Introducing design-build experiences at Singapore Polytechnic

Suat Hoon Pee & Helene Leong-Wee

Singapore Polytechnic
Singapore

ABSTRACT: Singapore Polytechnic was established in 1954 in Singapore to train middle-level professionals to support the technological and economic development of Singapore. It provides training in a wide range of practical, work-oriented fields of study. While it is well recognised that Singapore Polytechnic has been very effective in teaching students in the traditional classroom learning environment, as evidenced by the successful graduates it has produced over the last 50 years, changes are taking place in the economic and social landscape that necessitate a change in educational provision and practices in order to maintain the viability and quality of the education that Singapore Polytechnic provides. Since 2004, the Polytechnic has embarked on a number of new initiatives and approaches to ensure that its graduates are adequately prepared to meet the needs of the industry, and to live and work in a changing world. While developing this new educational model, the Polytechnic joined the CDIO Initiative as a collaborator when it was realised that there were many similarities between what Singapore Polytechnic and CDIO were trying to achieve. The authors discuss the initiatives that the Polytechnic has adopted in reformulating its engineering education in relation to the CDIO Standards and principles.

INTRODUCTION

In response to major developments in globalisation and the accelerating pace of technological changes, Singapore Polytechnic in Singapore has recognised that it has to make significant changes in how its students are educated in order to maintain the viability and quality of the education it provides. The Polytechnic is aware that the lifestyles and needs of students joining Singapore Polytechnic, and the industries they will join upon leaving Singapore Polytechnic, will be very different from those of today.

At present, however, there is an overemphasis in the education model on developing Singapore Polytechnic's students in the cognitive domain at the expense of other important areas, such as developing leadership and communication skills, a spirit of risk-taking, creativity, innovation and enterprise, and a global outlook.

In order to ensure that Polytechnic graduates are prepared for the 21st Century workplace, the institution has embarked on a process to redesign its curriculum to provide students with educational experiences that will enable them to develop essential habits of mind of open and reflective thinkers, effective life-long learners, and good communicators in both the local and global context.

Besides building the core foundational knowledge and skills necessary for understanding and applying key subject knowledge, four generic competences have been identified that all graduates, irrespective of their course of study, must attain. These competences are as follows:

- Thinking and problem-solving;
- Managing learning;
- Communication and teamwork;
- Professional ethics and values.

These core competences will be explicitly integrated into the teaching of content curricula where appropriate [1]. Specific, detailed learning outcomes for these knowledge areas and core competences will be written. This corresponds to Standard 2 of the *Conceive – Design – Implement – Operate* (CDIO) Initiative [2].

In some courses, integrated learning experiences that provide students with a more holistic approach to the learning of domain knowledge and generic competences are also being explored. The traditional approach of separate lectures, tutorials and practicals is being challenged, and new integrated approaches being tried. Also being explored is a more experiential and active learning approach to teaching and learning. Lecturers are integrating real world experiences in their teaching through site visits and assignments with a *real world* emphasis.

Emphasis has also been placed recently on promoting creativity, innovation and enterprise, and in nurturing an innovative attitude. Design has been identified as the vehicle that can be utilised to promote innovation. In the future, a greater focus will be placed on enabling Polytechnic students to go through the process of innovation systematically from conception to implementation and the use of user-centric research as a means to generate new innovations.

Together, these curricula changes will allow the Polytechnic to nurture graduates with the different skills that they need for the future. Indeed, the future brings tremendous opportunities, especially in Asia, but it will also bring many changes that cannot be foreseen today. The aim is to give students the chance to develop the skills, character and values that will enable them to meet the challenges and do well in their future.

The curriculum redesign process is still in its initial phase. Much more detailed planning and experimenting will need to be undertaken in order to achieve the standards spelt out by the CDIO Initiative in a coordinated and systemic manner. In this article, the authors report on the initial attempts to redesign the curriculum using CDIO as the context (Standard 1). In particular, the authors report on the project work component of the curriculum to which design-build experiences (Standard 5) have been integrated into subjects across the three years of study. This new curriculum provides real world and experiential learning experiences that build foundation knowledge and nurture the core generic competences (Standard 7) [3].

PROJECT IMPLEMENTATION IN THE SCHOOL OF ELECTRICAL AND ELECTRONIC ENGINEERING

As can be seen by the success of Apple, Google, Skype and others, competition is no longer in global scale-intensive industries; rather, it is in non-traditional, imagination-intensive industries. More and more, the 21st Century is being characterised by the production of elegant, refined products and services that delight users with the grace of their utility and output. With this in mind, engineering students should be trained to think and become more like designers, rather than traditional engineers who churn out algorithms, in order to thrive in this new economy.

Many educators have correctly identified creativity as an important skill for students to acquire. However, creativity alone is not enough. We have to also nurture the ability to create and provide students with ample opportunities to make something novel and new. Thus, the design and implement phases provide the process of making or undertaking something new; that is where design is more aligned with innovation – it is not just an attribute, it is fundamentally about *action*.

The design-build experience forms one of the key themes of CDIO. In the CDIO curriculum, there are two or more design-build experiences; including one at a basic level and another at an advanced level. Incorporating design-build projects is one of the initial efforts to implement CDIO in the School of Electrical and Electronic Engineering at Singapore Polytechnic. In particular, the Electrical and Electronic Engineering Diploma course has been redesigned so as to allow students to work on a design-build project in every year of their course of study.

In this course, students are exposed to the design-build experiences through three projects introduced progressively in years 1, 2 and 3, as shown in Figure 1. These projects are IDEA, the design and innovation project, and the multidisciplinary design project. While the general objective of these projects remains similar, the specific aims of these design-build projects vary as each provides different experiences and exposure as students mature in their course of study. This is elaborated on below.

Year 1 (IDEA Module)

The IDEA (Innovation, Design and Enterprise in Action) module is the first design-build project being introduced to all students. This is a 15-week module that all students at the Singapore Polytechnic have to undergo. It emphasises key aspects of the innovation process, which includes design and enterprise. A large part of this module exposes students to understanding users' needs, business plans and prototype making. This forms the underlying basis of this design-build project, which focuses on the conceive and design stages.

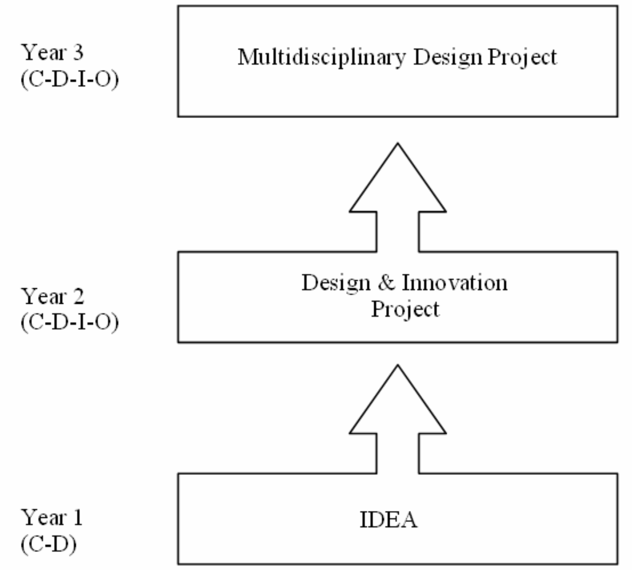

Figure 1: Project path in the School of Electrical and Electronic Engineering for the Diploma in Electrical and Electronic Engineering.

Students are expected to conceive and design a potential product. As their engineering knowledge is limited, they are not expected to build a comprehensive product. A concept represented in the form of a model or prototype is all that is needed. Inculcating the right attitudes and soft skills are key learning objectives in this stage.

Besides working in the classrooms, students are also exposed to the outside world based on the potential projects that they have to work on. Figure 2 shows a briefing session conducted at National Parks where students are required to design landscape tools for use in the parks of Singapore. This makes the project authentic and early exposure to personnel outside Singapore Polytechnic is good for students to realise that studies go beyond the classrooms.

Figure 2: Attending a presentation at National Parks.

In addition to attending the briefing session, students are also given the opportunities to try out the tools and equipment so that they can gain a better exposure to the discipline. This will help them in understanding the difficulties involved and to derive potential solutions.

Year 2 (Design and Innovation Project)

After going through one year of study, students are better equipped technically to carry out design-build projects in year 2. In this Design and Innovation Project module, students work together in groups in order to build a design-build project that integrates engineering knowledge gleaned from their other engineering modules.

Projects are grouped into three categories according to the subject of study chosen. The three projects are in the following domains:

- Aerospace engineering;
- Biomedical engineering;
- Electrical/electronic engineering.

The key aim of these projects is to provide opportunities for students to apply their engineering skills in an interesting and fun project. In addition to creativity, these projects should provide avenues for experimentation. With a higher level of motivation, it is hoped that students will be spurred to spend more time and effort in their studies.

Aerospace Project

In this aerospace project, students are given two key tasks; flying a helicopter toy model and to build a flying object using an assortment of parts. Both of these exercises aim at providing students with the exposure of handling a flying object so that they can better understand the aerospace modules when they study them in the course.

Microcontroller Project

Using a microcontroller, sensors and actuators, students build robotic objects that can manoeuvre in different configurations. Besides programming, students also carry out an integration of the hardware components as shown in Figure 3.

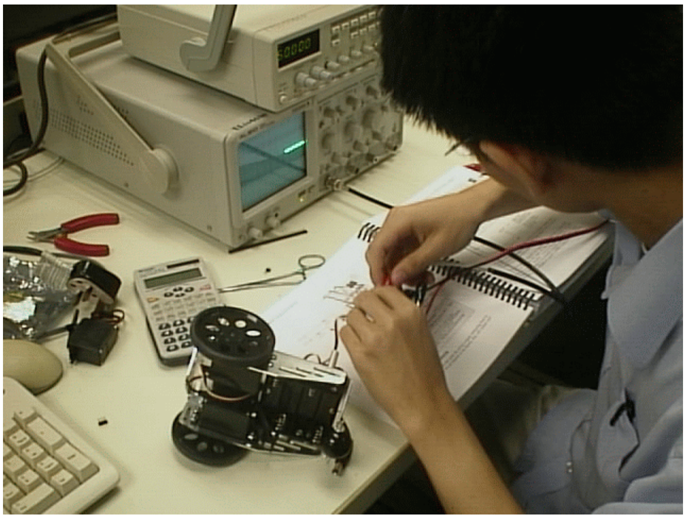

Figure 3: A student engaged in a microcontroller project for the Design and Innovation Project module.

Biomedical Project

In the biomedical project, students are given the challenge of formulating a problem that they desire to work on. The application can be a game or a more serious engineering project, as long as biomedical signals and the *Labview* program are being utilised by students in order to generate an output actuation.

All of the above projects are open-ended to varying degrees and students have the freedom to decide what they build. This is an important attribute of these projects if students are to develop qualities such as creativity, independence, taking the initiative and resourcefulness.

Year 3 (Multidisciplinary Design Project)

For the year 2 projects, students work within the domain of electrical and electronic engineering. However, the final year project exposes students to other disciplines, and provides an avenue for more scope and interaction with students from other disciplines. Students from the Department of Mechanical Engineering, Department of Electrical and Electronic Engineering and Department of Chemical and Life Sciences work together on this project. Thus, the range of project choices is very widespread. There are also many projects that are linked to industries.

This category of projects is being introduced in the 2006-2007 academic year, with approximately 20 students each from the Department of Mechanical Engineering and Department of Chemical and Life Sciences. There are also about 15 students from the Faculty Electrical and Electronic Engineering who began their projects in late April 2006.

This is an equally challenging exercise for students and staff, as there are many logistic and administrative issues that have to be resolved. Fortunately, there is a team of committed staff from the three departments working together and, hopefully, the results will justify the efforts poured into these projects.

KEY CONSIDERATIONS

While planning these projects, several considerations have to be taken and these are detailed below.

Collaboration with Industry

Collaboration with industry is an important consideration if the project is to be authentic. Staff has to take the extra effort to make connections with industry partners for the projects. Choosing the right partner is also an important issue. Industry partners have to provide project ideas that are of the correct level and are interesting enough for students to undertake. Also, their expectations have to be realistic as they need to understand that the projects are built by students in their teens.

Multidisciplinary Staff Team

Before starting on a multidisciplinary students' project team, a multidisciplinary staff team first has to be gathered. Forming a good team is essential as it predetermines whether or not the multidisciplinary project is going to succeed.

Readiness of Students

Students are very young when they start their diploma course and many are not ready for projects as they are not equipped with the appropriate skills and knowledge. Thus, these designed projects have to be progressive in their demands such that students do not become overly discouraged if they are unable to meet expectations.

Support from Technical Staff

Besides the academic staff, these projects need strong support from the technical support staff. These technical staff can render guidance and support to students, especially in making the hardware. Also, students have someone to turn to when they need to work outside the timetabled hours, since many technical staff are based in the laboratories and workshops during office hours.

Staff Training and Approach

The approach to education is no longer about preparing lectures and conducting prearranged laboratory sessions. Educational systems, with their desks in neat rows and systems of bells, were designed to prepare students for the demands of the industrial age. Without abandoning education in fundamental training, educators also need to pay more attention to promoting creative thinking and engaging students in challenging their ideas. Academic staff have to take the initiative and work towards training students differently.

Useful Tools and Frameworks

Any useful tools and frameworks that support these projects have to be developed and supported.

Design Attitude

Many institutions have projects in their curriculum for students to create artefacts. However, is that enough to train students sufficiently? If not, what is the missing ingredient for an enriching design-build experience? Derived from the CDIO Problem-Based Learning (PBL) projects implemented earlier, the author concludes that the attitudes of students and staff towards the projects are key determinants [4].

Design attitude is a key differentiating factor between a successful and not-so-successful project. With a design attitude, students approach each new design-build project with the desire to carry out something differently and better than he/she has undertaken before. This attitude gives students the impetus to experiment with unknown materials, technologies and methods. This is an important trait as the results of these students will be very different and interesting compared to other students who merely take the sure and easy route of deriving the solution.

Design attitude refers to the expectations and orientations one brings to a design-build project. A design attitude views each project as an opportunity for invention that includes a questioning of basic assumptions and a resolve to genuinely improve the initial conditions before these new solutions are applied. It is hoped that students can be eventually trained to relish the lack of predetermined outcomes that makes learning more exciting. Thus, the design-build projects should always provide opportunities where students are able to influence the final outcomes. Each project opens up an opportunity to ask oneself anew what is the real problem being faced and what is the best solution?

CONCLUSION

In the Diploma in Electrical and Electronic Engineering, students are exposed to the design-build experiences through three projects introduced progressively in years 1, 2 and 3. The specific aims of these design-build projects vary as each provides different experiences and exposures as students mature in their course of study.

In the first year, the focus is on students conceiving and designing a potential product. Inculcating the right attitudes and soft skills are key learning objectives in this stage. In year 2, students work in groups to build a design-build project that integrates engineering knowledge compiled from their other engineering modules. Building core engineering knowledge and skills are its main objective. The final year project exposes students to other disciplines and provides an avenue for more scope and interaction with students from other disciplines.

There are many factors that must be considered and carefully planned if projects are to become triggers to promote students' interest in their studies. For example, a structured framework with appropriate tools should be provided so as to enable students to optimise the key learning opportunities provided by projects. To activate students' interest and engagement, the projects that students work on should have *real world* relevance. It would be necessary to set aside time to build collaborative ties with industry and for students to be engaged in the relevance of the projects early on in the course. Lecturers need to adopt an approach to teaching that encourages creative thinking and innovation.

CDIO is now an institutional initiative at the Singapore Polytechnic, albeit in its initial stages. More lecturers from different subject areas will, in the coming months, explore how CDIO can be implemented in their different curricula. The curriculum redesign process reported above will serve as an example as to how some of the CDIO Standards can be implemented in an engineering curriculum, as well as the structures and support that need to be provided. However, much more detailed planning and experimenting will need to be undertaken in order to attain a systemic and sustained adoption of CDIO principles across the campus.

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