2nd International CDIO Conference
Linkoping, Sweden
13 to 14 June 2006

Reformulating Engineering Education at Singapore Polytechnic

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ABSTRACT

Singapore Polytechnic (SP) was established 50 years ago in 1954, to train middle-level professionals to support the technological and economic development of Singapore. SP provides training in a wide range of practical, work-oriented fields of study. These include courses in engineering, media and design, information technology, health sciences, chemical and life sciences, maritime studies, building and construction, and business, finance and law.

While it is well recognized that SP has been very effective in teaching students in the traditional classroom learning environment, as evidenced by the successful graduates it has produced in the last 50 years, changes are taking place in the economic and social landscape, which necessitate change in educational provision and practices in order to maintain the viability and quality of the education SP provides.

Since 2004, the polytechnic has embarked on a number of new initiatives and approaches to ensure that our graduates are adequately prepared to meet the needs of the industry and to live and work in a changing world. Some of the new initiatives include the teaching of critical reasoning, innovation and design, values and ethics, a broad-based approach to knowledge building, and an integrated and experiential approach to teaching and learning. While developing this new educational model, SP joined CDIO as a collaborator when we realised that there were many similarities between what SP and CDIO were trying to achieve. In this paper, we will discuss the initiatives SP has adopted in reformulating its engineering education in relation to the CDIO standards and principles. Also, the CDIO plan and achievements will be elaborated.

INTRODUCTION

In response to major developments in globalization and the accelerating pace of technological changes, Singapore Polytechnic (SP) has recognized that it has to make significant changes in how we educate our students in order to maintain the viability and quality of the education we provide. We are aware that the lifestyles and needs of the students joining SP, and the industries they will join on leaving SP, will be very different from those of today.

At present, however, there is an over-emphasis in our education model on developing our 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.

To ensure that our graduates are prepared for the 21st century workplace, we have embarked on a process to redesign our curriculum to provide our students with educational experiences that will enable them to develop essential habits of mind of open and reflective thinkers, effective lifelong learners, and good communicators in both the local and global context.

The new curriculum will feature a broad-based multidisciplinary approach to knowledge building and the integration of essential process skills, values and professional ethics. This corresponds to Standard 2 of the CDIO initiative. Besides building core foundational knowledge and skills necessary for understanding and applying key subject knowledge, four generic competencies have been identified that all graduates, irrespective of their course of study, must attain. These are Thinking & Problem-solving, Managing Learning, Communication & Teamwork, and Professional Ethics & Values. These core competencies will be explicitly integrated into the teaching of content curricula where appropriate. Specific, detailed learning outcomes for these knowledge areas and core competencies will be written.

Integrated learning experiences to provide students with a more holistic approach to the learning of domain knowledge and the generic competencies 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 real world emphasis.

Emphasis has also been placed recently on promoting Creativity, Innovation and Enterprise and nurturing the innovative attitude. Design has been identified as the vehicle we would use to promote innovation. Greater focus will be placed on the enabling our 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 us to nurture graduates with the different skills that they need for the future. The future brings tremendous opportunity, especially in Asia, but it will also bring many changes that we cannot foresee today. Our aim is to give our students the chance to develop the skills, character and values that will enable them to meet the challenges and do well in this future.

The curriculum redesign process is still in its initial phase. Much more detailed planning and experimenting will need to be done to achieve the standards spelt out by CDIO in a co-ordinated and systemic manner. This paper will report on our initial attempts to redesign our curriculum using CDIO as the context (Standard 1). In particular, it will report on the project work component of the curriculum to which design-build experiences (Standard 5) has been integrated into subjects across the 3 years of study. This new curriculum provides real world and experiential learning experiences that builds foundation knowledge and nurtures the core generic competencies (Standard 7) of Thinking & Problem-solving, Managing Learning, Communication & Teamwork, and Professional Ethics & Value.

PROJECT IMPLEMENTATION IN SCHOOL OF ELECTRICAL AND ELECTRONIC ENGINEERING

The design-build experience forms one of the key themes of CDIO. In this 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 CDIO implementation in the School of Electrical and Electronic Engineering, Singapore Polytechnic. In the Diploma in Electrical and Electronic Engineering course, students 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, Design and Innovation Project and the Multi-Disciplinary Design Project. While the general objective of these projects remains similar, the specific aims of these design-build projects vary as each provide different experiences and exposures as students mature in their course of study. They will be described in the following sections.

Before discussing these project modules, it is useful to first understand the rationale for introducing them.

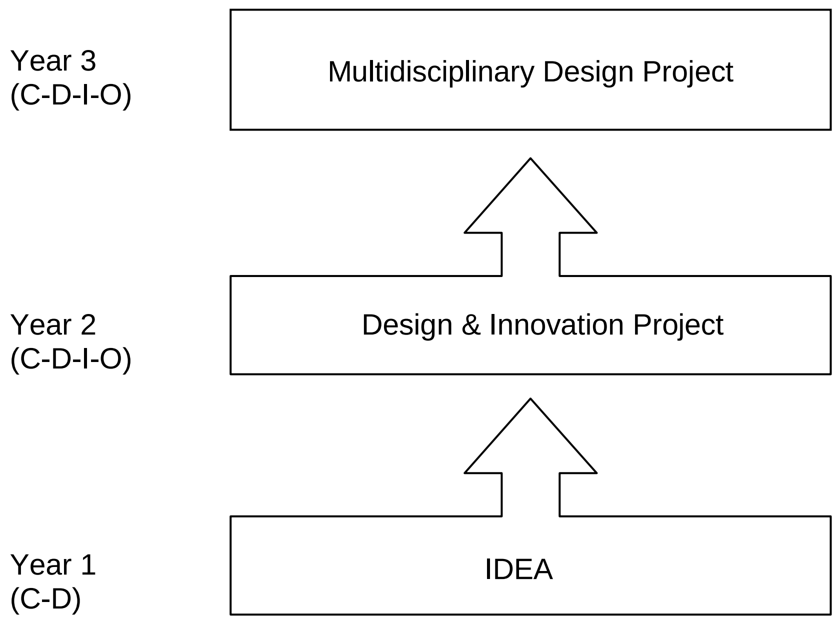

Figure 1 Project Path in School of Electrical & Electronic Engineering, Diploma in Electrical and Electronic Engineering

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 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 as it is the *ability* to create something new; we need to also provide students with ample opportunities to make something novel and new. Thus, the design and implement phases provide the process of making or *doing* something new. And that is where design is more aligned with innovation – it is not an just an *attribute*, it is fundamentally about *action*.

Many institutions have projects in their curriculum for students to create artefacts. Will that be enough to train students sufficiently then? If not, what is the missing ingredient for an enriching design-build experience? Gleaned from the CDIO PBL projects implemented earlier, the author concludes that the attitudes of students and staff towards the projects are key determinants.

"Design attitude" is a key differentiating factor between a successful and not-so-successful project. With "design attitude", students approach each new design-build project with a desire to do something differently and better than he or she has done. This attitude gives them 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 as compared with 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. Designers relish the lack of predetermined outcomes. 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?

Besides inculcating this design attitude, other skills such as getting to know the customers, creativity and design techniques are also covered in these design-build projects.

Year 1 (IDEA Module)

The IDEA (**I**nnovation, **D**esign and **E**nterprise in **A**ction) module is the first design-build project being introduced to all students. This is a 15-week module which all students in the Singapore Polytechnic have to undergo. It emphasizes on key aspects of the innovation process which includes design and enterprise. A large part of this module exposes students to understanding user needs, business plans and prototype making. This forms the underlying basis of this design-build project which focussed on conceive and design stages.

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. Eg 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

Besides attending the briefing session, students are also given the opportunities to try out the tools and equipment whereby they can gain a better exposure. This will help them in understanding the difficulties involved and to derive the potential solutions as can be seen in Figure 3.

Figure 3 Trying out different tools used by National Parks

Year 2 (Design & Innovation Project)

After going through one year of study, students are better equipped technically to carry out design-build projects in Year 2. For this Design and Innovation Project module, students work in groups 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 domains of aerospace, biomedical and electrical/electronic engineering. The key aim of these projects is to provide opportunities for students to apply their engineering skills into 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 encounter these modules in the course.

Microcontroller Project. Using micro-controller, sensors and actuators, students build robotic objects that can manuvere in different configurations. Besides programming, students will also carry out integration of the hardware components as shown in Figure 4.

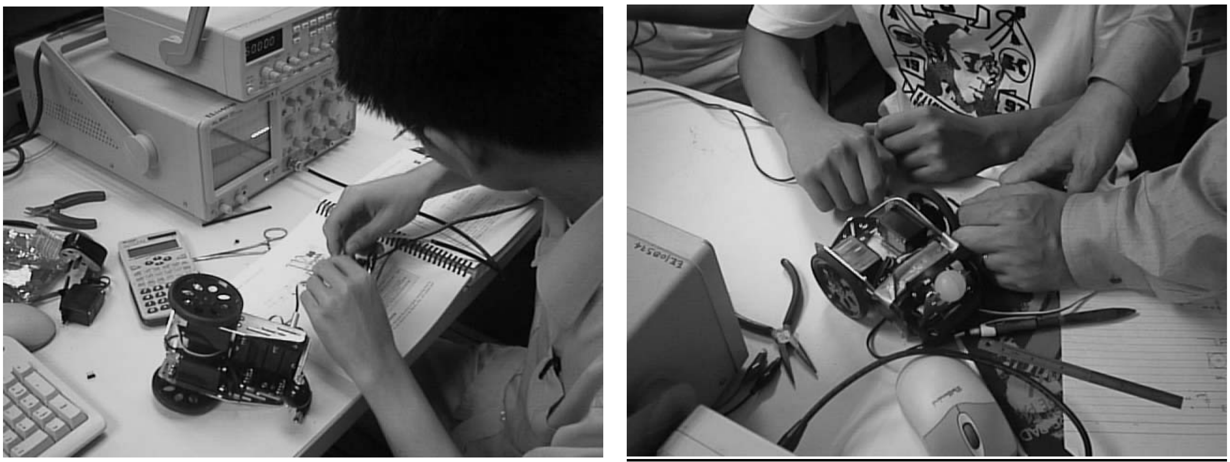

Figure 4 Design and Innovation Project (Microcontroller Project)

Biomedical Project. In this biomedical project, students are given the challenge of formulating a project that they desire to work on. The application can be a game or a more serious engineering project as long as biomedical signals and Labview program are used for generating an output actuation.

All of the above projects are open ended in varying degrees and students have the freedom to decide what they build. This is an important attribute of these projects if students were to develop qualities such as creativity, independence, taking initiative and resourcefulness. The syllabus of this Design and Innovation Project is attached at Appendix A.

Year 3 (Multi-Disciplinary Design Project)

For the projects in Year 2, students work within the domain of Electrical and Electronic Engineering. 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 Mechanical Engineering, Electrical and Electronic Engineering, and Chemical and Life Sciences work together on this project. Thus, the range of project choices is very wide spread. There are also many projects that are industry linked.

This category of projects is being introduced in Academic year 06/07 with approximately 20 students from the Mechanical and Chemical Engineering each. There are also about 15 students from Electrical and Electronic Engineering. Students started their projects in late April '06. The project titles for this year include the following :

a. Dispensing system for milk powder (initiated by local hospitals)
b. Automatic point of sale machine for bread (initiated by local bakery)
c. Massager device (collaboration with local company)
d. Fragrance Dispenser
e. Game station using exerciser machine

This is an equally challenging exercise for both 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 on these projects 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 they are as follows.

Collaboration with industry. This is an important consideration if the project has to be authentic. Staff has to take the extra effort to make connections with industry partners for 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. Also, their expectations have to be realistic as they need to understand that the projects are built by students.

Multi-disciplinary staff team. Before we can start on a multi-disciplinary students' project team, we have to first get together a multi-disciplinary staff team. Forming a good team is essential as it pre-determines if the multi-disciplinary project is going to succeed.

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

Support of 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 time-tabled hours since many of these technical staff are in the laboratories within office hours.

Staff training and approach. The approach to education is no longer preparing lectures and conducting pre-arranged laboratory sessions. Our 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, we also need to pay more attention to promoting creative thinking and engaging students in challenging their ideas. Academic staff has to take the initiative and work towards training students differently.

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

CONCLUSIONS

Projects are good vehicles for building key foundational knowledge and skills while nurturing personal and interpersonal competencies and values. They are also natural vehicles for students to apply the CDIO principles of product and system building skills. 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 provide 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 gleaned 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 to enable to students to optimise the key learning opportunities provided by projects. To trigger students' interest and engagement, the projects 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 in the course. Lecturers will need to adopt an approach to teaching that encourages creative thinking and innovation.

CDIO is now an institutional initiative, albeit at its initial stages, in the Singapore Polytechnic. More lecturers from different subject areas will, in the coming months, be exploring how CDIO can be implemented in their different curricula. The curriculum redesign process reported above will serve as an exemplar as to how some of the CDIO standards can be implemented in an engineering curriculum and the structures and support that needs to be provided. Much more detailed planning and experimenting, however, will need to be done to attain a systemic and sustained adoption of CDIO across the campus.

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[1] The CDIO Initiative. http://www.cdio.org

[2] Crawley, E.F, “The CDIO Syllabus: A statement of goals for undergraduate engineering education” Technical report, MIT CDIO Report no. 1. MIT, Cambridge, MA, USA, 2001.

[3] The CDIO Standards. http://www.cdio.org

APPENDIX A

Module Syllabus of Design & Innovation Project

Module Syllabus of Design & Innovation Project

A TECHNICAL KNOWLEDGE AND REASONING

1 Apply technical knowledge gleaned from other modules and sharpen reasoning skills.

1.1 Apply technical knowledge gleaned from related modules (Electrical, Electronic, Biomedical and Aerospace) to build the project.

1.2 Apply engineering reasoning and problem solving skills to identify and formulate problems.

B PERSONAL, PROFESSIONAL AND INTERPERSONAL SKILLS AND ATTRIBUTES

2 Cultivate desirable personal and interpersonal skills to succeed in work and life.

<u>Personal Skills</u>

2.1 Take initiative and be willing to take risks.

2.2 Cultivate resourceful disposition.

2.3 Able to persevere and be flexible.

2.4 Develop creative and critical thinking skills.

2.5 Reconcile contradictory perspectives, theories and facts in order to formulate hypotheses and derive conclusions.

2.6 Develop the motivation for continued self-education and develop the necessary skills for life long learning.

2.7 Manage time and resource wisely in task prioritization and be able to discern the importance and/or urgency of tasks.

<u>Interpersonal Skills</u>

2.8 Form effective teams and be able to fulfil the different team roles and responsibilities.

2.9 Work independently and with others, and to embrace various viewpoints.

2.10 Communicate effectively by writing, graphical and oral communication.

2.11 Raise and answer questions effectively.

C CONCEIVING, DESIGNING, IMPLEMENTING AND OPERATING SYSTEMS

3 Build a project by progressing through the conceive-design-implement-operate stages.

Conceive

3.1 Identify project needs and opportunities.

3.2 Formulate problem and examine critical questions.

3.2 Develop an action plan (incorporating model, analytical and numerical solutions, qualitative analysis, experimentation and consideration of uncertainty) to solve technical challenges.

3.3 Develop different alternatives and make recommendation of final solution.

3.4 Carry out experimentation and knowledge discovery.

3.5 Conduct print and electronic literature survey by use of on-line catalogues, databases and search engines.

3.6 Define necessary system functions, specifications and architecture.

Design

3.7 Understand the phases in design process and be familiar with the numerous design approaches.

3.8 Utilise knowledge in design of solution effectively.

3.9 Apply appropriate techniques, tools, and processes in the design phase.

3.10 Develop the implementation process in identifying goals and metrics for performance, cost and quality.

Implement

3.11 Carry out software implementation process by breaking down high level components into modules (including algorithms and data structures).

3.12 Integrate hardware with software using software with sensor, actuators and mechanical hardware.

3.13 Manage the implementation process by effective execution and resource allocation.

Operate

3.14 Optimise operations in order to achieve the goals for operational performance, cost, and value.