ADOPTING CDIO TO INTEGRATE ENGINEERING WITH BUSINESS

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ABSTRACT

The Diploma in Engineering with Business (DEB) is a three-year multidisciplinary diploma programme offered by the Singapore Polytechnic (SP) to students who have just completed their secondary school education. Students take courses in Engineering and Business that are taught by teaching staff of the engineering and business schools. The programme aims to produce graduates who are conversant and versatile in the practical application of both engineering and business concepts, hence becoming "business-savvy engineers". This broad-based curriculum also provides graduates with more flexible educational options, post the diploma, in either an engineering or business undergraduate programme. First introduced in 2009, DEB students undertake business courses, though somewhat standalone, from those of the engineering courses. Between 2010 and 2012, the DEB management team did a review of the programme using the CDIO framework. As a result, the team enhanced the curriculum in 2013 to integrate the learning of the engineering and business disciplines with mutually supporting disciplinary subjects based on the CDIO standards. This paper will describe how the DEB curriculum is designed to make explicit connections between the related engineering and business subjects, incorporating CDIO skills that include personal, interpersonal, and product and system building skills (Standards 2 and 3). The paper will also outline how the integration of CDIO learning outcomes and disciplinary skills in both engineering and business is translated into meaningful real world learning experiences (Standard 7) in this programme. The results of a survey conducted amongst the students who experienced the revised curriculum are also shared.

KEYWORDS

Integrated curriculum, engineering, business, Standards: 2,3,7

INTRODUCTION

The Diploma in Engineering with Business (DEB) is a three-year multidisciplinary diploma programme offered by Singapore Polytechnic (SP) to students who have just completed their secondary school education.

The programme offers courses conducted by teaching staff of the Schools of Electrical and Electronic Engineering, and Mechanical and Aeronautical Engineering and SP's Business School. Introduced in 2009, this programme aims to produce graduates who are conversant and versatile in the practical application of both engineering and business concepts, hence becoming "business-savvy engineers". This broad-based curriculum also provides graduates with more flexible educational options post the diploma in either an engineering or business undergraduate programme.

As with other diploma programmes offered by SP, the diploma adopts the SP education model of being broad-based and with a multidisciplinary approach. Students will also be equipped with specialised knowledge and skills to prepare them for work as well as with life-long learning skills and ability to pursue further academic studies.

The DEB programme aims to, amongst others, equip students with fundamental engineering knowledge and technologies, fundamental business skills and the knowledge to link engineering with business and also with life skills such as analytical skills, problem solving skills, communication skills and creative and critical thinking skills.

Although SP as an institution of higher learning started the adoption of CDIO engineering education framework in 2004, as outlined in Pee and Leong (2006), this was carried out in phases across the various engineering-related diploma programmes. Between 2010 and 2012, the DEB programme management team conducted a review of the DEB curriculum using the CDIO framework.

Akers and Radson (2013) provides four broad categories of engineering and business joint academic programmes, with varying degrees of integration between the two disciplines. These include joint business and engineering degree programmes, programmes which offer business courses within the engineering curriculum, engineering programmes with entrepreneurial experience, and engineering programmes with either minor or certificate in business courses. Examples of such programmes are described in Speckhart et al (2005), Schar et al (2013) and Burke (2013). These are however offered at the undergraduate and master's level. The approach that has been undertaken for DEB is based on the CDIO framework.

As a result, the curriculum was enhanced to integrate the learning of the engineering and business disciplines more strongly. This was done by integrating the learning activities of a first year engineering project, Engineering Design and Business Project I, with those of a business course, Principles of Marketing. In the second year, the learning activities of another engineering project, Engineering Design and Business Project II, were integrated with Professional Selling, a business course.

This paper describes how the DEB curriculum is designed to make explicit connections between these related engineering and business courses, and how CDIO skills like personal, interpersonal, and product and system building skills are incorporated and assessed (Standards 2 and 3). The paper will also outline the integration of CDIO learning outcomes and disciplinary skills in both engineering and business is translated into learning experiences (Standard 7) in this programme. The learning activities carried out in the relevant courses have been designed along the lines of the broad design model described by Sales (2014) which incorporates integration of technical content and other thinking and process skills.

IMPLEMENTATION

Year 1 Curriculum – Integrating engineering with business

One of the main business courses offered since the start of the DEB diploma programme is the course on Principles of Marketing (POM). This is offered as a course in the first-year of the Diploma Programme. This course introduces students to the basic principles and concepts of marketing and teaches them to develop a simple marketing plan to launch a product or service. The topics that are covered include an overview of the marketing process and the marketing environment, an understanding of target market selection, as well as the management of the marketing mix elements that include the 4P's namely: Product, Price, Place and Promotion.

The course is taught by teaching members from SP's Business School. It is delivered through lectures, tutorials and project discussions. Key concepts and theoretical aspects of marketing are

introduced in the lectures and reinforced in the tutorials and projects through discussion questions, individual and group market research, individual presentations and group reports.

Students undertaking Principles of Marketing are also required to complete two assignments. For both assignments, students work in teams of four, and up to six, students.

The first assignment requires each student team to prepare a market situation analysis for a particular industry and product or service. The market situation analysis include carrying out an industry analysis and highlighting industry trends and identifying major industry players. The student teams are also required to carry out a company analysis, including detailing the company's weaknesses and strengths relevant to achieving its mission and goals, SWOT (Strengths, Weaknesses, Opportunities and Threats), competitor analysis including identifying major competitors and their marketing mix strategies, and lastly a customer analysis through demonstrating a deep understanding of potential customers.

The second assignment requires the team to create a new and viable product/service for the company to launch. This can either be on a local, regional or global basis. The team is also required to structure a marketing plan (involving the 4 P's) for the company to launch the new product to the identified target market(s). At the end of the assignment, the team will need to deliver a comprehensive report detailing their findings, analyses and a marketing plan, carry out a formal oral presentation, and also to complete a reflective journal.

Previously students took this course independently of what they have studied in the engineering strands of the curriculum. There was no requirement for them to apply their knowledge in marketing within an engineering context. This situation reflects what is described in Heim and Erickson (1996) of how students are taught specialised knowledge but with hardly any synthesis. Most of the students tended to do a market situation analysis and marketing plan on non-engineering product or services from sectors such as finance, food and beverage, lifestyle and retail. There was usually little or no attempt to work on the engineering or technology sectors.

In 2013, the first year curriculum was enhanced with the introduction of a new engineering course called Engineering Design and Business Project I (EDBP I) to serve as a platform to make explicit, connections between engineering and business. Students have to take this course in conjunction with Principles of Marketing (POM) in the same semester.

EDBP I is designed as an introductory course that provides a framework for engineering practice in the building of an engineering product (CDIO Standard 4). In this course, students are introduced to the concepts of Conceive-Design-Implement-Operate (CDIO) in the context of the life cycle of an engineering product. Exposure to the Design-Build Experience (CDIO Standard 5) is also provided in this course through a project which the students need to conceive, design and build a prototype. To prepare students for this project, the concepts and techniques of design thinking are taught so that these can be applied during the conceive and design phases of the project. Training of students on fabrication and teamwork and communications skills are also included in this course. Most important of all, the learning activities are designed so that there are integrated learning experiences where the students can link and apply their disciplinary knowledge in the Principles of Marketing to the engineering product they designed in Engineering Design and Business Project I. In carrying this out, students are also expected to put into practice their product building as well as teamwork and communications skills (Standard 7).

Figure 1 shows the integrated learning experience that is designed to explicitly link Engineering Design and Business Project I course with that of Principles of Marketing.

The integrated experience begins with an activity in Principles of Marketing to prepare a market situation analysis. For this assignment, students work in teams of 4 and up to 6 students as was previously done prior to implementing the revised curriculum. However, with the revised curriculum, the project brief specifies that students must choose from one of six possible industries as follows:

- Consumer Electronics
- Telecom & Information Technology
- Automobile
- Healthcare Products
- Safety & Security, and
- Toys & Games.

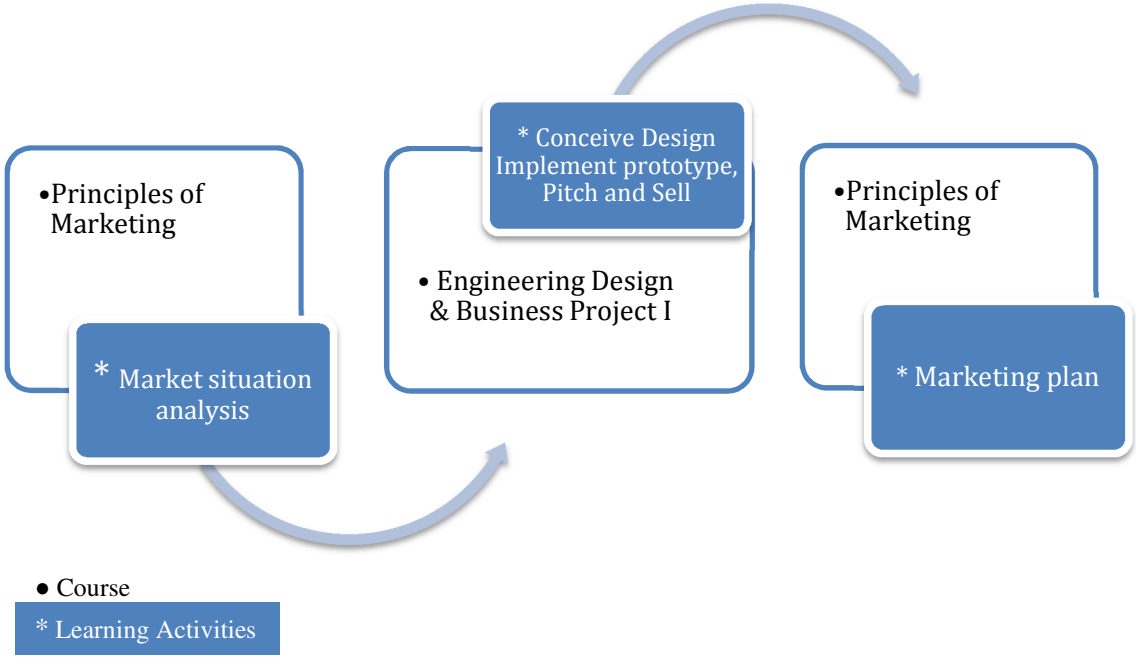

Figure 1: Integrated Learning Experience in EDBP I and POM

While working on the market situation analysis, the same team of students will embark on another activity that is incorporated in Engineering Design and Business Project I. In this activity, students will apply design thinking concepts and techniques to conceive a new product or service from the market sector that the team has identified in the market situation analysis done in Principles of Marketing. The team will then need to propose with justifications, the product or service that the team has selected.

Once the above activities are completed, the next activity requires the team to apply their basic knowledge in electrical and mechanical engineering acquired in other courses and their fabrication skills, to construct a simple prototype of the product or service. Upon completion of the prototype, they will do an oral presentation of their work, as if they are trying to pitch and sell the product or service as a possible business to the client.

This integrated experience ends with an activity in Principles of Marketing to prepare a marketing plan. This marketing plan is to cover the product strategy, price strategy, place strategy and promotion strategy for the product or service that was conceived, designed and built in

Engineering Design and Business Project I. An oral presentation of the marketing plan is to be made, as if they are presenting it to their client.

To summarise, the teaching of Engineering and Business in the first year of DEB is integrated with a curriculum that is designed to make explicit connections between the two very different disciplinary knowledge through the learning activities in Engineering Design and Business Project I and Principles of Marketing. At the same time, skills like personal, interpersonal, and product and system building skills are also incorporated in these two courses and translated into learning experiences through the activities as described above. With this integrated learning experience, students will be able to apply their business knowledge in an engineering context and vice versa. Skills like teamwork and communication skills, reflective and critical thinking skills, conceive, design and product building skills are also put into practice in these learning experiences.

Year 2 Curriculum – Integrating engineering with business

In the second year curriculum, an engineering project-based course called Engineering Design and Business Project II is used as a platform to anchor the integrated curriculum and also to provide the connections between engineering and business. This is summarised in Figure 2.

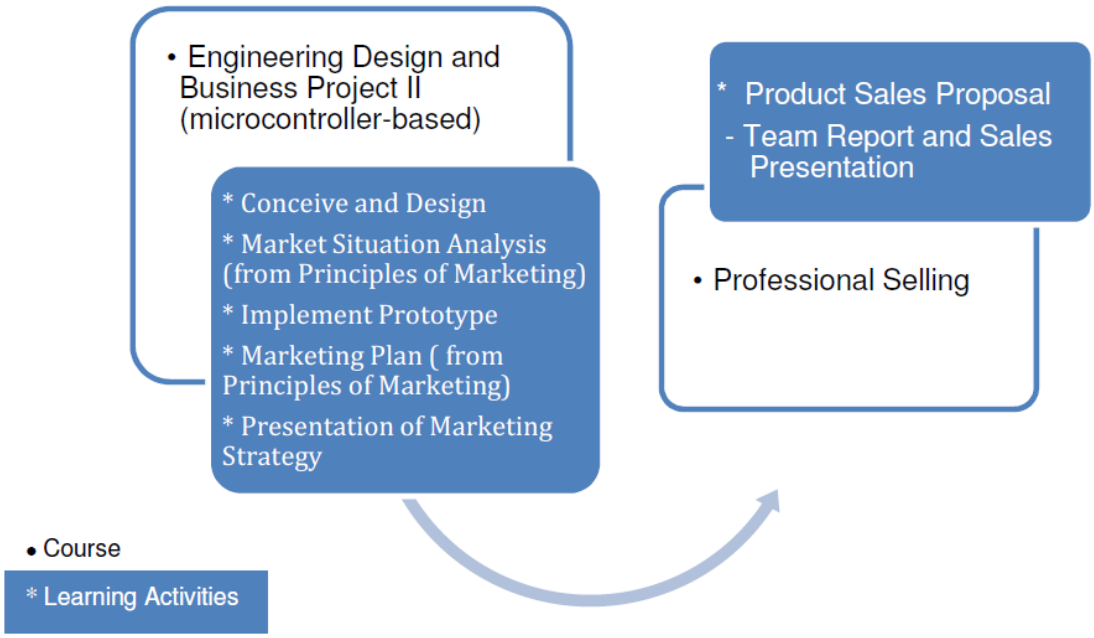

Figure 2: Integrated Learning Experience in EDBP II and Professional Selling

Engineering Design and Business Project II is a course that teaches the concepts of Microcontroller and its applications. Students learn how a microcontroller works, how to program it, as well as basic analogue and digital support circuitries, sensors, actuators and displays required for a microcontroller based application. This domain knowledge is taught in a series of lectures and tutorials with worked examples and discussions on applications. The theory learnt will be put into practice during the laboratory lessons where the students will perform a standard set of experiments.

Students will then apply what they have learnt to develop a microcontroller-based project. They are also restricted to propose their microcontroller-based project in 1 to 2 market segments, such

as those for the Silver Age, Aids for Physically Disabled, Health & Hygiene, Energy/Water Conservation, Green Environment, Home Automation, Productivity Improvement, Enhance Customer Experience, Education, Games & Toys, Security or any suitable market segment as identified by their team. They will work in teams to conceive ideas for the project, which they will then design and build. Students will be required to fabricate simple electronic circuits, program the microcontroller and then do circuit interfacing and perform trouble-shooting to get their projects working. They will also have to consider the business aspects of the project through developing a simple marketing plan and demonstrating how they will sell their product.

The microcontroller-based project described above is used to deliver the integrated learning experience. Besides applying the disciplinary content on microcontrollers, the project also utilises supporting contents from first year courses. This includes C-programming, which is the high level language used to programme the microcontroller, and electronics engineering which is required for the students to design the interface circuits. Design thinking techniques and system building skills taught in Engineering Design and Business Project I in the first year curriculum are also utilised to conceive, design and implement the project. Students also need to apply personal skills, such as engineering reason and problem solving skills, critical thinking skills throughout their project, especially in testing and troubleshooting their project, They also have to demonstrate their self-learning skills as the selection of the appropriate sensors for their project, and how to use them are left to students to research and learn on their own. Students are also expected to demonstrate good team work and communication skills which form part of the assessment of the project.

The technical and learning activities described for Engineering Design and Business Project II here are similar to those of the design-build project as described by Chong et al (2010), but with the additional business-related components built into it as well.

The integration of engineering with business is also effected through this project. Students have to apply what they have learnt in their first year course, Principles of Marketing, to prepare a marketing plan for their project. Through this activity, students will have the opportunity to consider the business aspects of what they have built and apply their business knowledge in an engineering context. Explicit connection between engineering and business is also made through linking Engineering Design and Business Project II with another business course called “Professional Selling” which students have to take in the same semester.

Professional Selling provides students with practical knowledge of the art and science of effective personal selling. It encompasses the learning of the comprehensive process of personal selling to consumers and businesses, and putting into practice under realistic scenarios and assessments. The coverage of the course includes the following:

- Understand basic principles, various techniques and process of personal and relationship selling,
- Understand the critical role of pre-call preparation in sales success and be able to apply the sales techniques.
- Understand and apply questioning techniques in recognizing prospect’s problem during a sales presentation.
- Understand and apply the various methods in handling customers’ objections and closing a sales presentation.

To provide an explicit connection between engineering and business, the students will have to prepare a product sales proposal (that includes sales brochures, product pictures, charts and/or

other sales materials) and make a sales presentation of the product that they have built in Engineering Design and Business Project II. This will allow students to put into practice their knowledge in Professional Selling to sell an engineering product.

To summarise, in the second year of DEB, integration of the disciplinary knowledge in engineering and business is achieved through the learning activities in Engineering Design and Business Project II and Professional Selling. In Engineering Design and Business Project II, students conceive, design & build a microcontroller-based product and then develop a simple marketing plan for their product and demonstrate how they will sell it. In Professional Selling, students will prepare a product sales proposal and conduct a sales presentation of the product that they have built in Engineering Design and Business Project II. This integrated learning activity will allow students to experience the real-life scenario of how an engineer would need to take into consideration the business aspects (such as marketing and sales) of an engineering product.

Moreover, while acquiring the respective disciplinary knowledge of these 2 courses, the learning activities also allows the disciplinary knowledge from supporting courses as well as CDIO skills like personal, interpersonal, and product and system building skills to be utilised and assessed simultaneously, thereby meeting the requirements of an integrated curriculum.

RESULTS

A survey was conducted for the first cohort of students who have undergone the revised curriculum. The response rate of the survey was about 85%. The results of the survey is summarised in Table 1.

Table 1. Summary of survey results for the first cohort of students

SA= Strongly Agree, A = Agree, N = Neutral, D = Disagree, SD = Strongly Disagree					
	SA	**A**	**N**	**D**	**SD**
1. The learning experiences in the DEB curriculum have helped me to apply knowledge from one course to another.	36%	53%	8%	0	3%
2. The learning experiences in the DEB curriculum have helped me to make connections and see the larger picture of engineering.	25%	61%	11%	0	3%
3. The learning experiences in the DEB curriculum have helped me to apply and integrate what I have learnt in my engineering courses with those in my business courses and vice versa.	19%	67%	11%	0	3%

The results showed that more than 80% of the respondents agreed that the learning experiences in the DEB curriculum have helped them to
(i) apply knowledge from one course to another
(ii) make connections and see the larger picture of engineering
(iii) apply and integrate what the students have learnt in their engineering courses with those in their business courses and vice versa.

This shows that the integrated curriculum implemented has achieved its aim of making connections between disciplinary knowledge and CDIO skills in an integrated manner, especially in integrating the learning and applying of the knowledge in the engineering and business disciplines.

CONCLUSION

In the first year curriculum, the learning activities in Principles of Marketing and Engineering Design and Business Project I are integrated. Students worked in teams to perform a market situation analysis and then proceed to conceive, design and build a prototype of a product from the target market that the team had identified in the market situation analysis. This is then followed by the final activity where the team prepares a marketing plan to launch the product to the target market.

In the second year curriculum, the learning activities in Engineering Design and Business Project II and Professional Selling are integrated. Students worked in teams to conceive, design and build a microcontroller-based product. They will then prepare a marketing plan and a product sales proposal as well as conduct a sales presentation of the product that they have built.

These learning activities have allowed students to apply and integrate what they have learnt in their engineering courses with those in their business courses and vice versa. The activities also provide a setting for students to experience the real-life scenario of how an engineer would need to take into consideration the business aspects (such as marketing and sales) of an engineering product. Besides the disciplinary knowledge, these activities also utilises disciplinary knowledge from supporting courses as well as allow CDIO skills like teamwork and communication skills, reflective and critical thinking skills, conceive, design and product building skills to be put into practice.

Feedback from students showed that most agree that the learning experiences have helped them to apply knowledge from one course to another, make connections and see the larger picture of engineering as well as apply and integrate what they have learnt in their engineering courses with those in their business courses and vice versa.

In implementing the integration of the engineering and business courses, the student curriculum hours remains the same with the use of resources such as facilities remaining the same prior to the integration. However, to implement the integration, the teaching staff of the Engineering Schools and the Business School certainly needed to work much closer together and on the same context for the courses.This echoes the kind of significant collaboration needed amongst teaching staff of different schools in order to bring about successful implementation of integrated programmes as described by Froyd and Ohland (2005).

In sum, we have adopted CDIO to design the DEB programme with an integrated curriculum that makes explicit connections between related engineering and business subjects as well as fosters the learning of disciplinary knowledge together with personal, interpersonal and product and systems building skills (Standard 2 and 3). Learning experiences built into the courses have also led to the integration of CDIO learning outcomes and the disciplinary knowledge in both engineering and business (Standard 7).

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BIOGRAPHICAL INFORMATION

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Shanker Maniam is a lecturer and also the Programme Manager for the Diploma in Engineering with Business course at the School of Electrical and Electronic Engineering, Singapore Polytechnic. Leveraging on his academic and industry experience, Shanker is actively involved in the development and delivery of the course based on the CDIO framework.

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