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IMPLEMENTING PROJECT BASED LEARNING USING CDIO CONCEPTS

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ABSTRACT

Singapore is a small and young nation of 4 million people. The foundation of our economy during the 70s and 80s was built on large scale manufacturing and production. During those stable times, education would have done an adequate job of equipping students with the specific knowledge to take up ready positions. Many would continue to work in the same company or industry till retirement. In the 90s, Singapore faces particularly severe challenges when the Asian economic and currency collapsed. Realizing that the formula for yesterday's success is no longer applicable for the unpredictable future, a different kind of training is envisaged. It is no longer sufficient for education to give tools and knowledge that will be out of date, but to develop competent learners who can continue to learn confidently and are equipped with other useful life skills for the knowledge economy [1].

To prepare our students for the knowledge economy, a new education model which aims to provide our students with a more balanced and holistic education integrating the teaching of (i) domain knowledge with (ii) people and process skills and (iii) values & ethics is being developed in Singapore Polytechnic. New innovative approaches to teaching, learning and assessment that promote creativity and authentic learning are being explored.

After learning about the CDIO concepts and realizing the potential of cultivating students with the desired skills, a pilot programme incorporating CDIO concepts into project-based learning was implemented in the Singapore Polytechnic in 2003. The projects were developed using CDIO theories where students worked through conceive, design, implement and operate stages. In these projects, students in a class of 20 are required to build an artifact that comprises sensors and control algorithms. So far, three cohorts of students have completed their projects. As the projects developed were highly innovative and creative, the local news program had featured some of the students' innovations. Besides completing the projects, students also developed other attributes such as creative and critical thinking, resourcefulness and learning to learn traits.

This paper provides information on how this CDIO project learning was carried out and shares valuable lessons learnt. This will be useful for educators who are keen to start similar programs.

INTRODUCTION

Singapore Polytechnic (SP), the first polytechnic in Singapore, was established 50 years ago in 1954, to train middle-level professionals to support the technological and economic development of Singapore. It provides students with training in a wide range of practical, work-oriented fields of study which 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. With about 40% of each primary one school cohort graduating from the polytechnics each year, the polytechnics play a vital role in training the key manpower for Singapore's economy.

The polytechnic has constantly updated the existing courses to keep abreast with the latest developments in technology and, where necessary, introduced new courses to meet the changes in our economy. For example, new courses in areas such as mobile and wireless computing, aeronautical and biomedical engineering have been introduced in the last few years.

Today, polytechnic graduates are highly valued as practice-oriented and knowledgeable middle-level professionals, managers and technologists who can implement plans and concepts effectively and efficiently. They also have a reputation for being entrepreneurial and creative.

Although Singapore Polytechnic 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, it continues to innovate so that it can also be effective in producing graduates geared to the needs of the 21st century.

REDESIGNING THE CURRICULUM

Changes are taking place in the social, economic and education landscapes in Singapore as well as globally. 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. The SP graduate will need to be innovative, be able to learn continually, have good communication skills and be able to work in multi-disciplinary teams[1].

At present, there is an over-emphasis 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. Traditional didactic instructional methods using lectures are the main mode of delivery encouraging passive and superficial learning. Lessons are discipline based with very little effort to show links and to integrate process skills and values.

INCORPORATING CDIO PRINCIPLES INTO THE FUTURE EDUCATION MODEL

Significant changes in how we educate our students, given what we know about how students learn and future technological and societal trends and realities, are being made in order to maintain the viability and quality of the education SP provides. This is to ensure that our students will have a global mindset, be creative, innovative and enterprising, and competent in areas beyond their core discipline, grounded on a strong set of core values.

SP has well formulated educational aims, contained in the vision statement (highly Competent; Innovative; Versatile; Imbued with sound values; committed to Lifelong learning), which are contextualised within the wider societal educational framework of Singapore (e.g., MOE's Desired Outcomes of Education).

Our new education model aims to provide our students with a more balanced and holistic education integrating the teaching of (i) domain knowledge with (ii) people and process skills and (iii) values & ethics (Figure 1). New innovative approaches to teaching, learning and assessment that promote creativity and authentic learning will be explored. Lecturers will be considered as designers of learning environment. We are also exploring integrating the use of notebooks and learning material.

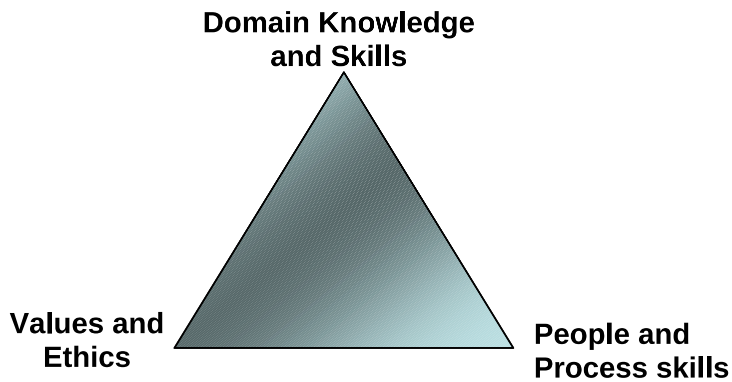

Figure 1: Singapore Polytechnic Education Model

The success of our new education model will be measured in terms of the qualitative change to the interactions in the classroom and the learning that students engage in and outside of it. Our goal would be to see our students become more passionate about their learning, our lecturers become facilitators who encourage exploration and experimentation and our schools and departments become centres of excellence and creativity, innovation and enterprise (CIE).

One of the key focus of the new Education Model is the promotion of creativity, innovation and enterprise (CIE). Under this key goal, students are introduced to the stages of **conceiving, designing, implementing** and **operating** in many ways: Firstly, through third year projects in which a corporate target of 50% to 80% of CIE component have been set for faculty to achieve; secondly, a new compulsory 30 hour institutional module, Innovation, Design and Enterprise in Action (IDEA), for all first year students. In this module, students use a design-based methodology to conceive and design their products. The students produce business plans for the final product and in some faculties, prototype their ideas. The best ideas from this module are provided with $50,000 to produce and market the product. Selected ideas are presented to a panel of judges which include industrial partners; thirdly, integrated project based learning where students work on projects that cover materials from various related modules and finally, multidisciplinary final year projects where students from three different disciplines work on common projects in their final year. The last two approaches are elaborated in the next sections.

INTEGRATED PROJECT BASED LEARNING

In 2003, the author started a small scale PBL project where the aims are to train students in acquiring desired learning habits such as resourcefulness, learning to learn skills and also to increase students' motivation to learn.

For this project, students are expected to build creative artifacts based on control and sensor theories. Specifically, students are required to develop a control system that detects a sensor reading and then generates an effect using the required actuators. Every group of students will develop the control algorithm using the Labview program running on a personal digital assistant (PDA). The PDA is used such that the solution is portable and may be mounted in school bags, bicycles etc.

Every project is unique projects as every group of students generally tackles a different problem. This is a key feature of this project based learning exercise as it is the intention for students to feel that they have the capability to solve problems that they personally feel important. Since it is a project of their choice, students should be more motivated to ensure that it gets completed. This concept is based on the belief that if students can be ignited with a passion to learn, then the chance of them excelling in their studies is enhanced. Also, this project allows some form of customization to suit students with varying capabilities where the better ones work on more complex projects.

To ensure that all students complete their projects on schedule, it is necessary for the project to be refined into concrete steps and the CDIO methodology is selected. The class of 20 students in each cohort was divided into six or seven groups of three to four students each. A total of 72 hours over 6 weeks were allocated for this project.

Key Steps: Conceive – Design – Implement – Operate

Students worked through the CDIO steps as they progressed from problem identification to the development of solution.

Conceive. The project commenced when students were asked to identify a challenging problem that they wish to work on. Students started the cycle by generating many possibilities of what they intend to do before zooming into the final project they wish to undertake. During this phase, students worked in their groups and carried out numerous discussion sessions. Many students also referred to web pages and magazines for ideas.

This is a very important stage and an entire week was scheduled for students to generate project ideas. Ample time was allocated as a wrong project selection will cause students to revisit this stage again later. During this phase, lecturers are highly involved in students' discussions and provide advices on the suitability of the project in terms of technical complexities and time constraints. The lecturer has to guide the groups to a good project choice while leaving them to make the final decision.

Design. After identifying the project, students need to develop the detailed design, identify and acquire necessary parts, test them and eventually develop the program. Students are encouraged to distribute their work so that they can each be responsible for a smaller task. Before making purchases, supervisors have to ensure that the parts requested by students are suitable before making final purchases to minimize wastage. After acquiring the parts, students generally need help in testing how they function. Other student group members will also be exploring the software programming functions at the same time. Starting from this stage, some students began to work more than the time tabled hours as they became quite intrinsically motivated.

Implement. The key tasks of programming and hardware fabrication are carried out during this stage. Upon completing the design of the program, students will generate the executable file and download them into the PDA. This is an exciting stage as it is simply exhilarating when students see their project work for the first time! However, it can also be very frustrating when the projects fail to work.

A lot of time was spent in helping students troubleshoot when the project is not working according to plan. Also, some students are given a lot of encouragement and guidance especially when the project fails to work after repeated trials.

Operate. This is the most rewarding stage as a major part of the project is already working. Most of the tasks are also completed and students need to fine tune their projects for enhanced performance and program efficiency.

After completing the entire CDIO cycle, all the projects are ready for viewing and assessment. Opportunity to exhibit the projects for external viewing would have been explored much earlier. If an external party is invited for the project viewing and presentation, then students have to be trained further in presentation skills and exhibition preparations have to be made.

During the entire conduct of the project, most students are kept on their toes as they progressed through the intermediate checkpoints and assessment. Besides generating a hive of activities, students also carried out higher order thinking skills at different phases of project as shown in Table 1.

Table 1: Higher Order Thinking Skills at Different Stages

Stages	**Tasks carried out**	**Higher Order Thinking skills**
C	Generate project ideas Research on project ideas Combining ideas Identify the project Presentation and defending idea	Creative thinking Critical thinking Synthesis
D	Generate designs Identifying necessary parts	Synthesis Critical thinking Creative thinking Part-whole analysis

		Resourcefulness
I	Implementation of ideas	Resourcefulness Synthesis
O	Fine tuning	Critical thinking

Students Develop Highly Creative and Innovative Projects over Short time
As of 2005, a total of eighty students from four cohorts had completed their PBL projects. Many interesting projects were developed and this section describes some of them

There was a group of students who designed a 'SMART' window that opens and shuts on its own, triggered by rain and motion sensors when they detect movement within the household. It is also not necessary to arch your back and reach out precariously over the window ledge anymore to clean that irritating grime off the glass panel as the same window has a motorized wiper that kicks into action on rainy days.

Other students have also built interesting devices that help to greatly enhance lives, such as a Carbon Monoxide Detection System that winds-down car windows and sends SMS-alerts to the drivers when they are in danger of inhaling too much toxic gas.

Instead of crawling out quietly from baby cribs, sensors are now be used for detecting the movement of infants which can activate a toy to entertain them while at the same time informing their parents using the wireless connection when the movement becomes too violent.

Shopping at the supermarket offers a totally new experience using the invented shopping cart. Some students had designed a cart mounted with sensors at the front and back. Based on the status of the sensors, the motors will turned on and off to follow the shopper. Thus, shoppers may browse freely in the grocery stores without having to push the cart around.

Outcomes of project based learning

While working through the projects over the six weeks duration, there were numerous opportunities for students to cultivate good habits of mind. Some of these observed intelligent learning behaviors were as follows.

<u>Persistence</u>. Students generally encountered a lot of problems in the initial phases of project during the conceive-design-implement stages. Students needed to persist despite the trying circumstances. One student commented that she was very stressed over the six weeks. However, at the end of it, she felt that her persistence paid off when the project started to work and she felt exhilarated.

<u>Motivation to learn has increased.</u> Some students tried to find out additional information which they needed for completing the project. There was a student whom the author spotted attending a web seminar. He found the web site and then sat quietly to attend the webinar to learn about motors for his project.

Learning how to learn. The project provided ample opportunities for students to learn about how to learn from their peers and teachers. There were several presentations made by students to share about their projects.

Thinking flexibly. As the project offered many opportunities for creative thinking, students have to think flexibly during their idea generation and design stages. From this exercise, students learned from each other more techniques of generating ideas.

Striving for accuracy and precision. The project will not work if students are sloppy in testing their circuits and programming. Thus, many are forced to strive for accuracy if they want their project to work.

Applying knowledge to new situations. After learning various subjects in their course, students applied the knowledge gleaned to complete this project. This is very different from the traditional situation where they only need to regurgitate the answers during examinations.

Data gathering. Students needed to carry out extensive research for ideas and information on the parts they needed. This opportunity is useful for training students to become more resourceful.

Creating, imagining and innovation. The projects completed by the students were generally very innovative. Projects from two of the cohorts were featured in the local news due to the creative solutions generated.

Integration. Students were required to integrate all the theories they have learnt in order to complete their projects.

Besides the above observations, a survey with XXX responses confirmed that this mode of learning is considered interesting and meaningful by students. A high score of 4.1 out of 5 was rated by students.

MULTI-DISCIPLINARY DESIGN EDUCATION

Another initiative modeled after the CDIO principles is the multi-disciplinary design training that is jointly offered by the School of Mechanical & Manufacturing Engineering (MM), Electrical and Electronic Engineering (EEE) and the Chemical and Life Sciences (CLS). This training focuses chiefly on product development and enterprise as shown in Figure 2.

The proposed training covers design topics in aesthetics, elements of design thinking skills and technology within the domain of product innovation. To promote synergy and produce creative designs, the training is multi-disciplinary in nature with lots of hands-on exercises. The proposed option is unique in that the curriculum is designed to emphasize the multi-disciplinary nature of design, creativity, engineering and entrepreneurship. It harnesses the creative potential of technically competent students and inculcates design capability and business intelligence. Students will be given additional training in three distinct domains, via Design Skills, Business Economics and Product Realization besides their core disciplinary knowledge. This additional knowledge provides the necessary conceptual, technical, product management and business knowledge for productization purpose.

Design Skills
These modules prepare students to develop creative design using a range of skills and techniques. Fundamental design skills, theories and concepts are taught through modules such as Design Techniques and Skills, Arts & Science of Colors and Creative Product Design.

Business Economics
This option goes beyond engineering, design skills and techniques, and includes the designer's ability to deliver a product with potential for commercialization. These will be taught through modules such as Writing skills for technological entrepreneur, Communication Skills for Entrepreneur and Business Planning for New ventures.

Product Realization
Students will undergo a semester long project in their final year of study. Each group comprises students from the various schools and they will work to design and produce a product jointly.

COURSE STRUCTURE

Besides taking lessons in their own domain, students from various schools will gather together from second year for the other design, business and product realization modules. The final exercise is a multidisciplinary project that spreads across an entire semester that lasts for four months. The first group of students will be starting their design modules in May 2005.

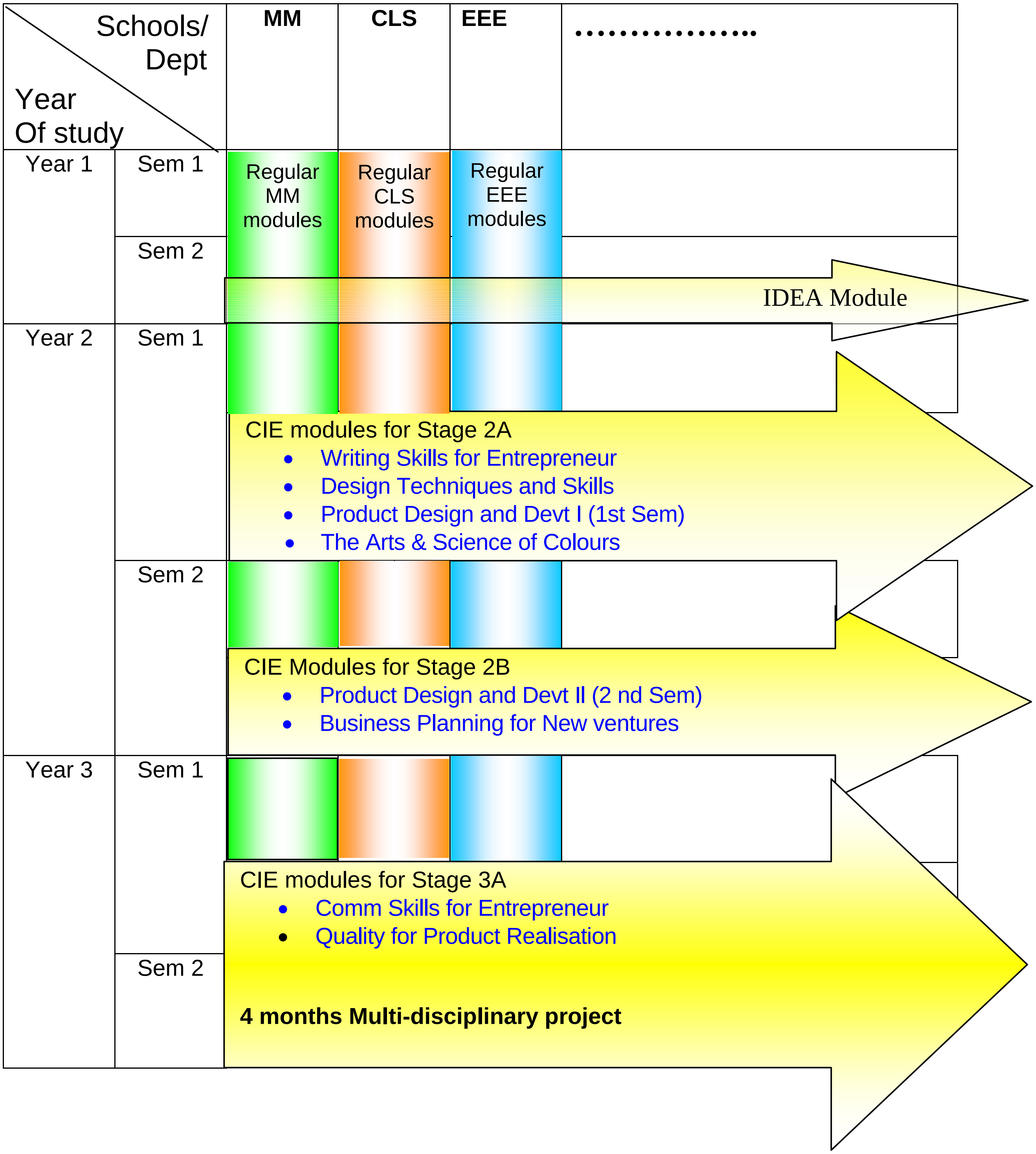

Figure 2: Curriculum Framework to infuse CIE Mindset and Multi-Disciplinary Project

CONCLUSION

In the implementation of project based learning in Singapore Polytechnic, CDIO concepts were adopted. The approach was found to be effective in motivating students to acquire domain knowledge and problem solving skills. It promoted a learnacy culture where dispositions and skills related to learning are valued.

The process as we work towards a new education model for the 21^{st} century is at present one of experimentation and exploration of new methodologies and teaching and learning concepts in an integrated curriculum which values people and process skill, ethics and values besides domain knowledge. The institution is presently also exploring other areas like pedagogy and assessment methods, workspace, values.

REFERENCES

[1] Wells, G., Claxton, G. "Learning for Life in the 21^{st} Century" Blackwell Publishing, ISBN 0-631-22330-4, 2002.

Project-based learning takes ideas from constructivism in which learning is seen as the construction of knowledge through interaction (Perkins, 1991; Piaget, 1969; Vygotsky, 1978 in op. cit.: 2), and constructionism (Harel & Papert, 1991; Kafai & Resnick, 1996 in op. cit.: 2) which takes the notion that people learn best when they construct an artifact that can be shared and reflected upon (ibid).Â developing language learning and skills. catering for individual differences. authentic use of the L2. developing problem-solving skills. enhancing cooperative learning. Based on the concept of CDIO, teaching should persist in the principle of â€œIntegrationâ€.[7] Teaching should combine different courses such as Basic Japanese, Spoken Japanese, Japanese Listening, Computer Basis, Multimedia Technology, etc. A comprehensive project should effectively combine those courses and then helps to cultivate students applied abilities.Â Implementation and Operation The Goal of Project. The project SDJCS converted the basic knowledge students acquired in different courses into practical skills. Five conversational scenes were designed for this project: Meeting for the First Time, Shopping, Telephone Communication, Seeing a Doctor and Travelling.Â 1. Be able to perform clear and fluent Japanese conversation. 2. Learn to use video editor. The CDIO concept is based on the design process in actual systems and product development, and the educational program following this concept is becoming a global standard in engineering education. By taking this educational program, learners can acquire the abilities to â€œconceive,â€ â€œdesign,â€ â€œimplement,â€ and â€œoperateâ€ as defined by CDIO Initiative. Kanazawa Institute of Technology (hereinafter called â€œour collegeâ€) joined CDIO Initiative, and is promoting advanced engineering education in Japan. Our college adopted the project-based learning (PBL) method in the creative subjects â€œDesign Project Iâ€ and â€œDesign Project II,â€ to conduct engineering design education for improving students' skills to detect and solve problems.