methods. Our workers, other than being skilled and knowledgeable, now need to be creative, innovative, and possess leadership and communication skills. Early efforts to address this issue focus on providing separate modules on teaching creativity and innovation, and communication skills. This created a silo effect where students did not see relevance in these modules in their course of studies.

In 2004, Singapore Polytechnic joined the CDIO collaboration and subsequently, began to embark on a full-scale implementation of the CDIO framework[2] in various engineering courses. Under this framework, the integration of knowledge amongst different modules was emphasized. In 2008, the first year curriculum of the DEEE course was overhauled such that a new module called 'Introduction to Engineering' was introduced, replacing the old 'Project 1' module. The original 'Project 1' module focused mainly on training students in hands-on skills such as soldering and printed-circuit board fabrication. Many students felt that it was a boring module as they could not see the relevance of what they were doing.

The new 'Introduction to Engineering' module forms the capstone for the first year curriculum where students use the knowledge that they acquired from other modules in the course for their projects. Besides providing training on the hands-on skills, the module also covers the conception and designing of the project, integration of domain knowledge from other technical modules, and training of students on their teamwork and communication skills. Evaluation of the implementation has just been completed[3].

In 2009, the revamp of curriculum extended to the second year. This paper describes how the second year curriculum has been modified to incorporate a capstone project module where once again CDIO skills and technical knowledge are integrated. The main challenge in the implementation is in the optimal use of curriculum time, laboratory and manpower resources. At the same time, we want to ensure the viability of the project so that students may be encouraged by its successful completion.

Through this redesign of the curriculum, we hope to provide our students a real world and experiential learning experience that builds on foundational knowledge and nurtures core generic competencies of creative and critical thinking, problem solving, communication and teamwork.

IMPLEMENTATION

In the Diploma in Electrical and Electronic Engineering (DEEE) course, a second-year student will do four core technical modules and one project module in a typical semester. Depending on the option that the student has chosen, the four core technical modules may be different. But some of the modules are common across different options. As an example, Table 1 shows the modules taken by the students for the Electrical / Electronics option and the Nanotechnology option.

Table 1
Modules taken by second year DEEE students for two of the options

Electrical / Electronics option	Nanotechnology option
Electromagnetic devices Sensors & Instrumentation Object Oriented Programming Microcontroller Technology Design & Innovation Project	Analog Systems Microcontroller Technology MEMS & Microsystems Device Fabrication Processes & Materials Design & Innovation Project

Prior to the CDIO implementation, the project module, formerly known as the Project 2 module, was in a form of a guided project where the specifications and requirements were given to students. Though the students were tasked to design the electronic circuits to meet the specifications, the requirements had been chosen such that there were little variations in the end results. In fact, the students would invariably be fabricating a standard printed-circuit board for their projects. In short, while a problem was seemed to be given, the exact solution was already known beforehand.

Early efforts on implementing the CDIO framework focused on the inclusion of conceive and design processes into the project module[4]. Open-ended problems were given to students instead of guided ones. However, various deployment issues surfaced during the implementation. With little constraint on the type of the solutions, many of the students' original ideas could not be realised. As there was no integration between the technical modules and the project module, knowledge crucial to the completion of the project was not taught in a timely fashion. Staff members taking charge of the project module had to conduct mini-lectures and tutorial sessions in order to help the students bridge the knowledge gaps. Furthermore, they might not have the expertise in the technical areas which the students needed help with.

To address the various problems encountered, a redesign of the second year curriculum was undertaken to tackle them holistically. The objectives of this redesign effort have been identified:

1. to facilitate the conceive-design process and, concurrently, produce viable project ideas,
2. to integrate knowledge from different technical modules with the project module and
3. to optimise use of curriculum time and resources.

In the initial phase of the curriculum design, two of the core technical modules were identified to be integrated with the Design & Innovation Project module. In the Electrical / Electronic option, Microcontroller Technology and Sensors & Instrumentation have been selected while in the Nanotechnology option, Microcontroller Technology and Analog Systems are in.

The following sections outline how each of the objectives of the curriculum redesign project has been addressed.

Conceive-design process

The conceive-design process was first introduced into the Design & Innovation Project module back in 2005[4]. The students were taught some creative thinking and design tools and they used them to conceive solutions to the problems that were given. So, little changes are needed in this aspect. However, the main problem in the project module then was the feasibility of the solutions.

In the new Design & Innovation Project module, a set of resource constraints are added to the open-ended problems for the students. In the laboratory, the students are provided with a set of electronic devices and components. They are to design a solution to the problem making use of the available hardware. The list of hardware provided for the students include:

- A microcontroller kit with various hardware interfaces such as LED, LCD, keypad, switches and so on.
- Sensors such as light-dependent resistors tilt switches, passive infra-red sensors, active infra-red sensors and so on.
- Actuators such as DC motors, solenoids, solid state relays and so on.

Theory and applications of most of the hardware provided are being taught in the core technical modules. For example, the microcontroller kit is used in the laboratory of the Microcontroller Technology module while the sensors mentioned are used in the laboratory of the Sensors & Instrumentation module. So, they would have already been familiar with all of these devices and hardware prior to the start of their projects.

For those devices which are not taught explicitly in any technical modules, a detailed description of the device – how it works, its typical applications and sample circuits – is provided for the students. Students can also use devices or hardware not provided if they are able to get hold of it and learn how to use it by themselves.

Notice that the list of hardware provided is actually the ‘brain’ of an electronic system and the input and output interfaces to this ‘brain’. So, students are at liberty to decide how the ‘brain’ works and what kind of inputs and outputs are needed. As the ‘skeleton’ of the system is already in place, students’ anxiety in fabricating the entire electronic system may be alleviated. They can then focus of conceiving more creative solutions to make use of this ‘skeleton’.

Integration of knowledge

One problem that we face in a modular curriculum system is that students tend to compartmentalise knowledge. In other words, they are not able to apply knowledge learnt one module in another. For example, a student may have learnt about amplifiers in the Analog Systems module. But when he tries to use the microcontroller to detect some weak signals from a sensor in the Microcontroller Technology module, he may not realise that he can use the amplifier circuits that he has learnt in Analog Systems module to amplify the signal. Sometimes, they may not even see the relevance of the knowledge that they have learnt.

The new Design & Innovation Project module attempts to change that by putting materials they have learnt in different modules together. As mentioned in the previous section, the hardware provided for their projects are devices or kits that they have used in different technical modules. Previously, during the hands-on laboratory sessions, students may conduct experiments to study the characteristics of the sensors or write a short program for the microcontroller to turn on an LED, for example. Though students may understand the function of the sensors or microcontroller after the experiment, they may not see the relevance or application of this knowledge. Now, they are required to integrate them together so that the final product can do the things that they want it to do. In the process, they will realise that all the things that they have learnt in different modules can now be put together.

Ideally, students should have gathered all the necessary technical knowledge before they embark on a project. But for a practical teaching curriculum, this is usually not possible to achieve. At best, we can only provide a form of just-in-time delivery of knowledge to the students. For the students to be able to do a project based on the knowledge or skills from the two core technical modules, it is important that those topics that are most useful for the project be taught first. Given time, students will absorb the knowledge, learn the skills and gain confidence to apply them in projects. So, this calls for a rescheduling of the teaching plans. The idea of teaching the topics in a 'logical sequence' in these modules may have to be abandoned. For example, in the Microcontroller Technology module, topics such as input / output ports, interfacing to external devices and firmware programming are taught earlier in term 1. Topics such as interrupt and memory organisations, which are not used in the project, are taught later. Similarly, for the Analog Systems module, topics such as power amplification are covered first so that students can make use of them as soon as possible.

Optimal use of resources

Originally, the Design & Innovation Project module was a 30-hour module where students were given two hours per week (15 weeks semester) of laboratory time for project. When the conceive-design process was first introduced, it was noted that for the first half of the semester, students were spending a lot of time discussing about the problem or doing research in the library or outside of the laboratory. So, the laboratory was not used most of the time. Then in the second half of the semester, when it was time for the implementing process, the students would spend many hours, way beyond their allocated time, in the laboratory working on their projects. And when they worked beyond their scheduled time, the teaching staff or technical support staff members might not be around to help or advise.

To address this issue, the teaching schedule for the project module has been modified such that only one hour per week is timetabled for the first seven weeks of the semester. Then, three hours per week is timetabled for the last seven weeks of the semester. While the total curriculum time remains unchanged, the laboratory resource is utilized more optimally. Table 2 shows the new teaching schedule for the project module.

Table 2
Teaching Schedule for the new Design & Innovation Project module

Term	**Teaching Week**	**Hours / Week**	**CDIO Stage**	**Remarks**
1	1	**1**	C	Briefing, team formation
1	2	**1**	C	
1	3	**1**	C	
1	4	**1**	C / D	Presenting the **C**onceived idea
1	5	**1**	D	
1	6	**1**	D	
1	7	**1**	D	Submitting a report on the initial **D**esign
	Vacation			
2	8	**2**	I	Project **I**mplementation starts
2	9	**3**	I	
2	10	**3**	I	
2	11	**3**	I	
2	12	**3**	I	
2	13	**3**	I	
2	14	**3**	I / O	Show & tell – **O**perating the project
2	15	**3**	O	

In view of the fact that the new Design & Innovation Project module has incorporated many of the application aspects of the various devices that the students learnt in the core technical modules, some of the laboratory experiments (or mini-projects) that the technical modules used to have are no longer needed. As such, instead of developing new experiments to replace those redundant ones, it is decided that they will 'donate' some of their laboratory time to the project module. Hence, four hours of laboratory time in the second term from each of the two core technical modules (Microcontroller Technology and Analog Systems / Sensors & Instrumentation) are given to the Design & Innovation Project module. Effectively, the project module becomes a 38-hour module.

Table 3
Teaching Schedule for the laboratory sessions of the second year modules

Term	Teaching Week	D&I Project	Micro-controller Technology	Analog Systems or Sensors & Instrument	Remarks
		hrs/wk	hrs/wk	hrs/wk	
1	1	**1**	**2**	**2**	
1	2	**1**	**2**	**2**	
1	3	**1**	**2**	**2**	
1	4	**1**	**2**	**2**	
1	5	**1**	**2**	**2**	
1	6	**1**	**2**	**2**	
1	7	**1**	**2**	**2**	
	Vacation				
2	8	**2**	**2**	**2**	
2	9	**3+2**		**2**	2 hrs lab of Microcontroller Technology 'donated' to the D&I Project
2	10	**3+2**		**2**	
2	11	**3+2**	**2**		2 hrs lab of Analog Systems or Sensors & Instrumentation 'donated' to the D&I Project
2	12	**3+2**	**2**		
2	13	**3**	**2**	**2**	
2	14	**3**	**2**	**2**	
2	15	**3**	**2**	**2**	

During those Microcontroller Technology (or Analog Systems or Sensors & Instrumentation) laboratory sessions, students will continue to work on their projects in respective laboratories as the project laboratory may not be available for them. In this way, students have actually more time to work on their projects and at the same time, see the relevance of the theory that they have learnt in the technical modules.

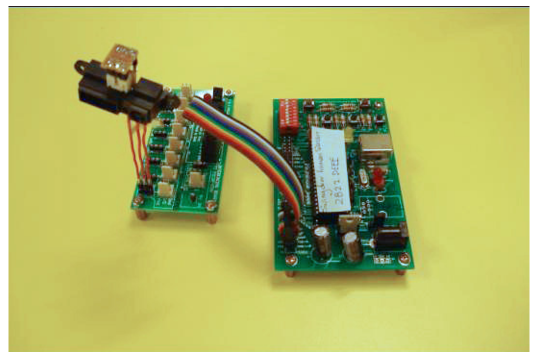
In terms of manpower resource, the uneven scheduling of the Design & Innovation Project module allows teaching staff members to have more time to help the students in the second half of the semester without increasing their workload. The rescheduling of the teaching topics mentioned in the earlier section also address the problem of teaching staff members having to conduct mini-lectures during project lessons. The time can now be better utilised to do the project instead.

Finally, the use of laboratory sessions of technical modules for projects allows students to seek assistance from teaching staff members of the technical modules. Since they are the subject experts, they will be able to better guide the students in their application problems.

RESULTS

In the first run of the revamped Design & Innovation Project module, the students have been told to conceive a project such that "*... the project proposed should be interesting and original, useful (in solving a real problem), feasible (i.e. can be done by students within the given time and cost constraints) and cost effective ...*" Some examples of the student project are shown in Figure 1.

Don't Stay Too Long At Your Desk!
With a pressure sensor placed on a chair, the system turns on a buzzer automatically when a person sits on the chair for too long.



Beware Swinging Door
With a sensor placed behind a swinging door, the system can show whether the door is clear or obstructed so as to prevent anyone from getting hit when the door is pushed open suddenly.

Figure 1 Some examples of the students' projects.

At the end of the semester, a quick tally of the student projects yields some interesting results: 40% of the projects are successful and are based on the original ideas conceived by the students; 49% of the projects are successful but some modifications or changes are made to the original ideas conceived by the students along the way; and 11% of the projects are not successful.

An overwhelming 89% of the projects have been completed successfully at the end of the semester. And they are the products of ideas conceived by the students themselves. Unfortunately, as this is the first run of the program for the entire cohort of 180, there is no meaningful prior result for comparison. Earlier efforts are based only on a class of 20 and it will not be appropriate to compare the success rate as such.

A survey was conducted for the first group of students who have gone through the redesigned curriculum. A summary of the results of the survey are shown in Table 4.

Table 4
Results of the survey conducted for the first group of students

SD = Strongly Disagree, D = Disagree, N = Neutral, A = Agree, SA = Strongly Agree Results in %					
	SD	D	N	A	SA
I am able to apply the conceive, design, implement and operate cycle in my D&I Project	3	2	21	57	17
As a result of the D&I Project, I am able to think more creatively and generate ideas for new products	3	3	27	51	17
I am able to connect and see the relevance of the concepts taught in other technical modules I take	2	1	17	54	25
As a result of the D&I Project, I develop a good understanding of engineering in the real world	3	3	24	55	15
The activities in the D&I Project make my learning more interesting and motivate me to learn more about electrical and electronic engineering	5	7	21	42	25

From the survey, 74% of the students agree or strongly agree with the statement that they are able to apply the CDIO cycle in their projects. This is an indicator of how well they have learnt the conceive-design process. 79% of the students agree or strongly agree with the statement that they are able to connect and see relevance between different modules. The integrated approach has helped the students to appreciate the linkages of the various modules. Finally, 67% of the students find that the D&I Project module make their learning of engineering more interesting.

For qualitative feedback of the new curriculum structure, students' portfolio entries were examined and focus group discussions for students were conducted. On the whole, the responses from the students have been positive. While most students could see the links between the project module and the Microcontroller Technology module, the linkage to the other technical modules appears to be much weaker.

CONCLUSION

When we first embarked on the redesign of the curriculum, we set three objectives for the project:

1. to facilitate the conceive-design process and, concurrently, produce viable project ideas,
2. to integrate knowledge from different technical modules with the project module and
3. to optimise use of curriculum time and resources.

The survey results and the success rate of the projects have shown that we have managed to facilitate the conceive-design process with the students producing viable project ideas. On the integration of knowledge, the survey has shown that majority of the students have come to see the relevance of the different modules in this project.

There has not been any increase in curriculum time or resource usage after the curriculum redesign. No additional manpower or laboratory usage time is required. So, we have managed to produce better results with the same amount of resources.

In conclusion, we have managed to redesign the second year curriculum of the DEEE course such that the project module facilitates the conceive-design process and helps integrate knowledge from different modules together without needing any extra resources. Survey results and focus group discussions with the students have indicated their preference to this curriculum structure.

Looking ahead, there are many more challenges to face as we consider expanding this Design & Innovation project structure to two semesters in the DEEE course and to other diploma courses. To identify the relevant core technical modules to partner with the project module requires careful planning. Rearranging the teaching schedules, choosing appropriate hardware or devices for the students and scheduling of laboratory usage all pose enormous challenges as we continue to forge ahead.

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Biographical Information

Chong Siew Ping has been a lecturer with Singapore Polytechnic since 1991. He graduated from National University of Singapore (NUS) with a honors degree in Electrical Engineering and later pursued his part-time Master of Science degree (in Electrical Engineering) in the same university. His professional interests are embedded system design, logic circuit design & FPGA (Field Programmable Gate Array)-based design. He was part of a team which developed & pilot-ran the module Design & Innovation Project, which allows second year students from the School of EEE (Singapore Poly) to go through the C-D-I-O process.

Chua Kay Chiang joined the Singapore Polytechnic in 1991 and is currently a Senior Lecturer in the School of Electrical and Electronic Engineering. His main expertise is in microcontroller systems design and he is instrumental in developing the teaching kit used in the Microcontroller Technology and Design & Innovation Project modules.

Christopher Teoh is a Senior Lecturer in the School of Electrical and Electronics Engineering. He is the course manager for the Diploma in Electrical & Electronics Engineering in the school. His current research interest is in the innovative use of different teaching methods, technology and assessments to encourage active learning.

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