A BENCH DESIGNED FOR ALL ASPECTS OF TEAMWORK IN CDIO PROGRAMMES

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ABSTRACT

Learning spaces designed for teamwork and active learning in CDIO-based engineering programmes need to be equipped with appropriate furniture. Spaces such as the new Active Learning Lab at the University of Liverpool have been designed to be flexible and to be re-configurable to suit widely different student activities. The specification for the furniture for this space therefore contained the following requirements:

- Nothing to be fixed to the floor, giving the potential for a single open space;
- Benches to accommodate teams of up to six students;
- Benches to be movable by one person, and to be capable of being linked to form a stage;
- Seating to be integral with the bench, so that when the benches are stored or configured as a stage no additional storage is required for seating;
- Maximum lockable storage available within the volume of the bench;
- No permanent projection above the flat upper bench surface;
- Power and data available on each bench via a single umbilical supply;

No ready-made solution meeting these criteria could be found from a commercial supplier so a custom solution was designed and 50 benches were commissioned. The design solution is presented in this poster.

INTRODUCTION

Learning spaces designed for teamwork and active learning in CDIO-based engineering programmes need to be equipped with appropriate furniture. Spaces such as the new Active Learning Lab (ALL) at the University of Liverpool have been designed to be flexible and to be re-configurable to suit widely different student activities. The ALL must accommodate 250 students working in teams of 5 or 6 who, on any particular day, might be engaged in any aspect of the CDIO range of activities. The space must be usable for team meetings, conceptual design, detailed engineering design, assembly and aspects of manufacturing, and ultimate testing and operation of products. The specification for the furniture for this space therefore contained the following requirements:

- Nothing to be fixed to the floor, giving the potential for each ALL to become a single open space;
- Benches to accommodate teams of up to six students, and to be robust enough for mechanical, electrical and civil engineering work;
- Benches to be movable by one person, and to be capable of being linked to form a stage;
- Seating to be integral with the bench, so that when the benches are stored or configured as a stage no additional storage is required for seating;
- Maximum lockable storage available within the volume of the bench;
- No permanent projection above the flat upper bench surface;

- Power and data available on each bench via a single umbilical supply;

No ready-made solution meeting these criteria could be found from a commercial supplier so a custom solution was designed and 50 benches were commissioned from British Thornton [1].

Key features of the benches are:

- The envelope for each bench is 2,000mm x 1,000mm x 920mm. Nothing protrudes beyond this envelope so benches can be abutted without gaps
- Load capacity (including the storage units/stools) is 900 kg
- Large castors
- Centre shelf which can be raised for storage and mounting of (e.g.) instruments (see Figure 4)
- Umbilical cord carrying power to six sockets and data to six outlets
- Stools/storage units with two castors and two fixed legs, which mount on steel plates within the bench for moving
- Bold colour-coded doors, so that each bench carries six stools of different colour, in which one team can store its tools, components and part-completed work. Thus the first-year students can be allocated the yellow cupboards, while second years have green etc.
- Every stool and every bench is numbered so that it can be identified after re-arrangement.

So far there has been no formal feedback from the student users, but anecdotally the benches have been well received, and the staff responsible for deploying them have found them easy to work with.

Figure 1 The benches in use by teams of six students

Figure 2 A bench in use for a bridge building exercise

Figure 3 Sixteen of the benches configured as a stage

Figure 4 The benches configured to create a large open space for "operation"

Figure 5 A bench with the central shelf raised and one storage seat removed

A plan of the bench and further pictures will be available at the conference on a CD.

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A CDIO APPROACH TO CREATIVITY, INNOVATION AND ENTERPRISE OPTION MODULES

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ABSTRACT

In 2005, a new Creativity, Innovation and Enterprise (CIE) Option was created for second year students to learn new skill-sets that are geared towards moving up the manufacturing value chain. This curriculum framework aims to infuse a mindset for Creativity, Innovation & Enterprise where students learn foundation product design and development skills in year 2 and apply them in their final year "CIE Option Project" (capstone project). This paper describes the achievements and results of the new option, making references to educational reforms and initiatives from Massachusetts Institute of Technology (MIT), Kanazawa Institute of Technology (KIT) as well as Singapore Polytechnic's best practices.

KEYWORDS

Creativity, Innovation, Enterprise, Engineering Design, Multi-disciplinary, Workspace

INTRODUCTION

Education Transformation

For Singapore to be competitive within the region, she has to move into higher value added manufacturing activities which involve developing Singapore's creative economy i.e. growing the design-driven industries (amongst them is product design and development). The push is to prepare trained workforce to engage in upstream activities and to groom a spirit of experimentation and entrepreneurship for original content creation. This allows Singapore to compete in the upstream position, and reduce the risk of competing via conventional means of cost and efficiency.

To facilitate infusion of design education into curriculum, the new CIE Option was launched for second year students which focus on training students with product design and development skill-sets as well as exposure to business basics. This framework was drafted based on MIT CDIO Standards, KIT Education Reform Initiatives and SP Educational Model.

The curriculum was designed to emphasize the multi-disciplinary nature of design, creativity, engineering, entrepreneurship and at the same time train students to meet industry

expectations. It also aims to harness the creative potential of technically competent polytechnic students and inculcates design capability and business practices.

Changes were made in the second year and third year curriculum to include modules that give students foundation design skill-sets in the second year with intensive project based learning in their third year. The integrated curriculum aims to give students:

1. strong technical and foundation skill-sets
2. practical skills through real world learning experiences
3. the opportunity for active applications to facilitate understanding and retention
4. a holistic training that includes personal, interpersonal, social and team building skills.

This paper highlighted three modules in the CIE Option, namely:
Second Year

1. Product Design and Development I (PDD1)
2. Product Design and Development II (PDD2)

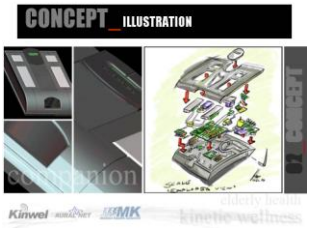
Third Year

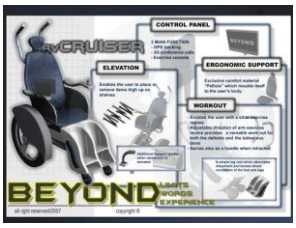
1. CIE Option Project (full time final year project)

PRODUCT DESIGN AND DEVELOPMENT 1 & 2 (PDD1 & PDD2)

In semester one of 2005, the first batch of CIE Option students began the new programme. The batch consisted of Mechanical Engineering (MM) and Chemical Engineering (CLS) students. They started with PDD1 foundation skills which include identify users' needs, ideation skills, defining product specifications and creating 3D concept models. PDD1 introduces basic design processes and techniques to students and in PDD2 they are given further in-depth skill-sets which they learn and apply them in their mini projects (CDIO design-build experience – Std 5).

In PDD1, students have to be conversant with product visualisation skills in order to create 3D forms of conceptual products. In PDD2, students venture further to refine their concepts; this time giving more thoughts into the details such as, the core technologies, rapid prototyping, human ergonomics, environmental and sustainable considerations. Below are some of the portfolios and presentations created by student teams. Some of the project poster presentations were sent to Kanazawa Institute of Technology (KIT) and exhibited at their engineering design poster session.





Mini project portfolios and presentation

SP students' posters displayed at Kanazawa Institute of Technology (KIT)

CIE OPTION PROJECT (CAPSTONE PROJECT)

In their 3rd year, the CIE option students follow a different training curriculum compared to mainstream students. They had to complete a one semester (15-weeks) of full time project work according to the CDIO stages and this is a major design-build experience programme for them. Here the project- based-learning, being full time, is more project-focused and intensive, somewhat similar to an industry setting.

To support the learning needs of this programme, the entire Integrated Project Centre (iPC) was renovated to provide the CDIO workspaces (Std 6). Unlike MIT's Guggenheim Aeronautical Laboratory where specific workspaces were designated for C, D, I and O; here, the entire iPC has to cater to the various stages of CDIO; adapting and 'transforming' as the needs changes. In addition, iPC is also used as an exhibition hall during the annual SP Spinnovex Exhibition where shortlisted final year projects are showcased. With these requirements in mind, the workspace was designed to be highly adaptable for the various stages of this programme; from C to D to I to O and to Spinnovex.

WORKSPACE TRANSFORMATION

To create a totally flexible workspace capable of 'transforming' to the needs, a custom built cubicle system was necessary. Each cubicle replicates an "engineering design office" with distinct colour scheme (representing multi-disciplinary collaborations) and an overhead signboard (for team identity). Student teams took to designing their own signboards to reflect their project themes and team identities. Each cubicle is also fully equipped with white board/paper holders for meetings, power sockets for notebooks, storage cabinets for bags and belongings, tables/side tables that can be arranged to suit the team's needs.

Conceive

This stage of the project usually requires teams to engage in ideation, brain storming and discussions with supervisors etc., which are supported by fact finding, research and surveys. Team meetings are carried out within the cubicle, complete with wireless internet access for students to explore options and possibilities.

Design

The teams then move on to this stage where details on developing project tangibles are needed. In the case of a multidisciplinary project like the aroma dispensing exercise game machine, MM students were involved in designing the hardware with CAD/CAID tools whilst the CLS students were identifying aromatic compounds and characterising formulations that will match the game scenarios at CLS labs.

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For product visualisation, the CAD/CAID Lab is located adjacent to the "engineering design office" and is fully equipped with workstations to support product design and development. What is unique about this setup is that all workstations are modular, i.e., each workstation with monitor is individually housed and can be set up at any locations within iPC to meet their learning requirements. Students find this flexibility most useful during the Implement and Operate stages where the availability of CAD tools near their project hardware helps to speed up modifications and design refinements.

“ENGINEERING DESIGN OFFICE” MODE @ iPC

CONCEIVE AND DESIGN

Teams settling in and putting up their signboards

Teams at work in their “Engg. Design Office”

Modular workstations at iPC’s CAD/CAID Lab can be moved from Lab to project site

Implement

As the project gets into this phase, there are more hands-on practical contents where assemblies, interfacing to electrical or chemical sub-systems, testing and troubleshooting are in progress. For larger projects that require more floor space, furniture within the cubicles can be rearranged to accommodate this requirement.

From ‘Office’ → (Conceive, Design)

To ‘Garage’ → (Implement, Operate)

Operate

The final phase is usually the most intensive stage of the project where bulk of the work is on the project hardware. Hence, each cubicle space is used as a “garage” with the tables rearranged. Students typically put in their last ditch effort to get the hardware operating; applying final touches to fine tune, test and enhance the appearance of their deliverables.

As the project exhibition date approaches, the “engineering design office” mode will now have to make way for the “exhibition” mode to prepare for Spinnovex. Students continue to work on their hardware while conversions of cubicles were carried out concurrently.

To reduce the need for additional storage space to house dismantled cubicle elements, the cubicle columns were reoriented and use as poster display boards. Similarly, the column sideboards were collectively joined to form the central divider with the C-I-E Towers providing the vertical support structure.

IMPLEMENT
AND OPERATE

Workspace is being transformed to “Exhibition” mode

Cubicles are reoriented and used as poster display boards

Central divider is formed by connecting cubicle sideboards (red arrows) to the C-I-E Towers (with green, blue and red display lights)

“EXHIBITION” MODE @ iPC during SPINNOVEX

Projects are moved in and setup for Spinnovex

CIE OPTION PROJECTS AT SPINNOVEX

Prof Matsuishi (KIT) on the xD Bike

MM / EEE team (Interactive Game-Bow & Arrow)

MM / CLS team (Physio-Beans)

RM Simulator team was featured in the Channel News Asia-Amazing Asia programme

Guest of Honour-Dr Chew (CEO of Singapore Science Centre) on the "Motion Simulator II"

EDUCATIONAL THEORIES

The CIE Option modules were based on several educational theories, namely Constructivism, Behaviourism and Problem based learning.

In constructivism, learners construct knowledge and meanings for themselves as they take in foundation knowledge (PDD1 and PDD2). They learn through their own experiences, building on their previous knowledge and using acquired experiences to solve new problems. The mini projects introduced in PDD1 and PDD2 gradually builds up their skills level in managing project work; starting with Conceive/Design in PDD1 and then Conceive/Design/Implement in PDD2. Also by increasing students' awareness of environmental impact and product life cycle considerations, they began to appreciate that product design as an all encompassing activity that needs to address not only functional requirements but also a host of other issues.

Behaviourism or 'operant conditioning' charges that all mental activity is a form of behaviour that responses to and interacts with environment stimuli. This led to the creation of a learning environment at iPC that best represents an industry scenario whilst working within the given space constraints. Having a personalised "engineering design office" with their own identity gives each team the added motivation and team spirit to meet their project challenges. By reinforcing what industry practises such as full-time project work, working within time and budget constraint, multi-disciplinary collaborations, self resource-fulness….these inevitably condition students to understand industries' expectations.

In incorporating Constructivism and Behaviourism into Problem-based-learning and making the process highly systematic (as in the CDIO approach), students are led through an instructional process that better prepares them in dealing with open ended real life problems. The mini projects in second year PDD1 and PDD2 prepares students for the final design-build experience (capstone project) and provides them a process framework for handling project work effectively.

Also the pervasive use of IT support systems at iPC continues to reinforce students' IT skills in leveraging on the latest technologies to enhance their learning. With these tools, students are able to learn both in the physical sense and, of increasingly importance, the virtual sense too.

The "engineering design office" workspace emphasises group learning through team work, social interaction and cross disciplinary learning through collaborations with students across the schools (MM, CLS and EEE). Students are therefore immersed in an environment that promotes collaborative inquiry across disciplines and develops co-operation, effective teamwork and mutual tolerance amongst team members. Such are the demands of the industry and incorporating these elements into their training will better prepare them for their working life.

CONCLUSIONS

From the results achieved by students in the CIE Option programme, it can be seen that building up students' skills in handling projects requires careful planning in the curriculum and syllabi that will not only provide the knowledge but also the "integration" and "use" of such knowledge towards solving real life problems. Using the systematic framework defined in CDIO standards, students are immersed in active learning activities that exposed them to 'design-build' scenarios; starting from mini projects to the eventual final year projects.

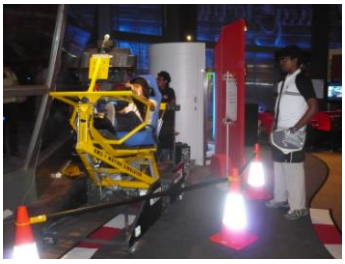
Reinforcement between theory and practice has been the key emphasis in education programmes at the KIT Yumekobo. The provision of facilities, workspaces, human resources to support theory and practice is also equally important and these were planned into the CIE Option right at the beginning.

The CIE Option's full-time intensive project over one semester also provides students a training environment that closely resembles that of the industry. Reporting daily to the Integrated Project Centre with biometric clock-in/out is a way of developing good work habits and attitudes that are vital to team project work. To further enhance team bonding especially when collaborating with students across schools, the programme starts them early in their second year with their PDD1, PDD2 modules and mini projects. The social interactions and team activities helps to build up trust and understanding between members and gave them the confidence in working with 'familiar' team players. For ad-hoc projects (e.g. industry based projects involving EEE students), the EEE students are introduced to the team in semester one i.e. one semester before the actual start of the full time project and this arrangement had shown to be effective.

Students' feedbacks on the CIE Option modules have been encouraging and their learning outcomes have not gone unnoticed. The RM Simulator was loan to the Singapore Science Centre for the "Science of F1 Exhibition"; the Massage Jacket and iExercise Machine generated interest amongst industry partners. A number of project teams also received commendations in gold, silver and bronze certificates for their project achievements.

‘RM SIMULATOR’ EXHIBITED AT THE SINGAPORE SCIENCE CENTRE “THE SCIENCE OF F1” EXHIBITION DURING THE INAUGURAL LAUNCH OF F1 NIGHT RACE IN SINGAPORE LAST SEPTEMBER

Front façade of the Singapore Science Centre with “The Science of F1” Exhibition banner



Students “Operate” on site during setup

Poster boards on the RM Simulator

The CIE Option programme has come a long way since it took in the first batch of students in 2005 and the building blocks that make it work….CDIO Standards, KIT Initiatives and SP Educational Model with integrated curriculum, adaptable workspaces, team building…all adds up to the goal of providing a sound education and skills training that aim to meet the needs of industries.

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MM/CLS Class of ’07-’08

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A COMPARISON OF THE CDIO AND EUR-ACE QUALITY ASSURANCE SYSTEMS

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ABSTRACT

In a CDIO programme, the CDIO syllabus, standards, and self-evaluation model constitute the core components of the programme's quality assurance system.

At the same time, CDIO programmes are also evaluated by national standards. A CDIO programme needs a quality assurance system which also fulfils these national requirements, and that is able to produce the evidence and documentation needed for a national evaluation with minimal additional effort. Efficient execution of this task requires understanding of the similarities and differences between the CDIO and national quality assurance systems.

In this paper, we consider the emerging European standards for accreditation of engineering programmes, the EUR-ACE standards. We account for a comparison between the CDIO syllabus and the EUR-ACE counterpart, the programme outcomes, and by the CDIO standards and EUR-ACE accreditation criteria, identifying similarities and differences. A discussion is conducted on the pros and cons of a rating scale-based system for continuous improvement and a threshold-based accreditation model.

The paper concludes that:

- The CDIO syllabus reflects a more encompassing view of engineering than EUR-ACE's, by considering the full product/system/process lifecycle, including the implementing and operating life phases. The proficiency levels of the CDIO and EUR-ACE are, however, difficult to compare.
- The EUR-ACE accreditation requirements are extensive and include elements not addressed in the CDIO framework, eg concerning financial resources and decision-making. The CDIO standards provide "solutions" on how to work with about ¾ of the issues raised in a EUR-ACE accreditation.
- Four of the CDIO standards (4, 5, 7, and 8) define educational elements which are not explicitly discussed in EUR-ACE accreditation requirements.
- An evaluation process based on a rating scale, such as the CDIO self-evaluation model, is more useful for continuous improvement than a threshold value scale, such as used in a EUR-ACE accreditation.

KEYWORDS

Quality assurance, CDIO, EUR-ACE, Engineering education

INTRODUCTION

CDIO, in a general sense, aims to raise the quality of the educational programs that apply the concept. CDIO includes a number of components that can be classified as quality assurance tools: In a CDIO programme, the CDIO syllabus, standards, and self-evaluation model constitute the core components of the programme's quality assurance (QA) system.

At the same time, CDIO programmes are also evaluated by national standards, for example in accreditations such as the US ABET [1] system, or in evaluations such as conducted by the Swedish National Agency for Higher Education [2]. A CDIO programme needs a quality assurance system which also fulfils these national requirements, and that is able to produce the evidence and documentation needed for a national accreditation/evaluation with minimal additional effort. Efficient execution of this task requires understanding of the similarities and differences between the CDIO and national quality assurance systems.

Earlier work has compared the CDIO syllabus with the ABET criteria, the UK-SPEC criteria [3], and the Swedish engineering degree requirements [4]. A common finding is that the CDIO syllabus states more encompassing and detailed learning outcomes for engineering education. The CDIO standards and the associated self-evaluation model have been used as part of a Swedish national evaluation of engineering degree programmes, demonstrating that they can be applied for systematic comparisons of key issues across a large number of programmes [5, 6].

The mentioned quality standards are all national. In this paper, we are considering an international quality assurance framework standard, namely the emerging European framework standards for accreditation of engineering programmes, the EUR-ACE standards [7]. These standards have been developed as a part of the Bologna process, and can be expected to be of growing importance in the future, at least in the European context. We are also investigating the documentation required for accreditation with that produced by a CDIO quality assurance system, and discuss the principal differences between accreditation-based quality assurance system and rating scale-based quality assurance systems.

The objectives of this paper are to:

- Clarify the similarities and differences between a CDIO and a EUR-ACE-based quality assurance system.
- Identify the strengths and weaknesses of each model.
- Identify future development routes for both the CDIO and EUR-ACE quality assurance systems.

The results will inform CDIO programmes on how to relate to EUR-ACE and on how to plan for an accreditation.

The remainder of the paper is structured as follows. In the next section we review the CDIO quality assurance system, focusing on the CDIO syllabus, standards and associated self-evaluation model. A similar review is then presented for the EUR-ACE framework. This is followed by a comparison and discussion. Finally, conclusions are listed.

THE CDIO QUALITY ASSURANCE SYSTEM

Improving educational quality is a fundamental goal for CDIO. CDIO standard five states that a CDIO programme should have a system that evaluates the programme against the CDIO standards, and provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement [3].

Table 1
CDIO syllabus at second level of detail [3].

1	**Technical Knowledge and Reasoning**		**3**	**Interpersonal Skills and Attributes: Teamwork and Communication**	
1.1	Knowledge of underlying science		3.1	Multi-disciplinary teamwork	
1.2	Core engineering fundamental knowledge		3.2	Communications	
1.3	Advanced engineering fundamental knowledge		3.3	Communications in foreign languages	
2	**Personal and Professional Skills and Attributes**		**4**	**Conceiving, Designing, Implementing and Operating Systems in the Enterprise and Societal Context**	
2.1	Engineering reasoning and problem solving		4.1	External and societal context	
2.2	Experimentation and knowledge discovery		4.2	Enterprise and business context	
2.4	System thinking		4.3	Conceiving and engineering systems	
2.5	Personal skills and attributes		4.4	Designing	
2.6	Professional skills and attributess		4.5	Implementing	
			4.6	Operating	

The standard further suggests that multiple methods should be used to evaluate the programme, including course evaluations, instructor reflections, entry and exit interviews, reports of external reviewers, and follow-up studies with graduates and employers. However, three components can be said to constitute the core of the quality assurance system of a CDIO programme:

- The use of CDIO syllabus to define the programme's goals, ie WHAT the programme aims to achieve.
- The use of the CDIO standards as a guideline when designing and operating the programme, ie HOW the programme goals are achieved.
- The use of the CDIO self-evaluation to measure the programme's progress towards fulfilling the CDIO standards, ie HOW WELL is the programme performing.

The CDIO Syllabus

The CDIO syllabus is a comprehensive list of engineering education learning outcomes. It was developed through a systematic process including comparison with reference models such as the ABET criteria, peer reviews, workshops and surveys [6]. It serves as a basis for developing a programme goal statement. It is intentionally limited to non-discipline-specific learning outcomes such as experimentation, communication and designing. The programme itself must complement these with discipline-specific subject matter learning outcomes, for example in thermodynamics. Moreover, the CDIO syllabus only lists topics. It is up to the programme, in consultation with its stakeholders, to establish suitable levels of proficiency for each of the topics in order to develop proper learning outcomes. Table 1 shows the CDIO syllabus at the second level of detail. The complete syllabus is very comprehensive and detailed, with 3-4 additional levels and in total lists more than 400 topics.

The CDIO Standards

In order to meet the goals stated by the help of the CDIO syllabus, the design of a CDIO programme is guided by the CDIO standards, a set of twelve principles that characterizes this educational model as well as general good practice in education [3]. The CDIO standards were developed in response to the request from programme stakeholders to be able to recognize CDIO programs and their graduates. The standards serve as guidelines for educational program reform and evaluation, create benchmarks and goals with worldwide

Table 2
The CDIO Standards [3].

CDIO STANDARD			
1	**CDIO as Context**	7	**Integrated Learning Experiences**
	Adoption of the principle that product, process, and system lifecycle development and deployment—Conceiving-Designing-Implementing-Operating—are the context for engineering education.		Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal and interpersonal skills; and product, process, and system building skills.
2	**CDIO Syllabus Outcomes**	8	**Active Learning**
	Specific, detailed learning outcomes for personal and interpersonal skills; and product, process, and system-building skills, consistent with program goals and validated by program stakeholders.		Teaching and learning based on active and experiential learning methods.
3	**Integrated Curriculum**	9	**Enhancement of Faculty CDIO Skills**
	A curriculum designed with mutually supporting disciplinary subjects, with an explicit plan to integrate personal and interpersonal skills; and product, process, and system building skills.		Actions that enhance faculty competence in personal and interpersonal skills; and product, process, and system building skills.
4	**Introduction to Engineering**	10	**Enhancement of Faculty Teaching Skills**
	An introductory course that provides the framework for engineering practice in product, process, and system building, and introduces essential personal and interpersonal skills.		Actions that enhance faculty competence in providing integrated learning experiences, in using active experiential learning methods, and in assessment.
5	**Design-Implement Experiences**	11	**CDIO Skills Assessment**
	A curriculum that includes two or more design-implement experiences, including one at a basic level and one at an advanced level.		Assessment of student learning in personal and interpersonal skills; and product, process, and system building skills, as well as in disciplinary knowledge.
6	**CDIO Workspaces**	12	**CDIO Program Evaluation**
	Workspaces and laboratories that support and encourage hands-on learning of product, process, and system building, as well as disciplinary knowledge and social learning.		A system that evaluates programs against these standards, and provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement.

application, and provide a framework for continuous improvement. The standards address program philosophy, curriculum development, design-build experiences and workspaces, new methods of teaching and learning, faculty development, and assessment and evaluation. Table 2 lists the CDIO standards.

The CDIO self-evaluation model

The determination of a program's progress towards fulfilment of the CDIO standards is accomplished through self-evaluation. The fulfilment of each standard is measured by a five-level scale, which is used to rate the progress towards the planning, implementation and adoption of each CDIO standard. The rubrics of the five-level scale are stated in Figure 1 (left). The scale ranges from "initial program-level plan or pilot implementation" to "complete and adopted program-level and comprehensive implementation of the plan at the course or program levels, with continuous improvement processes in place", and thus provide a step-by-step guide for programme evolution. Self-evaluation using the 12 CDIO standards and the five-level rating scale provides a tool for the monitoring of improvements via a series of evaluations where overall program improvement can be made visualized. See Figure 1.

The CDIO quality assurance components can then be included in a CDIO programme's quality assurance system, which should also include other components, such as course evaluation tools and student achievement follow-ups. As an example, Figure 2 shows the quality assurance system of Chalmers University of Technology's Mechanical engineering programme [9]. The quality assurance system is organized around a plan-do-check-act cycle with the CDIO components in relevant phases.

0	No initial program-level plan or pilot implementation
1	Initial program-level plan and pilot implementation at the course or program levels
2	Well-developed program-level plan and prototype implementation at the course or program levels
3	Complete and adopted program-level implementation of the plan at the course or program level under way
4	Complete and adopted program-level and comprehensive implementation of the plan at the course or program levels, with continuous improvement processes in place

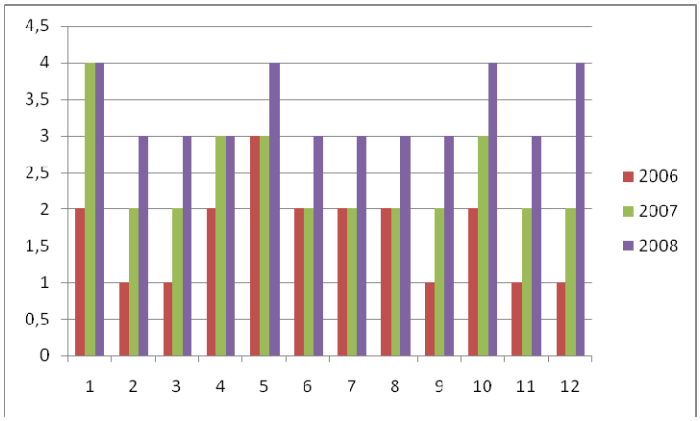

Figure 1. CDIO standards self-evaluation rating scale and chart showing improvement during a three-year period.

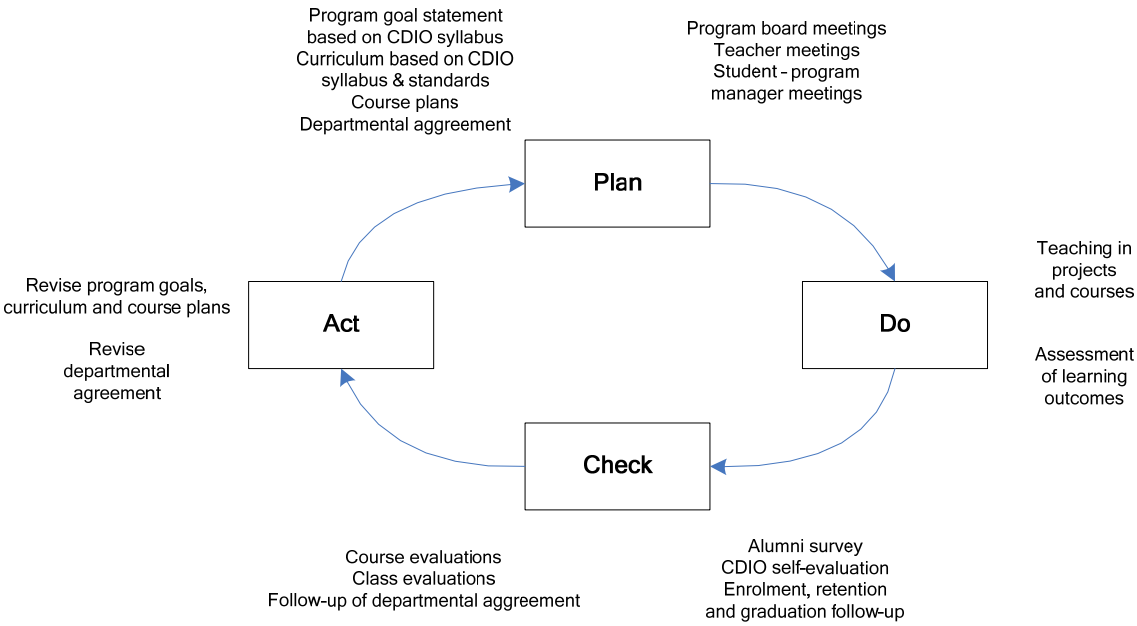

Figure 2. Example of quality loop in CDIO programme. Adapted from [9].

THE EUR-ACE QUALITY ASSURANCE SYSTEM

The Bologna process has in the European Higher Education Area (EHEA) resulted in a common qualifications framework comprising the 1st (bachelor), 2nd (master) and 3rd (doctor) degree cycles. Components of the framework include the EQF qualifications [10] and the ECTS credit system. European standards for internal and external quality assurance are proposed [11].

The EQF qualifications framework relies on stated learning outcomes that are rather general and applicable across all university education sectors. In order to effectively guide education design and accreditation processes for specific fields, more detailed learning outcomes need to be defined. As a result, "sectoral EQFs" are emerging. The sectoral EQFs have the aim of developing the high-level EQF characteristics into detailed learning outcomes that should characterize specific professional degrees. In the field of engineering, the EUR-ACE framework standards [7] are taking this role.

The EUR-ACE standards comprise three main parts:

- A set of programme outcomes for 1st and 2nd cycle engineering degrees.
- Guidelines for programme assessment and accreditation.
- A procedure for programme assessment and accreditation.

The EUR-ACE programme outcomes

The EUR-ACE programme outcomes describe the capabilities required of graduates from 1st and 2nd cycle engineering degree programmes. They can thus be viewed as the "syllabus" of the EUR-ACE. We will use the term the EUR-ACE syllabus in the following. The EUR-ACE syllabus is structured in six main categories: Knowledge and understanding, Engineering analysis, Engineering design, Investigations, Engineering practice and Transferable skills.

The EUR-ACE syllabus for 1st cycle degrees is shown in Table 3. The 2nd cycle version both adds progression with respect to the 1st cycle outcomes, and adds some additional outcomes, for example "Work and communicate effectively in national and international contexts". The outcomes are not numbered in the original document; we have done so here in order to facilitate the comparison presented in the next section.

EUR-ACE guidelines for programme assessment

The second part of the EUR-ACE standards is the guidelines for programme assessment and accreditation. It is stated that a programme that seeks accreditation should have in place:

- Programme educational objectives consistent with the mission of the Higher Education Institution and the needs of all interested parties (such as students, industry, engineering associations, etc.) and programme outcomes consistent with the programme educational objectives and the programme outcomes for accreditation.
- A curriculum and related processes which ensure achievement of the programme outcomes.
- Academic and support staff, facilities, financial resources etc adequate to accomplish the programme outcomes.
- Appropriate forms of assessment which attest the achievement of the programme outcomes.
- A management system able to ensure the systematic achievement of the programme outcomes and the continual improvement of the programme.

Table 3
EUR-ACE programme outcomes - the “EUR-ACE syllabus”.

1	**Knowledge and Understanding**	
	1.1	Knowledge and understanding of the scientific and mathematical principles underlying their branch of engineering
	1.2	A systematic understanding of the key aspects and concepts of their branch of engineering
	1.3	Coherent knowledge of their branch of engineering including some at the forefront of the branch
2	**Engineering Analysis**	
	2.1	The ability to apply their knowledge and understanding to identify, formulate and solve engineering problems using established methods
	2.2	The ability to apply their knowledge and understanding to analyse engineering products, processes and methods
	2.3	The ability to select and apply relevant analytic and modelling methods
3	**Engineering Design**	
	3.1	The ability to apply their knowledge and understanding to develop and realise designs to meet defined and specified requirements
	3.2	An understanding of design methodologies, and an ability to use them
4	**Investigations**	
	4.1	The ability to conduct searches of literature, and to use data bases and other sources of information
	4.2	The ability to design and conduct appropriate experiments, interpret the data and draw
	4.3	Workshop and laboratory skills
5	**Engineering Practice**	
	5.1	The ability to select and use appropriate equipment, tools and methods
	5.2	The ability to combine theory and practice to solve engineering problems
	5.3	An understanding of applicable techniques and methods, and of their limitations
	5.4	An awareness of the non-technical implications of engineering practice
6	**Transferable skills**	
	6.1	Function effectively as an individual and as a member of a team
	6.2	Use diverse methods to communicate effectively with the engineering community and with society at large
	6.3	Demonstrate awareness of the health, safety and legal issues and responsibilities of engineering practice, the impact of engineering solutions in a societal and environmental context, and commit to professional ethics, responsibilities and norms of engineering practice
	6.4	Demonstrate an awareness of project management and business practices, such as risk and change management, and understand their limitations
	6.5	Recognise the need for, and have the ability to engage in independent, life-long learning

Accordingly, the guidelines for assessment and accreditation are divided into five main sections: Needs, objectives and outcomes, Educational process, Resources and partnerships, Assessment of the educational process and Management system. For each of these sections, criteria, requirements and related evidence that should be included in the accreditation documentation are identified.

Table 4 shows the main guideline sections, criteria and requirements. The lists of evidence required for accreditation numbers circa 30 items, including needs identified for all stakeholder [1.1], curriculum [2.1] and number and competence of staff [3.1]. Due to spatial constraints, the full list of evidence is not included here. However, it can be argued that the documentation required for accreditation is comprehensive.

Table 4
EUR-ACE accreditation guideline sections, criteria and requirements.

Guidelines for Accreditation	Criteria to be assessed	Requirements
1. Needs, Objectives and Outcomes	1.1 Needs of the Interested Parties	Have the needs of the interested parties (such as students, industry, engineering associations, etc.) been identified?
	1.2 Educational Objectives	Are the programme educational objectives consistent with the mission of the Higher Education Institution (HEI) and with the needs of the interested parties (such as students, industry, engineering associations, etc.)?
	1.3 Programme Outcomes	Do the programme outcomes cover the programme outcomes, for accreditation (cf. Section 1)?
		Are the programme outcomes consistent with the programme educational objectives?
2. Educational Process	2.1 Planning	Does the curriculum ensure the achievement of the programme outcomes?
	2.2 Delivery	Is teaching delivered according to planning?
		Are counselling and support-workload offered to the students adequate to promote the achievement of the modules' specific learning outcomes?
	2.3 Learning Assessment	Have examinations, projects and other assessment methods, been designed to evaluate the extent to which students can demonstrate achievement of the learning outcomes of single modules and programme outcomes respectively throughout the programme and at its conclusion?
3. Resources and Partnerships	3.1 Academic and Support Staff	Is the academic staff adequate to accomplish the programme outcomes?
		Is the technical and administrative support staff adequate to accomplish the programme outcomes?
	3.2 Facilities	Are the classrooms adequate to accomplish the programme outcomes?
		Are the computing facilities adequate to accomplish the programme outcomes?
		Are the laboratories, workshops and associated equipment adequate to accomplish the programme outcomes?
		Are the libraries and associated equipment and services adequate to accomplish programme outcomes?
	3.3 Financial Resources	Are the financial resources adequate to accomplish the programme outcomes?
	3.4 Partnerships	Do the partnerships the HEI and the programme are participating in contribute to accomplish the programme outcomes and facilitate the mobility of the students?
4. Assessment of Educational Process	4.1 Students	Do the students enrolled in the programme have the right knowledge and attitudes to achieve the programme outcomes in the expected time?
		Do the results related to the students' career attest the achievement of the programme outcomes in the expected time?
	4.2 Graduates	Do graduates enter an occupation corresponding to their qualification?
		Do stakeholders (graduates, employers, etc.) confirm the achievement of the programme's educational objectives?
5. Management System	5.1 Organisation and decision-making processes	Are HEI's and programme's organisation and decision-making processes adequate to accomplish the programme outcomes?
	5.2 Quality Assurance System	Are HEI's and programme's Quality Assurance Systems effective to ensure the achievement of the programme outcomes?
		Are the delivery process', students' and graduates' results analysed and used to promote continual improvement of the programme?
		Are needs, objectives and outcomes, educational process, resources and partnerships, management system periodically re-examined?

EUR-ACE procedure for programme assessment and accreditation

The first step of the EUR-ACE accreditation process is the preparation of a self-assessment report according to the requirements listed in the previous section.

The report is examined by an accreditation team in preparation for a site visit at the university. The site visit should include meetings with the university management, academic and support staff members, current and former students, and employers; visits to facilities (libraries, laboratories, etc.); and review of project work, final papers etc. At the end of the site visit, feedback from the accreditation team is presented.

The accreditation team then writes a report. The fulfilment of each individual requirement is assessed, using a scale with at least the following three levels: Acceptable; Acceptable with prescriptions; Unacceptable. The overall achievement of the requirements is also evaluated using a scale with at least three levels: Accredited without reservation; Accredited with prescriptions; Not accredited. The university has the opportunity to check the report for factual errors.

The final accreditation decision is taken by an accreditation institution, and may be valid for up to six years. After that time, re-accreditation is required.

COMPARISON

This section presents a comparison of the CDIO and EUR-ACE quality assurance system components. We start by contrasting the programme goals of each approach – the CDIO and EUR-ACE syllabi. We then discuss how the standards of CDIO related are to the accreditation requirements of EUR-ACE. Finally, we seek to identify advantages and disadvantages of a rating-based quality assurance approach like that of CDIO with a threshold-based one, such as EUR-ACE's.

The CDIO syllabus vs. the EUR-ACE syllabus

The relationships between the CDIO and EUR-ACE syllabi are mapped in Table 5. In this table, the 2nd cycle version of the EUR-ACE syllabus is used as it includes a few additional outcomes as compared to the 1st cycle one.

However, prior to scrutinizing the table, we note that the EUR-ACE standard lacks a "portal" statement of what engineers do, comparable to CDIO's "Engineers Conceive-Design-Implement-Operate complex systems in a modern, team-based environment". The EUR-ACE documentation states the term "engineer" has been avoided because of the confusion that could arise from its widely different interpretations within Europe, including specific regulatory meanings in some countries [7]. However, through the main headings of the EUR-ACE syllabus, we observe that the "EUR-ACE engineer" seems to be primarily focused on Analysis-Design-Investigation, essentially the Conceive and Design phases in CDIO. By contrast, a "CDIO engineer" should also be able to Implement and Operate, to be able work throughout the full product/system/process lifecycle.

These differences are also visible in Table 5, where all EUR-ACE items have CDIO correspondents, while the CDIO syllabus categories 4.5 (Implementing) and 4.6 (Operating) lack EUR-ACE counterparts.

Table 5
EUR-ACE syllabus items vs. the CDIO syllabus.

EUR-ACE syllabus, 2nd cycle	CDIO syllabus level x.x																
	1.1	1.2	1.3	2.1	2.2	2.3	2.4	2.5	3.1	3.2	3.3	4.1	4.2	4.3	4.4	4.5	4.6
1.1	X																
1.2		X															
1.3			X														
1.4						X									X		
2.1				X													
2.2				X										X	X		
2.3				X										X	X		
2.4			X	X										X	X		
3.1														X	X		
3.2							X							X	X		
3.3						X								X	X		
4.1					X												
4.2					X												
4.3					X												
4.4			X		X												
5.1		X	X	X													
5.2		X	X	X		X											
5.3		X	X	X													
5.4												X	X				
6.1									X								
6.2										X							
6.3								X				X					
6.4													X				
6.5							X										
6.6									X					X			

It should also be noted that there are significant differences between 1st and 2nd cycle goals in the EUR-ACE syllabus. If the analysis is limited to the 1st cycle EUR-ACE requirements, more differences can be observed. For this cycle, the EUR-ACE syllabus also lacks correspondents to 2.3 (Systems thinking), 3.3 (Communication in foreign languages) and 4.3 (Conceiving).

A principal difference between the EUR-ACE and CDIO syllabi is that proficiency levels are “given” in the EUR-ACE syllabus, whilst they should be developed by a CDIO programme by surveying its stakeholders. Comparing proficiency levels is complicated by the one-to-many relationships between some syllabi items. Nevertheless, some comparisons can be made by translating EUR-ACE syllabi items to the MIT activity based proficiency scale [8] and comparing them with data from CDIO syllabus surveys. The MIT scale was developed for the first CDIO syllabus survey and provides a proficiency taxonomy with five levels (Table 6):

Table 6
MIT activity-based proficiency scale.

1	To have experienced or been exposed to
2	To be able to participate in and contribute to
3	To be able to understand and explain
4	To be skilled in the practice or implementation of
5	To be able to lead or innovate in

Table 7
Comparisons of proficiency levels (PL) in EUR-ACE,
in a Swedish CDIO syllabus survey, and in the Swedish degree ordinance.

CDIO syllabus item	EUR-ACE		Swedish survey		Swedish degree ordinance	
	Text	PL	Text	PL	Text	PL
2.5 Professional skills	Commit to professional ethics, responsibilities and norms of engineering practice	2	Able to participate/able to explain	2.6	Demonstrate awareness of ethical aspects of research and development work	1
3.1 Teamwork	Function effectively as leader of a team that may be composed of different disciplines and levels	5	Skilled in the practice of teamwork	3.9	Engage in teamwork and cooperation in groups of varying composition;	4
3.2 Communication	Work and communicate effectively in national and international contexts.	4	Able to understand/ skilled in the practice of communication	3.6	Clearly present and discuss their conclusions ... orally and in writing, in national and international contexts	4

We can then compare the proficiency levels for three EUR-ACE syllabus items which have single CDIO syllabus item correspondents, with data from a survey of Swedish industry leaders on their expectations on graduates [12]. The related statements from the Swedish degree ordinance for the MScEng degree are introduced as a benchmark [13]. See Table 7.

It is apparent from Table 7 that the stated proficiency levels vary. EUR-ACE states a significantly higher goal for team leadership capabilities (3.1 Teamwork). However, it can be questioned if it is a realistic goal for all recent graduates from a 2nd cycle engineering programme to have this capability. For 3.2 Communication, the desired proficiency levels are reasonably similar. For 2.5 Professional skills, the spread is the largest.

The major differences between the EUR-ACE and CDIO syllabus are similar to those between the CDIO syllabus and the ABET criteria [8] and between the CDIO syllabus and the Swedish engineering [4]. However, the somewhat higher level of detail of the EUR-ACE syllabus as compare with the two other syllabi (25 items vs. 10 and 12, respectively) results in a simpler mapping. There are more one-to-one or one-to-few relationships in the EUR-ACE-CDIO table. This should facilitate the application of the EUR-ACE as a tool in educational development. However, the CDIO syllabus has 3-4 additional levels of detail, supporting programme-level as well as course-level educational development.

The CDIO standards vs. the EUR-ACE requirements for accreditation

Now let us consider the relationship between the CDIO standards and the EUR-ACE requirements for accreditation. The EUR-ACE accreditation standards/criteria are “Whats”, ie they state what should be achieved but not how, it is up to the accredited university to devise solutions. The CDIO standards are “Hows”.

Table 8 shows that CDIO standards address of 18 out of 24 EUR-ACE requirements. Criteria that lack corresponding CDIO standard include teacher and support staff availability, entrance requirements, organization, financial resources, throughput time and partnerships. On the next level, the EUR-ACE standards identify about 30 evidentiary items that should be part of the accreditation self-assessment package. About 2/3 of these can be directly addressed through CDIO materials. However, the EUR-ACE accreditation criteria also require many specific documentary evidence which are not CDIO-specific, including

Table 8
EUR-ACE accreditation criteria vs. CDIO standards

Guidelines for Accreditation	Criteria to be assessed	Requirements	CDIO Std
1. Needs, Objectives and Outcomes	1.1 Needs of the Interested Parties	Have the needs of the interested parties (such as students, industry, engineering associations, etc.) been identified?	1, 2
	1.2 Educational Objectives	Are the programme educational objectives consistent with the mission of the Higher Education Institution (HEI) and with the needs of the interested parties (such as students, industry, engineering associations, etc.)?	2
	1.3 Programme Outcomes	Do the programme outcomes cover the programme outcomes, for accreditation (cf. Section 1)?	2
		Are the programme outcomes consistent with the programme educational objectives?	2
2. Educational Process	2.1 Planning	Does the curriculum ensure the achievement of the programme outcomes?	3
	2.2 Delivery	Is teaching delivered according to planning?	12
		Are counselling and support-workload offered to the students adequate to promote the achievement of the modules' specific learning outcomes?	
	2.3 Learning Assessment	Have examinations, projects and other assessment methods, been designed to evaluate the extent to which students can demonstrate achievement of the learning outcomes of single modules and programme outcomes respectively throughout the programme and at its conclusion?	11
3. Resources and Partnerships	3.1 Academic and Support Staff	Is the academic staff adequate to accomplish the programme outcomes?	9, 10
		Is the technical and administrative support staff adequate to accomplish the programme outcomes?	9, 10
	3.2 Facilities	Are the classrooms adequate to accomplish the programme outcomes?	6
		Are the computing facilities adequate to accomplish the programme outcomes?	6
		Are the laboratories, workshops and associated equipment adequate to accomplish the programme outcomes?	6
		Are the libraries and associated equipment and services adequate to accomplish programme outcomes?	6
	3.3 Financial Resources	Are the financial resources adequate to accomplish the programme outcomes?	
	3.4 Partnerships	Do the partnerships the HEI and the programme are participating in contribute to accomplish the programme outcomes and facilitate the mobility of the students?	
4. Assessment of Educational Process	4.1 Students	Do the students enrolled in the programme have the right knowledge and attitudes to achieve the programme outcomes in the expected time?	
		Do the results related to the students' career attest the achievement of the programme outcomes in the expected time?	
	4.2 Graduates	Do graduates enter an occupation corresponding to their qualification?	12
		Do stakeholders (graduates, employers, etc.) confirm the achievement of the programme's educational objectives?	12
5. Management System	5.1 Organisation and decision-making processes	Are HEI's and programme's organisation and decision-making processes adequate to accomplish the programme outcomes?	
	5.2 Quality Assurance System	Are HEI's and programme's Quality Assurance Systems effective to ensure the achievement of the programme outcomes?	12
		Are the delivery process', students' and graduates' results analysed and used to promote continual improvement of the programme?	12
		Are needs, objectives and outcomes, educational process, resources and partnerships, management system periodically re-examined?	12

examples of final projects, examination papers, budget, research merits and so on. Preparing for a EUR-ACE accreditation is a comprehensive activity. However, a programme that carries out a CDIO introduction will have worked through a majority of the issues raised in the accreditation process.

Some CDIO standards do not appear in Table 8; this applies to CDIO standards 4, 5, 7 and 8. These standards refer to CDIO-specific curricular elements (introductory courses, design-implement-experiences) and pedagogical approaches (integrated and active learning). These elements are essential for the quality of a CDIO programme. However, it is not evident how these elements will be valued in a EUR-ACE accreditation.

The CDIO self-evaluation model vs. the EUR-ACE accreditation process

Finally, let us consider the two models from a quality assurance process perspective. The key differences between the models are summarized in Table 9.

A CDIO self-evaluation is typically performed internally. However, the external view of an accrediting team may be more critical and provide more reference to educational practices at other universities. The external and compulsory nature of an accreditation may also give a stronger sense of urgency for change needs identified in the self-assessment step or pointed out by the accreditation team: Someone from the outside is requiring us to make these changes. An internal, voluntary evaluation such as a CDIO self-evaluation based one may also be slower in accommodating emerging external goals.

An evaluation towards a rating scale, such as the CDIO self-evaluation model, is more suitable for continuous improvement: It is a recurring activity, and it provides for target-setting and follow-up of multi-year improvement projects, whereas a threshold-based evaluation such as a EUR-ACE accreditation does not provide the university with any direction for future development, beyond fulfilling the requirements. A CDIO self-evaluation, with its more limited information requirements, is possible to update annually, whilst an accreditation typically takes place with six-year internals. The CDIO self-evaluation model also supports follow-up of “How” educational elements (introductory course, integrated learning etc) which are not considered in the EUR-ACE requirements, which are stated in “What” terms, and refrains from prescribing specific curricular elements (except for “projects”) and pedagogical approaches.

A possible future development direction for the EUR-ACE standards is to incorporate some rating-scale elements, enabling systematic comparisons between different engineering programmes, and guiding continuous improvement beyond the threshold value. The feasibility of inclusion of such components has been demonstrated by the Swedish national agency for higher education [2]. If the trend towards ranking-oriented evaluations continues, a CDIO standards-based self evaluation can be an important part of the evaluation package. The EUR-ACE standards could also refine the requirement for a quality assurance system, to state that a system with a proven support for continuous improvement is required.

One possible future development of the CDIO self-evaluation model includes encouraging a stronger external element in the evaluation, perhaps by inviting external evaluators, or by conducting bilateral university evaluations. An external view could bring in new perspectives and contribute to raise the quality and completeness of the (self-) evaluation data. Another development is to encourage universities to customize the CDIO self-evaluation model, for instance by including measurements and goals for student retention in the same follow-up.

Table 9
Comparison between CDIO self-evaluation process and EUR-ACE accreditation process

CDIO self-evaluation	**EUR-ACE accreditation**
Internal evaluators	External accreditation team
Internal goals	External goals
Voluntary	Compulsory
Evaluation with respect to rating scale	Threshold
Yearly	Six-year intervals
Limited amount of data	Comprehensive amount of data

CONCLUSIONS

The paper compares the elements of a CDIO quality assurance system with those of EUR-ACE. We conclude that:

- The CDIO syllabus reflects a more encompassing view of engineering than EUR-ACE's, by considering the full product/system/process lifecycle, including the implementing and operating life phases. The proficiency levels of the CDIO and EUR-ACE are, however, difficult to compare.
- The EUR-ACE accreditation requirements are extensive and include elements not addressed in the CDIO framework, eg concerning financial resources and decision-making. The CDIO standards provide "solutions" on how to work with about ¾ of the issues raised in a EUR-ACE accreditation.
- Four of the CDIO standards (4, 5, 7, and 8) define educational elements which are not explicitly discussed in EUR-ACE accreditation requirements.
- An evaluation process based on a rating scale, such as the CDIO self-evaluation model, is more useful for guiding a continuous improvement process than a threshold value scale, such as used in a EUR-ACE accreditation.

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Biographical Information

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A Design and a Practice of ELDP Project --- LMS, Podcasting, and English Presentation Class

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ABSTRACT

This paper introduces a new type of English presentation course that emphasizes project work and internet technology. The course model discussed here was conducted at the authors' institution during the 2008 academic year over a period of 4-months. The principle behind the project was ELDP, which stands for "English class Linked to a Direct Product", and it is based on two themes: "creation" and "public participation", with English being the project's target language. Specifically, students created a podcast movie, or vodcast, which could be shared with others. The ELDP module was conducted during the second term of a yearlong course, in which the first term was devoted to more traditional PowerPoint presentations that stressed public speaking skills, visual aids, and question-and-answer sessions. Under the ELDP project, students not only used English to create educational videos, they also had to acquire non-linguistic skills, such as uploading video to a server, downloading mobile content, and becoming familiar with the learning management system (LMS). While such a project can be demanding, the purpose-driven, real-world nature of the task can be motivating for students. It will be concluded in this paper that the concept of "creation" and its beneficial effects extends beyond engineering, and is applicable to the broader field of English education as well. For example, the vodcasting project mentioned in this paper could provide a platform for both English learners and educators to introduce and promote their communities, countries and cultures to the world at large.

KEYWORDS

ICT, Podcasting, Presentation Class, ELDP

1. BACKGROUNDS

Let us start by introducing of the National College of Technology in Japan, where this paper's authors are currently employed. In 1961, the Ministry of Education of Japan incorporated the nation's colleges of technology (translated as *kosen* in Japanese) into a system of five-year higher educational institutions to meet the strong demand from industry

against a background of rapid economic growth. Our institution provides five years of integrated continuous professional education and accepts students with a junior high school diploma. Figure 1 shows the Japanese educational system in more detail.

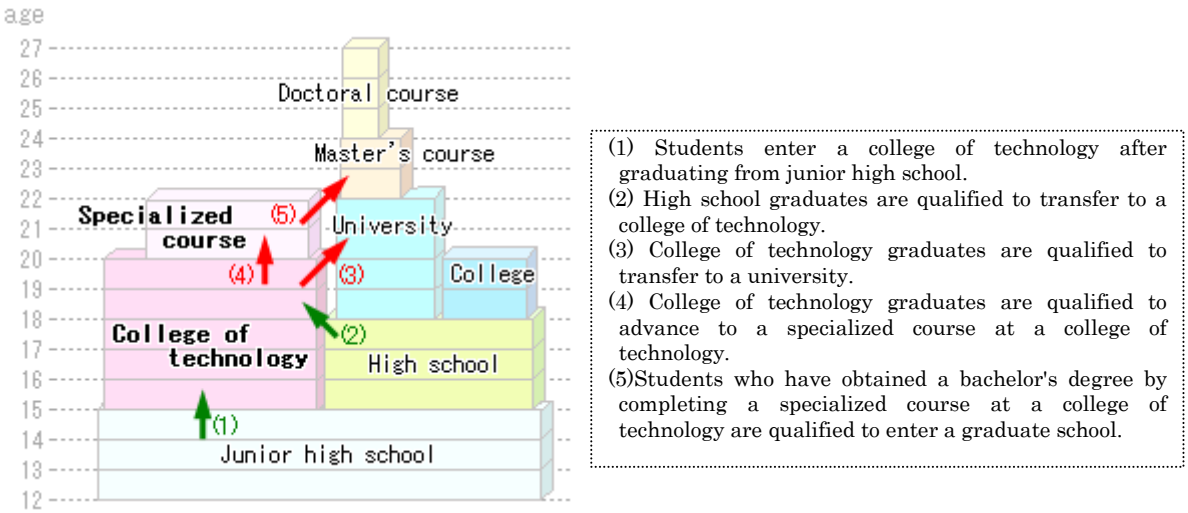

Figure 1. Outline of School System in Japan
(http://www.kosen-k.go.jp/english/outline3.html)

1.1 English Education at the National College of Technology in Japan

JABEE (Japan Accreditation Board for Engineering Education) is an organization which evaluates and accredits the engineering education programs of universities and most of the *kosen* in Japan. The educational program of Oyama National College of Technology was authorized by JABEE in 2005.

According to the standard provided by JABEE, *kosen* students must score a 400 or higher on the TOEIC (Test of English for International Communication) Test before graduating from a two-year specialized course. At Oyama Kosen, we require that students must score over 350 on the TOEIC by the end of their 5th year in order to acquire credit towards certain English classes. The average score of the 178 students who took the TOEIC Institutional Program Test as their term exam on Aug. 4, 2008, was 386.5 (Max: 995, Min: 175).

Since many students entering *kosen* similar to ours come directly from junior high school, the initial level of their practical English ability is usually lower than those students entering after high school. Thus, it is essential to offer an opportunity for students to learn both the fundamentals of English usage, as well as practical English applications in the real world.

1.2 English Presentation as a National Policy

A strategy for educating "Japanese people who can use English" was announced in 2003 by the Japanese Ministry of Education, and is composed of the following basic ideas: (i) the introduction of English education at the primary level; (ii) developing skills, such as debating, negotiating, discussing, etc., at the high school level; and finally, (iii) developing professional communication skills, such as professional or academic presentation, in university or college. However, there are a large number of arguments presented against this national policy. One common criticism is, as in [1] in the references below, that it lacks a crucial vision for learners' internal motivation in a linguistically homogenous "Teaching English as a Foreign Language (TEFL)" environment such as Japan, and also that there is a hollowness to the term "practical English ability", which is noted in the policy. This, however, does not mean that improving practical English proficiency is totally implausible. Rather, it seems necessary to come up with ideas that will motivate students to be independent learners and study English continuously. It is our belief that ELDP and its concepts of "creation" and "public

participation" compensate for these criticisms and provide the adequate motivation for learners to use the target language.

1.3 English Class as "Creation" and "Public Participation"

The project described in this paper promotes "creation" through group work and public evaluation. Since student-produced vodcasts are uploaded to the podcasting server in our school, learners know that their work will be seen and judged by their peers. This forces them to think carefully about the content of their vodcast and motivates them to produce something that is worthwhile watching. In short, introducing these concepts into our English syllabus encourages students to try harder in the TEFL classroom.

1.4 Utilizing ITC Tools and E-learning Systems

Since this project involves using various kinds of ICT tools, students need to be adept at using them in order to achieve the project goals. Additionally, the class utilizes a learning management system (LMS), web 2.0 technologies, such as podcasting, and other ICT tools, like video cameras, voice recorders, and movie production software. The LMS in our school was originally constructed for TOEIC practice, but now serves a dual purpose by allowing students to work on their IT English projects outside of class (although the system is restricted to onsite access). The class syllabus also includes computer literacy and software tutorials. It therefore has become possible for both educators and students to take advantage of the collaborative and social nature of web-based technologies in order to make learning more meaningful and rewarding.

1.5 Relevance to CDIO Standards

CDIO standard 7 states the importance of "integrated learning experiences" in one practice or exercise. The project described in this paper requires students to use the English language, while at the same time promoting both media and computer literacy, as mentioned above. Learners are expected to not only display a good command of English in the given situation, but also to know how to share their work with an audience using web 2.0 technologies and portable devices, such as the iPod and PSP (Play Station Portable). The theme of this year's class was to create a video presentation and vodcast of a famous local sightseeing spot near our school that would be appealing to foreign tourists and easily recognizable. The project also involved receiving permission from city officials to use certain images due to copyright and privacy issues. The class included people from other universities, English teachers, and foreign students. Collaboration is an essential part of our project. Details on its organization are given in chapter 2 below.

2. THE ELDP FRAMEWORK

ELDP project work originates from the concept that "the activity of creation leads to enhancing learner's motivation." It is necessary for learners to develop a positive attitude and to be motivated to use the target language. Creating a meaningful product in English leads to confidence, a sense of achievement, and a further willingness and interest to use the language. In Japan, the keyword *monodukuri* is often referred to as "fundamentals relating to production and creativity." Our work is a case study in applying this concept to English education. The basic scheme of our understanding of *monodukuri* is illustrated in Figure 2, which is an extended version of [2] in the references below:

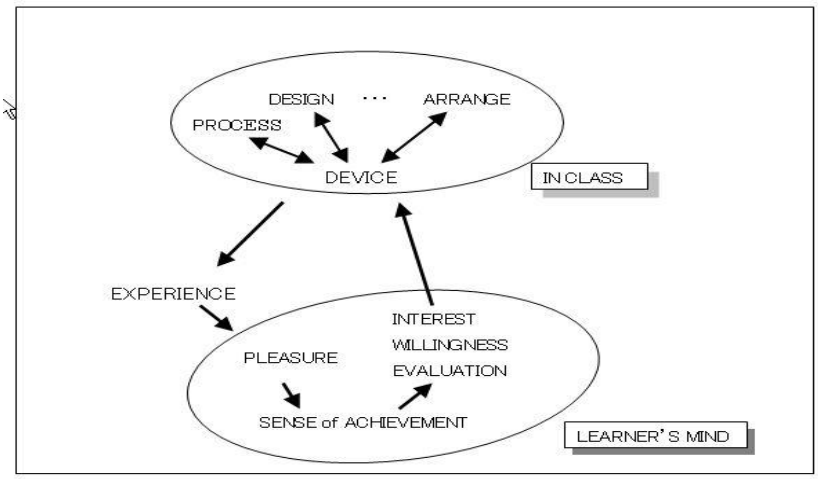

Figure 2 The Outline of Creativity Education

The three basic components are (1) E-learning, (2) Presentation, and (3) Creation. E-learning activities include collecting class information and submitting homework through the LMS, and to make effective use of the podcasting system. The "Creation" activity involves field research, recording, editing, and uploading to the server.

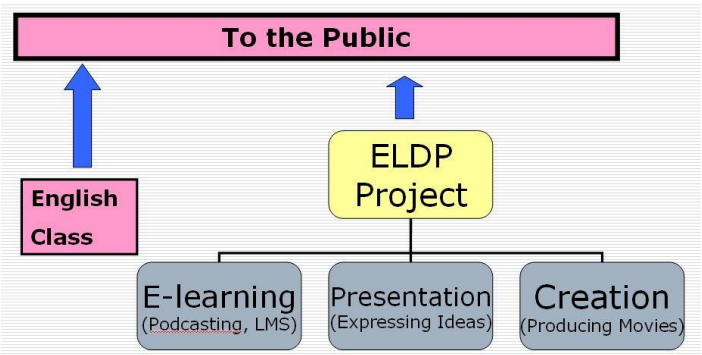

Figure 3 The Outline of ELDP Framework

Since English teachers are sometimes not comfortable with information technology and related devices and software, there are various support personnel in the ELDP organization who help us with class management. The system is in accord with item 7 of the CDIO standards, which calls for the involvement of industrial partners and other stakeholders in the design of learning experiences. Our collaboration constituents are given in Figure 4 below.

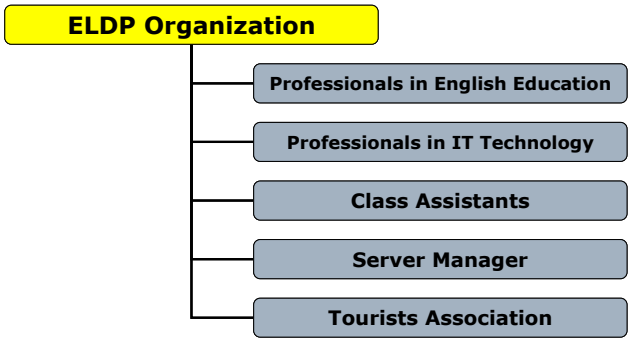

Figure 4 The ELDP Organization

The project also contains an experimental study on information engineering and how the podcasting system works according to the types of receiving devices and how reliably and quickly audio files are transmitted to them. In order to prove its effectiveness, the author set

up the heretofore mentioned theme of introducing a famous local spot to foreign tourists. However, thus far the experiment has not been carried out because of the school's security policy of restricting access to the main school server from outside the school. This is an issue for further research.

3. SYLLABUS

Let us move on to a more detailed description of the class syllabus. As shown below, the students will try two different kinds of presentations: PowerPoint presentation and video presentation. The first kind of presentation is rather familiar to students; they have done at least once for their graduation study. As a presentation for an English class, they must be aware of posture, gestures, eye-contact, and visual aids in terms of English education.

Students naturally are unsure of the second type of presentation, since they have no prior experience. One student told the author that he had never used a so-called video camera. This is where group work helped, because it allowed students who do not like speaking English to take the role of the teacher and instruct the student about video cameras.

At the conclusion of the 4-month course, students completed three PowerPoint presentations and two video ones, all of which were saved to the author's computer. The syllabus is given in Figure 5 below.

week	Class Plan	Homework	Class Activity
1	Guidance, Self Introduction Speech	Preparing for self introduction	Self Introduction
2	Text Reading (Types of Presentation)	Summary of the Textbook	Show and Tell Presentation
3	Text Reading (On Cellular Phone)	Summary of the Textbook	Show and Tell Presentation
4	Text Reading (On Global Warming)	Summary of the Textbook	Quiz Activity
5	On PowerPoint Presentation	Summary on Organization	Quiz Activity
6	Preparation for Presentation Contest	Prepare for one's Own Role	Discussion with Native Instructors
7	Preparation for Presentation Contest	Prepare for one's Own Role	Discussion with Native Instructors
8	**PPT Presentation Contest**	Prepare for one's Own Role	Communication with Judges
9	Guidance of Video Presentation, Media Literacy, Purpose, Collaboration	Bring Theme	Grouping
10	Description and Understanding of Nikko (Sightseeing spot)	Devise an Organization	Group Discussion
11	Group Discussion, Planning for Field Research	Devise a further Organization	Group Discussion
12	FIELD RESEARCH (Visiting Nikko)	Prepare Video and Recording Tools	Group Discussion
13	Preparation for Video Presentation Contest, Software, Uploading	Prepare for one's Own Role	Group Discussion
14	Preparation for Video Presentation Contest, Video Editing	Prepare for one's Own Role	Group Discussion
15	**Video Presentation Contest**, Class Summary, Concluding Remarks	Questionnaire, Brief Report	Class Evaluation

Figure 5 Syllabus

4. THE PODCASTING BLOG SYSTEM

Podcasting is the syndication of audio or video files using RSS (Really Simple Syndication). We can listen to the contents of a feed using a reader or aggregator that supports podcasting,

or we can listen to them on an iPod or similar device. We do not have to have an iPod to listen to a podcast or watch a vodcast. Podcasts can be displayed on websites with clickable links to audio files and many of the standard RSS readers have begun supporting audio enclosures. Moreover, via wireless LAN, a variety of media formats can be sent to PSPs (Play Station Portable produced by SONY) or PDAs (such as iPAQ of hp). PSP is a portable machine originally created to enjoy video games, and many young people carry them in Japan.

Podcasting uses RSS 2.0, an extended version of RSS. RSS 2.0 can specify an audio file, such an mp3, with an “enclosure tag” in its XML file, allowing users to automatically receive new files whenever they are posted. The general scheme of podcasting is illustrated in Figure 6 below.

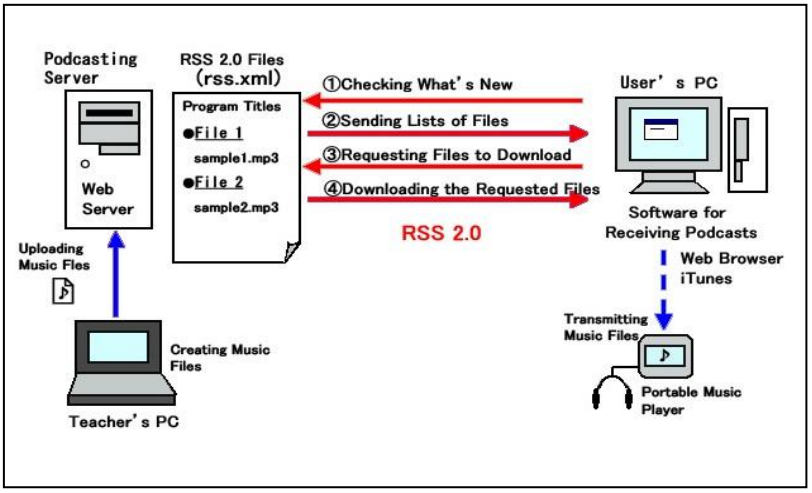

Figure 6 Outline of the Podcasting System

Podcasting is based on the RSS technology widely used in blogs. Many popular open-source blogging scripts, such as the one illustrated below, will automatically insert the necessary podcasting enclosures into the RSS feed, making it easy to set up a podcast. The blog format also makes it easy for a podcaster to write show notes about each video file (see Figure 8)

Considering these things, the blog system adopted here is Wordpress ME, which is an open-source system with a Japanese interface capable of running in an intranet environment. Several different file types can be sent via RSS (see Figure 7).

	kinds of extensions podcastable
sound	mp3, mp4, m4a
movie	Mp4, m4v,mov Flv, avi, mpeg, asf, wmv

Figure 7 Types of Files

Figure 8 Top Page of Our Blog

The basic specifications of our podcasting server are as follows in Figure 9 illustrated below.

CPU	Intel Pentium III 600MHz
RAM	768MB
HDD	20GB
OS	Fedora Core 5
HTTP Server	Apache 2.0.34
PHP	PHP 5.1.6
RDBMS	MySQL 5.0.18
Blog System	WordPress ME 2.0.9
WordPress Plugin	PodPress 3.8

Figure 9 Hardware and Software

As an experiment, the author asked 40 students to download 4.0 MB mov files simultaneously from the English class LL room. Although some students had to wait several minutes, eventually all the machines were successful in fetching the files.

5. WHAT WAS GOING ON IN THE CLASS

5.1 Initial Motivation

Sixteen students attended the 2008 academic year class. Since this would be a new, unfamiliar course that differed from the traditional grammar-oriented English classes that are very common in Japanese colleges and universities, including our institution, students seemed to be anxious. On a questionnaire at the end of the course, however, while half of the students answered that there was some initial anxiety to speaking English in public, all of them said that it had disappeared as the term passed and the presentations ended up being a great experience.

5.2 English Proficiency

Students wrote scripts for their presentations, and because editing every script would have been very time consuming for a single teacher, the author was fortunate to have had two native speakers available to help. As an additional benefit, students seemed to try to communicate with native instructors in English during the editing process. Some students answered in the questionnaire that talking to a native speaker was really a good experience.

However, it must be said that the students' English in their presentation was far from complete. Therefore, next year it will be necessary to provide students with more time to prepare beforehand and consult with teachers. In particular, some students wished they could have worked on their pronunciation more so their English would sound more fluent and "beautiful".

5.3 Questionnaire

In order to rate how satisfied the students were with the course, a questionnaire covering the following points was given:

(1) What was the most enjoyable thing about each presentation?
(2) Write freely about what appealed to you (or did not) regarding the video presentation.

Figure 10 shows the PowerPoint presentation feedback. English composition, English pronunciation, and standing in front of people were equally challenging things for most students. Interestingly, however, working on PowerPoint seemed less stressful. Figure 11 displays the questionnaire data for the video presentation. Students reported that the field research was an interesting part of video production process, and half of those surveyed wish to collect materials outside of class if given another opportunity in the near future.

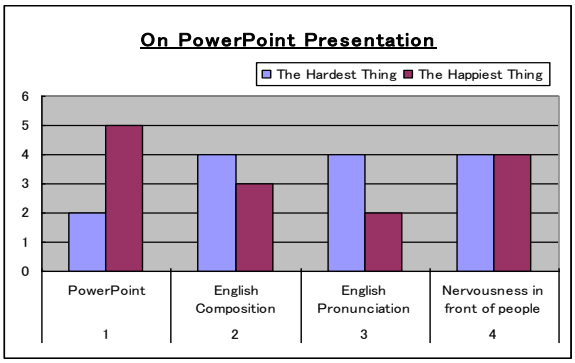

Figure 10 On PowerPoint Presentation

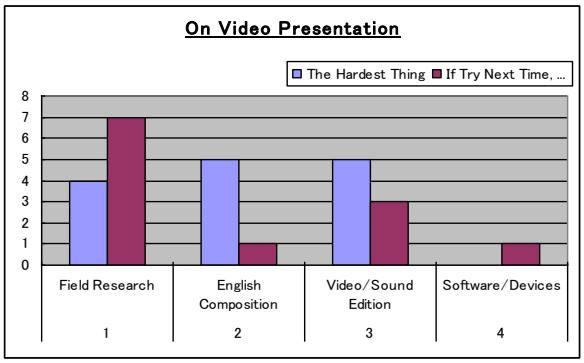

Figure 11 On Video Presentation

The questionnaire also contained open-ended feedback about the various course components. One question was on what was the most interesting lecture given in the class. In particular, many students seemed very pleased with a talk given by a guest native-English teacher at a university located in our city on presentation manners and body language. The points are summarized as follows:

○Speakers Body
Shoulders back / Open your feet / Look at their (audience's) eyes
○Speakers Voice
Loud enough for the person in the back / Pause between ideas / Use 4 voice types (low, high, soft, loud) / Feel your face muscles
○Speak slowly and clearly

Class Notes by a Student, Dec. 1, 2008

This feedback made the authors realize that students are more interested in basic presentation skills than how to make use of ICT tools. Therefore, it is important for instructors to keep in mind that no matter how popular and efficacious the information technology might become in the future, students still want most to be able speak confidently and effectively in front of others.

Lastly, the authors were pleased to learn that many students found the class very interesting and enjoyable, in spite of its difficulty. When viewing all the videos during the last class, students seemed somewhat embarrassed yet pleased with their work. They were also surprised that everything worked successfully in the end and that they could view their downloaded videos on the author's iPod and PSP. Two videos are given below in Figure 10, where the picture on the left hand side is a record of PPT presentation and that on the right is a video created by students. These videos are uploaded onto the podcasting server in our institution.

Video is an effective tool for communication, different from books and traditional public presentations, and can allow introverted students to be more direct and convey their feelings easier, and offers alternative tasks and roles for students who are not good at speaking or writing English.

Figure 10 Two Types of Presentation (Viewed on QuickTime)

Figure 11 Movie Displayed on iPod (Left) and PSP (Right)

6. FUTURE PERSPECTIVES

6.1 Evaluation on This Project

As pointed out by the reviewer(s), the paper so far gives insufficient information on the benefits to students' learning and intended learning outcomes through the class. More should be said to evaluate whether the pedagogic approach met these more effectively than traditional approaches. Since there has been no such class as video presentation, I have no critical data on the evaluation comparing this project with the grammar-oriented traditional approach. More precise questionnaire research on students' benefit or intended learning outcomes is necessary on the basis of larger numbers of students to clearly state that the class suggested here is satisfactory to the students. This is what we are doing now on the basis of students this year. As far as the students' interest is concerned, however, most students answered in the questionnaire that their interest in English presentation was enhanced after the class (See Figure 12 below). As stated above in this paper, motivating students to try an English presentation is a crucial factor in a totally TEFL environment. One of the outcomes and the benefits on the part of students is this "enhanced motivation" inside the learners. In this sense, one goal can be said to have been achieved in this class.

	interest in presentation in English	
grade	before the class	after the class
1	1	
2	4	2
3	6	5
4	3	5
5		2
ave	2.8	3.5

Figure 12 Students' Interest Before/After the Class

6.2 Some Implications for the Future

Needless to say, the project detailed in this paper is under the preliminary stage and needs to be improved in addition to the suggestions made by the reviewer(s) in the above section. Conceptually, there are two types of problems that need to be solved: hardware (cost, security policy, school system) and software (how to teach). The former problem is the most challenging. To make headway in our e-learning strategy, the ELDP project server needs to be accessible from the outside. One solution is to set up an outside dedicated server next year, if time and money allow.

A very promising aspect of this project is that student video work can be used to promote local communities. Podcasting is a powerful technology because it allows student-generated media to be easily and cheaply distributed to portable devices. This means that foreign tourists visiting a particular area might be able to subscribe to entertaining and educational travel guides produced locally by students. In other words, visitors could learn about the area not just through a typical guidebook, but from those who know the place best: the people who live there. Motivating and empowering learners to use English to teach others about their culture and community is a win-win situation for both the student and the visitor. In conclusion, the ideal sketch of this project is given below:

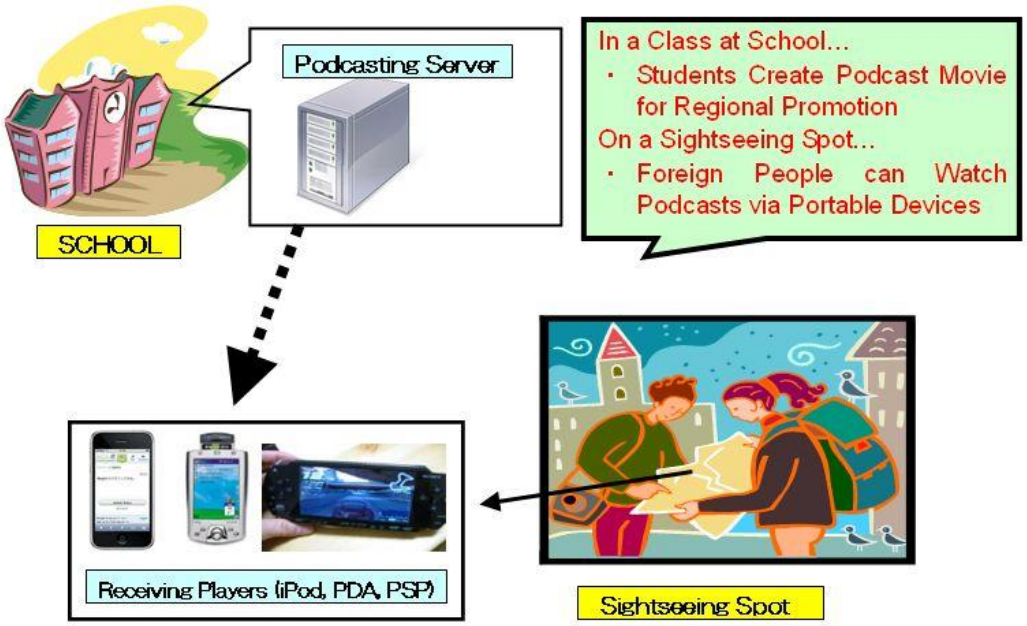

Figure 13 One Future Image of the System

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[2] "Monodukuri kenkyu (Study on Making)", 2003, Osaka Prefecture Education Center.

Biographical Information

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A Design-Directed "Architectural Design" Course for Civil Engineering CDIO Program

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ABSTRACT
In year 2005, College of Engineering at Shantou University adopted the CDIO Initiative. Based on the CDIO education framework, a syllabus for "Architecture Design" course that is opened to sophomore has been drawn to replace the old one of "Building Construction". The CDIO competencies are incorporated into the course conduct. Except the classroom teaching, as another important part, an assignment is reformed from previous individual design-task to a teamwork-design. It is processed in a way of proposal – discussion– design through both of teamwork and the class activities. When finds problem, amending design after discussion are required till to reach the task's goal. The implementation process for this reformed Design-Directed Course is stated in the paper first. And then, the changes that of the new course transformed by CDIO approach are given. The impact of the practice to the ability, knowledge and personality are analysed by looking at the students' work and progress. After the first run of the course, the achievements and flaws of the course are studied and the future improvements are proposed in this writing as well.

KEYWORDS
Civil Engineering, course transform, CDIO, Architectural Design,

INTRODUCTION
Since year 2008, a design-directed "Architectural Design" course for Civil Engineering Program has been built to replace its predecessor of "Building Construction". Cultivating CDIO [1] competencies based undergraduate students is the main target of the course study. This course was implemented by the 2006 intake class first. According to the "Ability interrelated EIP-CDIO Mode" [2] set by Shantou University, a new course syllabus which is not only focused on the learning technical knowledge, but also for developing the student's personal and interpersonal competencies was issued to follow CDIO ideas.

COMPREHENSIVE COURSE TRANSFORM BY CDIO APPROCH
Changes
As a comparison between previous course of "Building Construction" and the reformed one of "Architectural Design", it can be seen in table 1 that significant changes on curriculum objectives, teaching content and method, as well as the assessment standard are made after the CDIO education framework introduced into the course.

Table 1
Comparison between the course that before and after be transformed

	before	after

Course Objectives	guide students to understand the functions of various components of buildings and learn the design methods of building construction	a) understand the functions of various components of buildings; b) practice the process of whole architectural design; c) Develop CDIO competencies with special attentions on self-learning, team-study and C-D-I-O in social environment.
Course Contents	a) Knowledge, including principle of architecture, basic knowledge of design and civil construction ; b) Construction design, complete the plans, elevations and details of a given building.	a) Basic knowledge of architecture and construction design, civil projects with the social and natural environment element and Energy-saving building design; b) An extension knowledge, series of engineering problems that for the design with a special emphasize on the sustainable civil engineering. c) Team-based architectural design project.
Methods	a) Basic knowledge part was accomplished through the classroom teachings up to 48 hours b) A joint construction design practice for a week.	a) Basic knowledge part was accomplished through the classroom lecturing and self learning for 24 hours in a total duration of six weeks. b) The extension knowledge part was accomplished in 6 hours in three weeks. Students needed to perform self learning and team-learning through classroom discussions. c) Team-based architectural design project lasting the whole semester. Students needed to refer back to their conceptual designs in the cornerstone project performed in the last semester, and modified their preliminary architectural designs according to new knowledge learnt in this course with an emphases on environment protection and resource saving.
Assessment	a) examinations b) level of the Building structure design	Assess to the whole CDIO process. The object of evaluation includes: a) research reports b) discussions record of improving the design c) examination of architecture knowledge d) level of the architecture design e) Performance and summary
Score criteria	Score of the exam (80%) + Design (20%)	Process of team-work (30%) + Score of the exam (20%) + Outcome of design and show (50%)

The Projects

To stimulate the interests and creativity of students, we selected "Residence", the most fundamental and substantial building type as a design object. The projects are identified in table 2. Each project has clear design topics and practical engineering conditions. The students were allowed to choose a work freely.

Table 2
"Project" to be chose

	Project topics	Design Topics
1	"Green city" residence	the residence with a good ecological environment and landscape
2	“Harmonious " residence	the residence meet the needs of different social strata to live together
3	"Adaptive" residence	the residence solving the multi-generational co-live and the residential population change
4	“Economical” residence	the residence For the urban low-income home
5	"Green practice" residence	Energy saving house

Repeatedly CDIO Process

The students were divided into fourteen groups (three in each group) and went through two entire CDIO cycles. The first cycle was to set up a profile for the building. The second one was to work out the detail design. The characteristics of each stage are stated in the below:

Conceive stage

In this stage, the students took all possible ways of being carried out in-classroom and out of classroom, including literature study, website search, discussion, consulting available experts, to build up a basic concept for the project. At meantime, teachers joined the seminar to ensure that the idea proposed by student is reasonable.

Design stage

Under the teachers’ guidance of as to answer any related questions and monitor progress, the students conducted their design work through the case study, discussion, debate, task analysis and drawing.

Implement stage

Within a short course study period, it seems impossible that students to complete a whole building construction process that is from design to put into use. Therefore in this stage, the implement effects of the design work were estimated by means of “experts”, “public” and “owners”. In which each team displayed their design work, when the rest teams took the role of “public” to evaluate the acceptance of the building and give their comments. Teachers acted as the “experts” to check whether the design is reasonable and in accordance with the national norms. At the same time, the teachers and students were also supposed to be the owner of a designed building to valuate if the work meets their requirements.

Operation stage

When a team was displaying their work, they also had to defend, debate or maybe take the criticism commented by the rest in the class. After the evaluation, each team had to revise their design according to the comments given during defence. Thus, the design work had been improved in the operation stage.

THE TRSFORM’S EFFECTS

Taking the results from questionnaire survey to combine with the observation made by the teachers and the outcomes got during the course study, it can be seen that some effects were produced after the course has been transformed from previous one.

Active attitude to learn

To accomplish an architectural design work, it involves many aspects of related knowledge, With a reception-learning method taken in “before transform”, students could hardly understand and apply the principles for their design task. But as a big benefit from the course transformation, it can be seen on the data given in table 3 which students evaluated

themselves, the interesting in course-study accounted for 70% high, much more than before. Meanwhile, the reformed teaching method including the new-designed C-D-I-O learning procedure has also been widely acknowledged by the students.

Table 3
Students' self-evaluation data after "Architectural Design" course study

Item / Grade	Interest in leaning	Practical Ability	Communicative competence	creativity	Self-study	knowledge
Very good	10%	10%	20%	20%	40%	15%
good	60%	65%	70%	65%	50%	70%
General	25%	25%	10%	15%	10%	15%
poor	5%	0	0	0	0	0

Table 4
Survey for the course of "Architectural design"

Item / Grade	Learn from teamwork	learn from competition	Learn from evaluation
Very good	15%	10%	20%
good	45%	55%	50%
General	25%	25%	25%
poor	15%	10%	5%

Improvement of Students' Ability

It can be seen that the students improved their self-learning capacity and team spirit significantly after this architectural design. Although the products designed by the students can not be perfect with their current limited knowledge and skill, but they had exhibited their creativity, interests and care for the society and environment, which are expected to be retained and developed for their lifetime. There is a case indicated the promising progress of the student's CDIO competencies. A team consists of three girls that chose the project "Adaptive" residence.

Self learning capacity

This task was relatively difficult for a beginner. When the course started, a girl worried that she could not do it with her limited knowledge and ability. Teachers encouraged her to process her work step by step as long as the progress can be seen. So she went to the process frankly, she did field research, analysis design case with teachers, then took part in team discussions, followed by carefully drawing, writing the text, presentation and improving program . After the work, she had accumulated a lot of first-hand information gained through discussion, and the draft. At end of the day, the girl told teacher that now she can face to the design work without being afraid of. This course enhances not only the potential to self learning, but also the confidence of students.

Teamwork ability

The complexity of architectural design requires students to adopt teamwork to work together for a job. As shown in Figure 1, it is a standard floor plan for residential building. It is rely on teamwork to determine the consistently space sizes and various components size. One team member said in a report that "In this course, I learnt how to communicate and discuss in a group to reach a consensus, more than how to design. We have to divide the work,

cooperate in teamwork and be good at listening to the views of others. Only by team can we finally get to our results.”

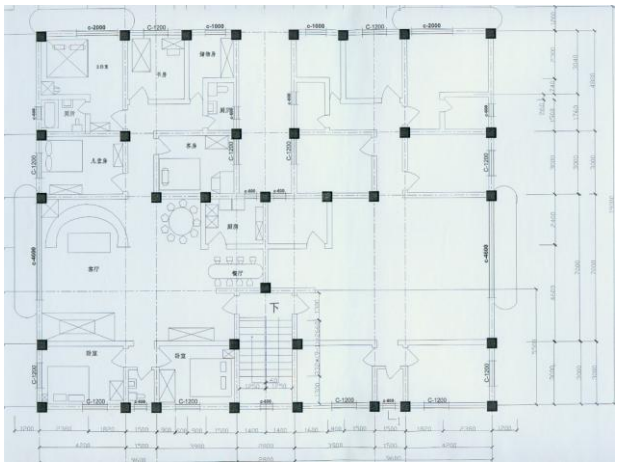

Figure1. The standard floor plan for residential building

The ability to develop products in social system

The team’s task is to develop a "adaptation" residence solving the multi-generational co-live and the residential population change, which is a typical task of developing product to meet the needs of society. First of all, the team focused on the contents of the current family life, the one-child family composition and population changes, as well as the elderly and their children separated in space and spatial variability; then used their knowledge to arrange the function, space and components of building; after they took part in the show and presentation in class, expressing their design ideas and features, accepting the teacher and student evaluation, they improved the design finally. This CDIO process is consistent to the actual development of products logically. Students naturally exercise the ability to develop products in social system.

As shown in Figure 2 is the improvement of team at CDIO process compared before and after. On the show in class, other students acted as "critical customers" and pointed out that the lighting problems, the room’s condition is not comfortable, the windows do not quite reasonable, and the doors are not reasonable with the structure in pre-program. The team accepted these advices and improved their program. One team member said in report that” The biggest gain is that we are able to constantly optimize our desired "adaptive" residential building. In fact, I think we will have a lot of improvements, when we enrich the professional knowledge. We will really be able to design our dream home! "

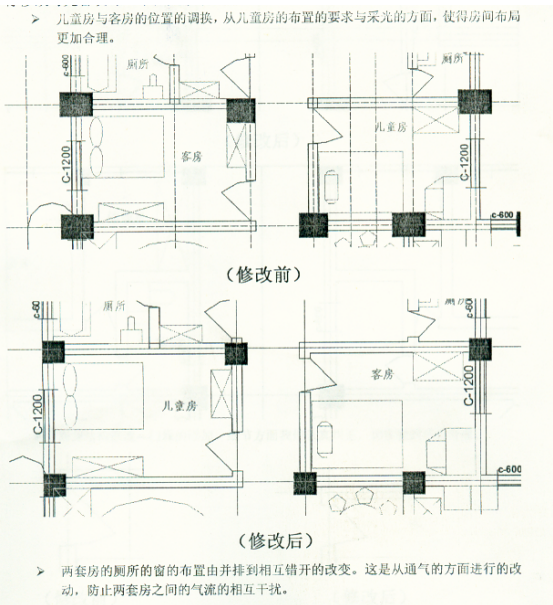

Figure2. The improvements for plan

Foundation of the Followed Course

This course is a secondary project of integrated curriculum system that based on EIP-CDIO mode. There are other projects such as "structural and geotechnical engineering design" and "advanced Civil Engineering design" followed [3].

The team studying methods and the form of exchange that formed in this course will be retained. At the same time, the outcome of this design will be the research subjects of the following curriculum. Students can sustain thinking and improving the residential building and construction "design" when they are in the process of deeper expertise. In particular, this project will cultivate the ability to help students get to their broader professional fields.

THE PROBLEMES AND CHALLENGES

Evaluation of Capacity

The curriculum developed capacity-building objectives (in table 1), and have achieved some success. However, the evaluation of capacity-building is mainly by subjective "feelings" of teachers currently. It is important to find more objective and effective assessment methods.

Motivate Student's Teamwork

In this course, teachers try to motivate student's teamwork. Although the use of the "competition" and "add creative points" has been generally welcomed by students, there are always free riders in team efforts. How to reduce the numbers of free riders and to educate on team spirit, integrity and team ethics is still a problem to be solved.

Use of Error-correcting-based Learning Methods

Driven by design motive, coupled with self-learning method, students need to access and collect a large number of knowledge, data and examples. These may come from textbook. More frequently they are collected from the internet. The information quality and credibility of the data can be very different. The students are still lacks of necessary knowledge and skills to make the judgments. So mistakes are inevitable. Some of our students encountered these problems and hesitate to go any further. They felt much more comfortable relying on the teachers. Teachers should have awareness of the use of error-correcting-based learning methods to help the students find relevant and correct data. In the new model, teachers also should face up to students to achieve the level of the design problem has always been to improve for the purpose of student ability rather than knowledge of the rights and wrongs of the past to high demands.

Faculty Competency

EIP-CDIO requires faculty much more than simple knowledge transmission. Like what is common in the world, most engineering faculty may not have strong engineering experience. How to improve the faculty engineering and CDIO competency would be a serious challenge. Faculty members should update their pedagogical concepts and conduct. Transform from traditional teacher's role to facilitator's role.

CONCLUDION

Shantou University College of Engineering, Department of Civil Engineering is exploring the CDIO engineering education philosophy into practice by CDIO approach, within the Chinese environment. A Design-Directed "Architectural Design" course was transformed and implemented. The practice has achieved our anticipated goal. Favourite results have been achieved. We will continue to our reform to solve more problems.

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A WEEK LONG EVENT OF MILLENNIUM DEVELOPMENT GOALS

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ABSTRACT

One of the main goals of the Millennium Development Goals (MDG) is to promote engineering education, capacity building and applications for poverty eradication and sustainable development. Noting the recommendations of the World Engineers' Conventions in Hanover, 2000 ("Humanity, Nature and Technology"), and Shanghai, 2004 ("Engineers Shape the Sustainable World"), regarding the importance of engineering in social and economic development and the need for capacity building, and noting that the third World Engineers' Convention will be held on December in Brasilia in 2008 ("Engineering: Innovation with Social Responsibility").
ISEP and other institutions will organize a week long event to publicize MDG to the students. In this presentation we will go to present the program and the internships offered to students.

KEYWORDS

Millennium Development Goals, UNESCO, Engineering Education

INTRODUCTION

CDIO, as a framework to produce the next generation of engineers, provides students with an education stressing, beside others, operating real-world systems.
Engineering education must take into account the surrounding environment, namely the goals set by international organizations and governments as they will represent additional opportunities for students at the labour market.
This poster will also link the MDG event at ISEP with CDIO standards 1, 2, 5 and 8.

WHAT ARE THE MILLENNIUM DEVELOPMENT GOALS?

The Millennium Development Goals (MDGs) are eight goals to be achieved by 2015 that respond to the world's main development challenges. The MDGs are drawn from the actions and targets contained in the Millennium Declaration that was adopted by 189 nations and signed by 147 heads of state and governments during the UN Millennium Summit in September 2000.

The eight MDGs break down into 21 quantifiable targets include:

- **Goal 1: Eradicate extreme poverty and hunger**
  - Halve, between 1990 and 2015, the proportion of people whose income is less than one dollar a day.
  - Achieve full and productive employment and decent work for all, including women and young people.
  - Halve, between 1990 and 2015, the proportion of people who suffer from hunger.

- **Goal 2: Achieve universal primary education**
  - Ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling.

- **Goal 3: Promote gender equality and empower women**
  - Eliminate gender disparity in primary and secondary education preferably by 2005, and at all levels by 2015.

- **Goal 4: Reduce child mortality**
  - Reduce by two-thirds, between 1990 and 2015, the under-five mortality rate.

- **Goal 5: Improve maternal health**
  - Reduce by three quarters, between 1990 and 2015, the maternal mortality ratio.
  - Achieve, by 2015, universal access to reproductive health.

- **Goal 6: Combat HIV/AIDS, malaria and other diseases**
  - Have halted by 2015 and begun to reverse the spread of HIV/AIDS.
  - Achieve, by 2010, universal access to treatment for HIV/AIDS for all those who need it.
  - Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases.

- **Goal 7: Ensure environmental sustainability**
  - Integrate the principles of sustainable development into country policies and programmes; reverse loss of environmental resources.
  - Reduce biodiversity loss, achieving, by 2010, a significant reduction in the rate of loss.
  - Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation (for more information see the entry on water supply).
  - By 2020, to have achieved a significant improvement in the lives of at least 100 million slum-dwellers.

- **Goal 8: Develop a Global Partnership for Development**
    - Develop further an open trading and financial system that is rule-based, predictable and non-discriminatory. Includes a commitment to good governance, development and poverty reduction-nationally and internationally.
    - Address the special needs of the least developed countries. This includes tariff and quota free access for their exports; enhanced programme of debt relief for heavily indebted poor countries; and cancellation of official bilateral debt; and more generous official development assistance for countries committed to poverty reduction.
    - Address the special needs of landlocked and small island developing States.
    - Deal comprehensively with the debt problems of developing countries through national and international measures in order to make debt sustainable in the long term.
    - In cooperation with pharmaceutical companies, provide access to affordable essential drugs in developing countries.
    - In cooperation with the private sector, make available the benefits of new technologies, especially information and communications.

Figure1. The eight MDGs Goals

WEEK PROGRAM

The week long event of Millennium Development Goals will be held on October not only at ISEP but at others institutions and in Porto city. There are several universities, Non Governmental Organisations for Development (NGOD) and other organizations involved, such as: Universidade Católica do Porto; Engenho & Obra (NGOD); Agência ODM; Escola Superior de Educação do Porto, Campanha do Milénio das Nações Unidas, Centro Regional de Excelência em Educação para o Desenvolvimento Sustentável da Área Metropolitana do Porto.
During this week the students will show their work related with the MDGs Goals. There will be a national photograph contest and an interuniversity documentary contest about MDGs Goals.

We are also going to organize a marathon at 17th October, at the International Day of Poverty Eradication.

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ABC WATERS PROGRAMME (CENTRAL CATCHMENT) – CONTEXT FOR STUDENT LEARNING

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ABSTRACT

The Active, Beautiful and Clean (ABC) Waters programme by PUB, the national water agency of Singapore, aims to restore the waterways and create new waterscapes in Singapore so as to bring people closer to water and provide a beautiful environment for all to enjoy. The conventional engineering approach for designing man-made channels is replaced by an integrated view that includes engineering, science, landscape design, urban design and a commitment to community connection. Singapore Polytechnic has adopted the Singapore River and Kallang River at Bishan Park, and will be adopting and organising activities at the Marina Reservoir. All these places are in the central catchment of Singapore. The paper describes how the adoption programme can help engineering students better appreciate the external and societal context for engineering systems and the engineering profession and provide learning experiences for students outside classrooms. This is aligned with the Conceiving-Designing-Implementing-Operating (CDIO) syllabus, a component of which is focused on the external and societal context.

KEYWORDS

Waterways, adoption, students, community, societal context, content

INTRODUCTION

ABC Waters Programme

The Active, Beautiful and Clean (ABC) Waters programme by PUB, Singapore's national water agency, aims to restore the natural rivers, lakes and waterways and create new waterscapes in Singapore so as to bring people closer to water, the scarce resource in the island nation. The conventional engineering approach for designing man-made channels is replaced by an integrated view that includes engineering, science, landscape design, urban design and a commitment to community connection. Concrete drains and canals will be transformed into natural streams with habitats for aquatic and marine flora and fauna. Community spaces beside the waters will be created for new lifestyle activities and attractions. More recreational choices such as kayaking and leisure boating will be offered. These are in addition to the engineering systems to be put in place, for example careful design to ensure adequate drainage, the recirculation of water in the system to create flowing waters, and basic treatment measures for the waterways such as litter traps, rain gardens, bio-retention systems and infiltration trenches.

With this nexus of engineering systems and societal impact, the ABC Waters Programme provides an excellent platform for engineering students to better appreciate the external and

societal context that engineers operate in. It also helps the students appreciate the engineering principles and technical concepts learnt in the classroom, for example in the module on Hydrology & Hydraulics. The Singapore Polytechnic (SP), through its adoption of various water-bodies under the ABC Waters programme, has involved the students from the Diploma of Environmental Management and Water Technologies (DEWT) and Diploma in Civil Engineering & Management (DCEM) courses to work with government agencies, NGO, industry and the community. The adoption programmes are described in more details below.

ADOPTION PROGRAMMES

Adoption of Singapore River

SP has officially adopted Singapore River since January 2006. As part of the adoption programme, SP has been working closely with Waterways Watch Society (WWS), a non-governmental organisation, to monitor the water quality in Singapore River. Since 2005, SP, together with the Environmental Engineering Society of Singapore, WWS and PUB, has been organising the World Water Monitoring Day from 18 September to 18 October every year. On the World Water Monitoring Day (WWMD), students from various schools, including SP, use water testing kits to test the levels of dissolved oxygen, acidity, clarity and temperature of water at Singapore's reservoirs and waterways such as Kallang Basin and Singapore River.

The exercise is part of the global efforts of WWMD which aims to create awareness of the importance of clean water. Such activity helps to nurture ownership among young Singaporeans and encourage us to be guardians of our water, which will ensure the sustainability of our precious water resources. For the past 3 years, over 40 SP students and staff have participated in the WWMD.

SP has also organised Singapore River Raft Race (SRRR), an annual event, with the objectives to nurture creativity and spirit of adventure, raise awareness of recycling & environment, encourage healthy life style and raise funds for charity. In 2007, there were 100 rafts from 35 organisations registered for the race and some 2000 people participated in SRRR including the fringe events. Since 1997, SRRR has raised some $1.2 m for 21 charities to date.

Adoption of Kallang River at Bishan Park

SP has officially adopted the Kallang River at Bishan Park since November 2007. The ABC Waters Programme at the Kallang River is currently in progress. Upon the completion of the project, the DEWT and DCEM students will assist in analysing and monitoring of water quality in the river. The students will also be involved in gathering feedback from residents on community spaces created near the waterways, planning outreach programmes to secondary schools to raise awareness of protecting the precious resources, conducting research on cultural heritage of the Kallang River and developing signages to educate the public.

Adoption of Marina Reservoir

SP will be adopting the Marina Reservoir, Singapore's first reservoir in the heart of the city in June 2009. Marina Reservoir is created by a barrage built across the mouth of Marina Channel. It is set to boost Singapore's water supply, alleviate flooding in the low-lying areas of the city and provide a new venue for water recreational activities. Some 40 DEWT students have been trained as volunteer guides to share with local and foreign visitors the Singapore Water Story and the function of the barrage at the Sustainable Singapore Gallery

at Marina Barrage. It is an enriching learning experience for the students – not only can they better appreciate the engineering knowledge acquired in class, they are able to communicate the concept and idea to the community.

CONTENT FOR CLASSROOM TEACHING

In the classroom, DEWT and DCEM students are taught the hydrological cycle, catchment management, stormwater management and design of drainage systems. They learn to design trapezoidal or rectangular concrete drains using conventional methods such as using Manning's equation. They learn that raw water is collected within the catchment areas as runoff and to ensure the quality of raw water, rules and regulations are usually imposed by the authority to restrict development and human activities within the catchment.

Through the adoption programmes, students are exposed to innovative features of the ABC Waters Programme initiated by PUB, where the conventional engineering approach to resolve flooding and drainage problems, i.e. designing concrete man-made channels, are now replaced with natural streams with habitats for aquatic and marine flora and fauna. Instead of protecting the waterways against any human activities, the community is now encouraged to get close to the water bodies and participate in various recreational activities such as kayaking without compromising the water quality in the waterways. This can be made possible with the basic water treatment measures put in place along the waterways such as the litter traps and infiltration trenches.

CONTEXT FOR CLASSROOM TEACHING

With the participation in various activities of the adoption programmes, students can have a better understanding on how engineering concept is being applied in real life context and keep abreast of the latest technologies adopted by the industry. The partnership with the government agencies, NGO, industry and community will help broaden the students' perspectives in real working world and develop them as whole, mature and thoughtful individuals.

In addition, through participating in the adoption programmes, our students learn to appreciate the importance of water in the context of a water-scarce resource country like Singapore. This importance is reflected by PUB's tagline: *Water for All: Conserve, Value and Enjoy*. Students learn to conserve water as they come to know that it takes great effort to collect every drop of water; they learn the value of water and take greater ownership of our waterways and reservoirs and they enjoy the water bodies through the various water sports and activities at the waterways.

CONCLUSION

The adoption of water-bodies by SP and the involvement of engineering students in the programme is an example of programmes focusing on the external and societal context, which is a significant component of the Conceiving-Designing-Implementing-Operating (CDIO) syllabus. Exposing the students to the industry as well as participating in the community allow them to have a better appreciation of the external and societal context that engineers operate in. This will prepare them as active citizens and professionals to help conserve, value and enjoy Singapore's waters.

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Achieving Effective Learning in Engineering Laboratory Classes

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ABSTRACT

This investigation looks at how effective lab classes are in the Mechanical Engineering courses at Queen's University Belfast in the context of modern approaches to engineering education. The laboratory program here is of a traditional type, where students work through a number of separate three-hour lab classes associated with their engineering science modules over the semester. The laboratory exercises (29 in total) are grouped according to whether they are 'demonstrations'; 'controlled exercises' or a 'structured investigation' (a more open exercise where students must plan all or part of the experiments). Student feedback was sought on each of the exercises to evaluate how effective the learning had been in each case. The majority of labs, as with most traditional programs, are controlled investigations and these varied in the extent of active learning and exposure to problem-solving or real-life application. The student feedback correlated strongly with the degree of active learning and relationship of the exercise to a real engineering problem.

The laboratory evaluation also examined more generic 'aids' and 'barriers' to effective learning in lab classes. The effectiveness of the lab demonstrator/facilitator was clearly highlighted as being an extremely important factor to the student learning experience. Another issue which clearly impacts on the motivation of the students to learn is the nature of the lab assessment. In most cases students are required merely to follow the steps given by the manual/demonstrator so there is very little opportunity to assess students' contribution and skills. As a result, there is very little divergence in the individual marks allocated to students and little motivation for the students to actively engage in understanding/analysis/discussion of the lab.

Using the results of the student feedback and evaluation, general practice in setting-up a laboratory exercise has been identified and suggestions given for future improvement over a traditional lab programme.

KEYWORDS

lab classes, active learning, reflective learning, constructive alignment

INTRODUCTION

The laboratory programme investigated in this work applies to years 1 and 2 of the undergraduate courses in Mechanical Engineering at Queen's University Belfast (QUB). Approximately 80 students are enrolled in each year and these are divided into groups of five or six for the lab classes. Each lab lasts for three hours and groups rotate between the classes on a weekly basis throughout the semester; therefore different groups will cover

different labs at different points during the semester. The laboratory programme is not part of any specific module but is intended to support all the engineering science subjects (Materials, Mechanics, Fluid Dynamics, Thermodynamics), with some labs aimed at more general, transferable skills (presentation skills, teamwork). Students are marked out of 5 for each engineering science lab and the average mark contributes to 5% of the overall mark for each of the aforementioned modules. The labs are run by Ph.D. students who allocate marks to each individual based on their contribution to the class. Laboratory classes occupy more than 10% of the timetabled hours for Mechanical Engineering students over the first two years of the course, hence it seems important to examine whether this significant time resource is used effectively.

The role of lab classes in engineering education

The roles of laboratory classes in engineering education have been discussed previously in the literature [1-2], with agreement on a wide range of goals including: learning scientific information; understanding the process of scientific investigation; learning technical skills (use of equipment etc.); appreciating the application of knowledge and methods; and developing communication and teamwork skills. However, there is a current need to address the role of lab classes within the context of modern engineering educational aims. A recent report commissioned by the Royal Academy of Engineering in the UK [3] has recognized that the UK is experiencing a shortage of high calibre engineers (despite increasing numbers of graduates post-1992). This report has identified a need to

'provide more experience in applying theoretical understanding to real applications and the open ended problems faced by industry' in engineering courses'.

The CDIO Initiative was developed with input from academics, industry, engineers and students and informs a framework of curricular planning and outcome-based assessment which emphasizes experiential and hands-on learning and, as such, promotes active and interactive learning techniques. The CDIO syllabus further emphasizes 'Problem Solving', 'Systems Thinking' and 'exposure to Conceiving Designing Implementing and Operating engineering systems' as key skills for students. As the lab programme comprises a substantial part of the interactive and 'hands on' element of learning for the early years of an undergraduate programme then alignment with these goals is important.

What is effective learning?

The Institute of Education [4] puts forward the following definition of effective learning:

'reflective activity which enables the learner to draw upon previous experience to understand and evaluate the present, so as to shape future action and formulate new knowledge'.

The key features highlighted in this and other definitions [e.g. 5] include:

- An ACTIVE process
- Involving REFLECTION on what has been learned to make connections between previous experience and present or future situations

In this light, the lab program in Mechanical Engineering is evaluated in terms of whether it aligns with the learning aims of modern thinking in engineering education and whether it offers sufficient opportunities to involve students in active learning processes and develop skills in self learning. It is important to examine issues which impede attainment of these goals and identify methods which result in more effective achievement of these learning aims.

EVALUATION OF LAB CLASSES

The evaluation of the Mechanical Engineering lab classes has been approached in a number of different ways.

1) Individual labs were evaluated by examination of the lab manuals to determine opportunities for learning and by student feedback.
2) General feedback from students was sought on the overall lab programme in terms of the CDIO syllabus.

Breakdown of individual lab classes

According to the UKCME (UK Centre for Materials Education) Lab Classes Guide [6], there are three types of lab class:

- Demonstrations – containing little of no student participation
- Controlled Exercises – Students are given instructions to carry out an exercise which has a known outcome
- Structured Investigation – The method of investigation is more open to the students, they are required to plan all or part of an experiment.

It is useful to group the lab classes in these categories and consider the relative strengths and techniques of each.

A number of the classes are largely demonstrations (e.g. of CAM and CAE software), where the students have little opportunity to actively get involved in the experiment. These types of laboratory class were largely unpopular with the students as they felt the material was irrelevant to their studies, and the demonstrations were not engaging. Many students also commented that for a number of these labs the material could easily be covered in the classroom and appeared to feel that this was a waste of laboratory time. Within these labs there was very little opportunity for the students to engage in active learning processes; student comments included '*we just followed instructions*' and '*learned nothing useful*'.

A large proportion of the labs fall under the category of 'controlled exercise' where students had more participation but followed a defined step-by-step methodology. These labs were generally associated with application of theory covered in lectures to a practical situation. This type of investigation was most popular when students found the theory particularly difficult (with many stating that they were able to understand the theory much better from taking part in the experiment than from lectures) and when the theory would be examined. Students also emphasized that good handouts and clear description of the theory was important. Students also appreciated when this type of lab class was clearly associated with a real-life application, for example in the case of engine testing, analysis of beam loading etc. Conversely, some labs had a very clear 'real-life' application (for example, selection of the most suitable material for a particular function by testing the physical properties of a number of different options), however this did not guarantee that the students found it interesting if they themselves did not have much opportunity to participate in the experiment or if the theory was quite simple and undemanding. Another example involves investigation of the properties of steam, which was pointed out to the students as being extremely important to power generation; however students found the actual experimental procedure boring, complicated and irrelevant. The electrical engineering labs which demonstrate circuit analysis techniques and electromagnetic theory were also unpopular. Students commented that the experiments did demonstrate the lecture material quite well but found them long and tedious and many failed to see any relevance of studying electrical engineering as part of a mechanical engineering degree.

Very few of the lab classes involved a more open, problem solving approach as associated with a structured investigation. A few good examples are present in the second-year program, which includes a competitive team exercise to design and build a beam with the best strength-to-weight ratio, and an assignment to design the optimum length of tripod legs where they are required to apply theory covered in class. These types of investigations are

very popular with the students, who stated that they found them enjoyable and felt they promoted better understanding.

Evaluation of the overall lab programme

A large number of students (42 first years and 31 second years) were asked to evaluate the lab programme of their current year of study at the end of the year. The aim here was to look specifically at how well students felt that the lab classes gave them exposure to the key elements of the CDIO syllabus. They were asked to what extent they felt the lab programme in that year of study had developed the following:

- Technical Knowledge
- Problem Solving
- Experimental techniques
- Systems Thinking
- Professional skills
- Teamwork/Communication Skills
- Exposure to Conceiving Designing Implementing and Operating

The results are displayed in Figure 1.

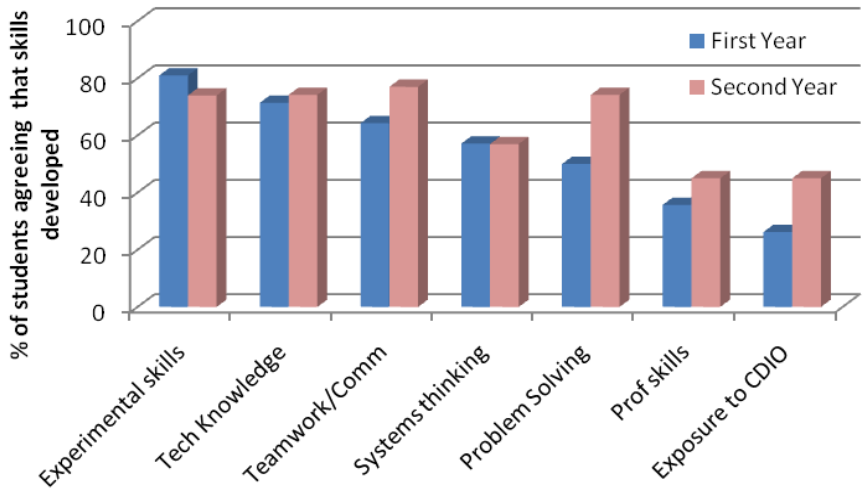

Figure 1. Percentage of students who agreed the lab programme gave them exposure to specific skills.

First years felt that the lab classes gave them good exposure to the traditional aims of lab classes: experimental techniques; Technical Knowledge; and Teamwork/Communication. However, the more aims more specifically associated with the CDIO syllabus were rated much weaker; only about half the students felt they'd had exposure to Systems Thinking and Problem Solving. Perceived exposure to Professional Skills and CDIO was even lower (36% and 26% respectively).

The results from the Second year evaluations were similar, except that there was much stronger agreement here that they had had an opportunity to develop problem solving skills. There was some improvement over the rating by First Years in the perceived exposure to Systems Thinking; Professional Skills and CDIO but again less than half the class agreed on these points.

Specific positive comments from the First Year students included gaining a better understanding of theory; having some good demonstrators; and they enjoyed working in small groups and meeting new people in the class. However there were also a lot of negative comments, with some labs being '*long and dull*' being the most frequently cited complaint.

Another common complaint related to the timing of labs – due to the rotations some groups covered certain labs before the theory was covered in lectures. Poor demonstrators in some cases also featured as one of the worst aspects of the lab classes – suggesting that the performance of the individual demonstrators can have a major influence on how much students get out of the lab. Other comments included '*lack of autonomy*', '*stress due to poor understanding*', '*not much analysis of results*', '*wanting more discussion and less dictation*', '*some labs rushed and poorly explained'*. There was also a worryingly high number of references to '*pointless calculations and pointless graphs*'. There was also a suggestion that most students lost interest after lab reports were submitted (essentially meaning that there were no further demands for assessment except to turn up).

Some of the feedback from Second Years was very similar; on the positive side with applying theory to practice, gaining better visual understanding, and exposure to 'hands-on' learning. On the negative side, timing was again a common complaint, some too long/dull and some poorly explained, were also echoed, as were sentiments relating to the lack of demonstrator enthusiasm and in some cases poor ability to explain the experiment. Some labs were seen as 'pointless' and one response stated a lack of creativity and interest in the lab program. There were conflicting responses from some students who felt they were given too much help and others who felt they were 'thrown in at the deep end' in some topics. Suggestions from students included affording a greater element of discovery for students; updating equipment; and including more project work.

IDENTIFIED BEST PRACTICE

It was clear from the student feedback that there are many shortcomings associated with the lab programme, however there were a small number of labs that were very popular with the students and which aligned well with the CDIO objectives. The most positive feedback related to the open investigations in the second year course which involve the students in active learning processes and more open-ended problem solving. The best example is a 'Beam Design and Test' lab – this involves students working in teams which compete against each other to design and build a beam with the best strength-to-weight ratio. The investigation is spread over three weeks: in the first the students work on the initial design of the beam and are encouraged to use the theory they have covered in lectures. In the second week, the students test their beam and are given an opportunity to identify the weaknesses and develop an improved structure. The final test is then carried out in the third week and students are encouraged to reflect on why certain designs performed better or worse than others. The teamwork and competitive aspects of the task make it an enjoyable one for the students and they felt it fostered greater understanding of theory than other more controlled investigations. This is one of the few labs to involve the students in both active and reflective processes and is an excellent example of applying Kolb's learning cycle [7] which states that learning requires a process of 'Doing, Reviewing, Learning and Applying'. Students have a valuable opportunity to learn from trial and error and from making mistakes [8]. This task allows appropriate amounts of support to be given to individual students to maintain interest and challenge yet ensure understanding – more help given to those who need it – either by their peers or by the demonstrators. An important aspect of the investigation is that the students are not led to any 'right' or 'wrong' answer; rather students are given the opportunity to 'construct' knowledge for themselves. Humans are '*active meaning makers*' [9], and according to Jackson [10] '*teachers must provide a learning environment where students search for meaning, appreciate uncertainty and inquire responsibly*'.

That said, the 'controlled investigations' are not without value. In these cases students were asked to follow a step-by-step procedure to arrive at a pre-determined result. This approach is not completely without merit; 'Doing' is a key factor underpinning successful learning [8] and obviously undergoing a practical process offers possibilities for greater depth of

understanding than purely theoretical work. This is particularly true as some students will have a natural preference for 'learning by doing' [11,12]. Therefore physical experience of theory covered in lectures ensures that these learners who may struggle with written or oral explanations in the classroom have an opportunity to learn in a way that suits them. This is supported by several comments from students to the effect that they understood theory much better after covering it in a lab. However, such a 'closed' approach to laboratory investigation results in a fairly limited learning experience; student feedback indicates that many are bored and unchallenged by lab classes and want greater opportunities for discovery and to exercise initiative. Labs demonstrating pertinent aspects of the theory should not be discarded but ways of making them more active should be considered, while other demonstrations may be better delivered in tutorial classes or in lectures using video clips etc.

AIDS AND BARRIERS TO EFFECTIVE LEARNING

The evaluation of the lab classes highlighted a number of different issues impacting on achievement of learning aims. Firstly, the role of the lab demonstrator was clearly highlighted as being extremely important to the students. Lack of understanding and lack of interest in the lab was often due to poor explanations, lack of enthusiasm and rushing the lab on the behalf of the demonstrator. Lab demonstrators are given no training in small group teaching and preparation may well be limited to receiving a copy of the lab manual from the course lecturer. As a result, the postgraduate demonstrators may be ill-prepared for the lab in terms of the aims and objectives and may be ill-versed in the theory. Therefore, any attempt to enhance the content and structure of the lab programme should also address training of those delivering the teaching.

Another issue which clearly impacts on the motivation of the students to learn is the nature of the lab assessment. It has been stated that "*Assessment defines what students regard as important, …If you want to change student learning then change the methods of assessment*" [13]. As in most cases students are required merely to follow the steps given by the manual/demonstrator there is very little opportunity to assess students' contribution and skills. As a result, there is very little divergence in the individual marks allocated to students and little motivation for the students to actively engage in understanding/analysis/discussion of the lab. It has been argued that the descriptive nature of lab reports can lead students to adapt lecture notes as opposed to thinking in a reflective way about their work; alternative lab assessments including on-line quizzes and short hand-ins have been found to result in higher levels of student motivation and understanding [14]. If we want to develop skills in engineering practice and applying theory to solve problems we need to design assessment aligned with these aims [15].

CONCLUSIONS AND SUGGESTIONS FOR IMPROVEMENT

- The lab classes in Mechanical Engineering at QUB provide better understanding of theory by giving the students a chance to learn through practical experience.
- Effective learning is limited by the dominance of controlled experiments in the lab programme which do not engage the students in active learning processes.
- Some good examples are evident of laboratory activities which support modern engineering educational aims of enabling students to tackle open-ended problems and apply theory to 'real-world' engineering practice. Student feedback indicates that they want greater opportunities to exercise initiative and creativity through this type of exercise.
- Student feedback has highlighted the importance of the laboratory demonstrator in achievement of effective learning from the lab class.
- The nature of laboratory assessment should be addressed to align student learning with the modern aims of an engineering education.

In attempting to improve the lab programme, current experiments should be assessed first in terms of whether they afford an opportunity for students to engage in active and reflective learning process. Can the lab be adjusted in some way to make it more open-ended and give the students an opportunity to make mistakes? Could the relevance to real-world engineering problems be made stronger? If not, perhaps the experiment could be better demonstrated in a lecture/tutorial class.

With the current, traditional, lab programme many key skills are not being realised strongly enough. Our students struggled to understand the relevance of other disciplines (Electrical Engineering); to appreciate the links between the various aspects of engineering science in system and to understand how theory applied to Conceiving, Designing, Implementing and Operating systems. A fairly radical shake-up of the programme is necessary to imbed these skills and the need for more open-ended project work is clear. There is a need to move away from the standard 3hour exercises executed on a 'round-robin' basis throughout the semester. An alternative approach may be to run a more limited number of projects, similar to the beam test, were students work on planning, testing and redesign over a period of weeks and are given appropriate levels of support from tutors in a facilitator role. A staged approach, whereby students are given a lot of guidance in early labs in order to equip them with basic skills, going on to structured investigations and ultimately project work has implemented in some engineering schools [16]. Obviously there are challenges in covering all aspects of the curriculum and in timetabling and resources which require creative solutions – for example students could be divided into different groups to select from a variety of project investigations which they would then teach to their peers.

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Biographical Information

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ACTIVATING A SECOND YEAR MEASUREMENT LAB SEQUENCE

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ABSTRACT

MECH 215 is a core measurement course in Mechanical and Materials Engineering at Queen's University with a lab component intended to maintain active learning skills fostered in the common first year program. In contrast to cookbook labs it is more process focused and drives student engagement through several active learning techniques. The learning objectives of a typical undergraduate lab experience are often undermined by the conflicting objectives of completing the task as quickly as possible while producing a good mark. The MECH 215 sequence intentionally reduces the complexity of the lab content in order to focus on the process and require active engagement in the measurement activity through several simple techniques.

- Incomplete information is provided in the lab material. Students are required to discover necessary characteristics of the available equipment and make independent decisions in order to meet the objectives.
- Just in time delivery of knowledge is provided in several ways. The students work in small groups within a larger lab plaza, so discovered information travels peer to peer. TAs and a faculty member monitor progress and deliver assistance only when students have hit a roadblock.
- Planned failure is incorporated into the activities with the expectation that some (or all) students will not get high quality data or flawless instrument performance. Overcoming these problems exercises critical thinking and engineering decision making skills in the lab environment.
- Multiple paths to a successful outcome exist for the activities. Students have choices to make in how they use the available resources.

The paper outlines the sequence of activities with specific examples of the application of these principles in practice and illustration of the flow of measurement concepts. This approach to giving labs provides some efficiencies of scale from having many groups active on the same activities at the same time, but also requires more faculty engagement in the delivery. A cost comparison between delivery methods in the same environment is made, showing that substantial advancement of CDIO syllabus objectives can be reached for little or no incremental cost.

KEYWORDS

Measurement, Laboratory, Cost, Active Learning

INTRODUCTION

For the past generation lab activities included in a typical North American Mechanical Engineering curriculum have involved only slightly more active learning than the typical lecture / assignment / exam courses they accompanied. These “traditional labs” generally focus on the demonstration of some physical principles developed in a lecture course by making measurements as reliably as possible on a mechanical system such as an IC engine, then completing some analysis and comparing the results to the idealized models derived in class. Characteristics of these labs include:

- A well integrated test system, with good quality instrumentation installed professionally to provide reliable data.
- Data display and recording systems pre-programmed and pre-wired for efficient and consistent performance.
- Lab documentation with detailed specifications of the hardware, instrumentation, and software involved.
- Step by step operating instructions to guide the students through the measurement process, and often the analysis phase.

These characteristics succeed in providing all students with a similar experience, exposing them to operation of a real system while collecting enough good quality data to analyze, producing predictable results that support classroom instruction. The well integrated package and detailed instructions allow the students to complete the lab activity in as little time as possible with minimal additional instruction or supervision and a very limited chance of failure at the task. Productivity is high by typical measures that focus on what content is taught, rather than on learning outcomes as in the CDIO approach [1].

Unfortunately, these seemingly positive characteristics also lead to some negative results with regard to learning outcomes:

- There is a significant amount of effort and expense involved in creating the integrated lab package, so they tend to be the same from year to year even as they become outdated.
- Running the same lab each year allows the students to pass down their lab reports as aids to the next year’s students, or for outright copying, which the predictable lab outcomes make difficult to detect.
- Labs in support of lectures are generally aimed at linear, steady or periodic operations that can be adequately described analytically in class and easily measured. Ignoring the non-linear, transient performance that is often important.
- Cookbook instructions do not require any engineering skills or knowledge to follow during the lab session, and provide no decision making options, limiting student engagement and thus reducing student learning.
- Learning objectives are further undermined by the conflicting objectives shared by both the students and the TAs delivering the lab. Both would like to complete the task as quickly as possible to move on to something else, and both would like the result to produce a good mark for the undergraduates. The result is even more streamlining of the lab process so that the undergraduates move through it as quickly and smoothly as possible, leaving with all the data required for the analysis, but little understanding of the how the results were achieved, or why.

The first two can only be thoroughly addressed by changes in resources and rewards associated with the lab activities. Resources alone are not enough without motivated faculty to make new activities part of the program. This paper addresses the approach to and experiences with reducing the last three by creating a linked sequence of labs with variable outcomes, engaging students through incomplete specifications, decision making as part of a team, and active assembly of the test equipment.

LAB SEQUENCE

The sequence of labs in the course is designed to flow in conjunction with topics addressed in the lecture portion of the course, however the labs also build on each other, carrying tools and concepts from one lab to the next.

Lab Zero: Labview was added to the sequence to provide students an opportunity to get familiar with simple Labview programming and operation for data acquisition and is a TA guided implementation of a simple virtual instrument (VI) that they will use throughout the sequence to record transient voltage data.

Lab One: General Instrumentation has the students work with and compare the features of simple bench instruments like a digital multi-meter, analog oscilloscope, and computer data acquisition (using the VI developed in lab zero) by using them to measure the output of a signal generator, battery voltage and resistance of ¼ watt resistors. Emphasis is on uncertainty, sources of error, and sampling rate requirements.

Lab Two: Temperature Measurement uses the instruments from labs zero and one to measure the behaviour of thermometers, thermocouples and resistance temperature detectors (RTDs), and introduces the wheatstone bridge for measuring small resistance changes. Emphasis is on transient response and developing a first order model.

Lab Three: Stress and Strain uses a cantilever beam load cell to develop the idea of calibration for the characteristics and accuracy of a measurement system. Strain gauges in a wheatstone bridge give a near instantaneous response while the physical system mass and stiffness determine the second order dynamic response of the complete system.

Lab Four: Position Measurement repeats the calibration process with a rotary potentiometer then introduces the effects of noise in extracting measurements of angular velocity and acceleration from the raw position data. An additional segment has students determine the measurement capabilities of a complex system by examination of the output. GPS units and an optical position tracker have been used.

Lab Five: Pressure and Flow has students using a water manometer and solid state pressure transducers to measure steady and transient pressures, and then to measure the static pressure from taps on a small piping system driven by a vacuum cleaner. Pressure drop in the pipe is measured, as well as start up and shut down transients.

This sequence provides an opportunity for students to learn some important concepts in measurement and testing as well as the physics of the system behaviour. They encounter physical phenomena from previous or current curriculum which they can analyze, as well as elements like heat transfer they do not yet have the theoretical tools for. It can be carried out with inexpensive, uncomplicated equipment. It can be implemented in just about any facility, although a purpose built facility like the lab plazas in the Integrated Learning Centre at Queen's [2] provides an ideal venue. Unfortunately, it can also be streamlined to allow students to complete all the necessary measurements for each segment and be out of the lab in half an hour, having learned little or nothing while actually *in the lab*. That streamlining is eliminated by actively engaging students in the process through the structure of the activity.

PREPARATION

Lab Zero prepares the students for the idea that they will actually be thinking and acting during the lab periods, while working in a group of three or four. A clear set of step-by-step instructions is provided to create a VI and test its functioning. This segment was only split off from the general instrumentation lab when we realized just how many sub-functional outcomes were possible from those instructions. As a separate segment there is time for

each student group to debug their own VI to produce a tool they will use in all of the other labs. Students introduce personal elements as simple as names that give them ownership of the tool.

ACTIVATION

Labs one through five are distinctly different in being more open ended and lacking step-by-step instructions. Students must make their own decisions on how to achieve the measurement objectives and how to determine when those objectives are met. That includes completing all instrument connections themselves, and fabricating some of the test equipment. These elements allow students to take multiple different approaches to the measurement task, and because multiple groups are working alongside each other in the same space they learn from interactions between groups taking different approaches. This can be best illustrated by examples.

In lab one students move around the room with DMMs measuring the results achieved by other students. The result is student motivation to maintain quality in comparison to their peers and a unique data matrix to analyze for overall uncertainty in the process. They identify connections to make from device spec sheets and experience errors with poor or reversed connections after stripping insulation from the wires to make those connections.

In lab two each student starts with a short length of thermocouple wire that must be welded to make a junction and then connected in various configurations of measurement and reference junctions. They experience recoverable failure in their welds, with highly variable results. Groups that rush to complete the measurements see that their circuits of twisted wire connections cause them reliability problems even in the short term compared to those who solder the joints or use terminal blocks. Their constant reference temperature is provided by placing the reference junctions between two bricks with liquid crystal temperature strip, resulting in a different, uncontrolled reference temperature on different days (Figure 1).

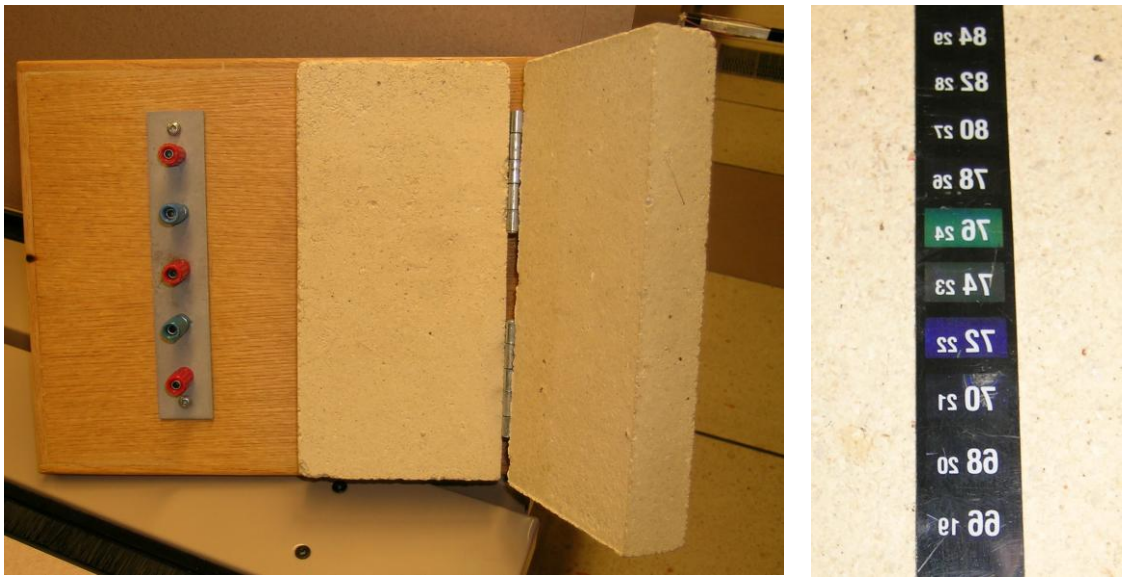

Figure 1. A simple system for connecting thermocouples and providing a reference temperature between two bricks. The LCD strip provides an imprecise reference in the uncertainty analysis. The burn mark on the left is evidence of student soldering in the lab.

In lab three each group glues strain gauges to a cantilever beam, then solders leads to the gauges, with an eventual success rate of about 95% – we keep a beam in reserve for those

few groups who just can't get it to work in the time. Before even they starting they must first decide where to put the gauges on the beam and in which orientation.

Calibration of the load cell is performed by applying various weights held in a bucket, or otherwise (Figure 2). The students are not provided with reference weights but must use text books, lumps of scrap steel or anything else available and weigh their materials on a digital scale. They obtain irregularly spaced calibration points and must make their own decisions about how many are enough.

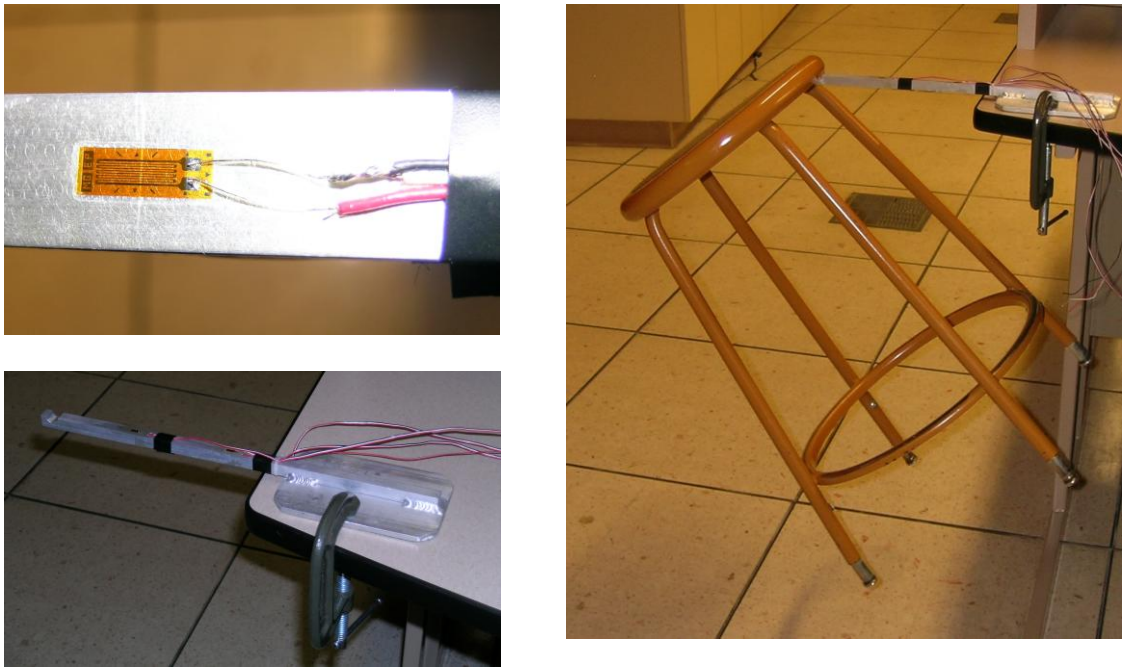

Figure 2. In the strain measurement lab students first glue a strain gauge to the aluminum cantilever beam, then solder leads to the gauge. This is made somewhat easier by the larger pads on Intertechnology student gauges. The beam construction allows easy clamping to a bench and the notch in the end of the beam allows suspension of a bucket or other objects.

In lab four students are challenged to measure which among them can turn the potentiometer knob at a most nearly constant angular velocity. In converting voltage to angular velocity they must first find a suitable circuit and then find a way to numerically differentiate the results without amplifying the noise too much. They discover some scheme (usually a moving average) to low pass filter their data.

In lab five they see a slow transient response from a manometer responding to a balloon popping step function (Caution: some students have a bad reaction to popping balloons so a warning and accommodations may be necessary) and a slow transient response from a solid state pressure transducer monitoring a vacuum cleaner running down and need to establish instrument response as distinct from system response.

In lab two students are simply asked to measure the time response of a thermometer suddenly dunked in hot water. They must decide how to measure time, how often to take readings, how long to take readings, and how to accomplish this as a group – it is difficult to manage timing, reading and recording alone.

Throughout the sequence they are measuring voltages or resistances that they must convert to other units through calibration factors they have determined themselves. There are many ways to assemble circuits of these low voltage components, most of which are harmless and offer learning opportunities in the debugging. We have explicit checkpoints where damage might result and have added small resistors to the wipers of the potentiometers to prevent outright shorts, but generally encourage students to test their ideas and learn from the experience.

GUIDANCE AND CONTROL

All of these uncertainties produce different responses in different students and each group and situation needs a different response from instructors. Active learning requires active guidance and control to recognize differences and respond appropriately, in ways that are usually beyond the capacity of a typical graduate student TA. The lab sessions must have supervision from somebody like a faculty member, adjunct, or senior technical staff member to keep things on track.

Some groups are all business, have read the materials in advance, come in and complete each task quickly and fully, and probably didn't need the lab experience because they have already achieved the learning outcome goals somewhere else.

Some groups are ill prepared but ready to try anything. They will complete some sequence that comes close to meeting the objectives, but may not recognize that their data are inadequate until long after the lab session when they go to write up.

Other groups are hesitant to try anything for fear that it may be wrong and would prefer to wait for an instructor to do it for them.

Those three descriptions are almost caricatures in their generalization, however they represent a large portion of the class. When things are going well the instructors will checkpoint the first type of group to make sure they are on the right track and compliment them on their preparation. The second group will notice that things are going well for the first group and will probably incorporate some of those techniques when their own first attempts don't work out so well. The third group may start their own efforts once they notice that nothing really bad has happened to groups one and two. If the population in the lab section is fairly balanced then this process will take little instructor intervention, but if there's a shortage of well prepared and competent groups, then the instructor needs to initiate and guide the process.

The eager, but ill prepared groups need to be redirected to recognize what they are missing and think a little more before acting, while the hesitant groups need to be encouraged to try out a few well considered actions to test what works, and if there is time, the businesslike groups need to be encouraged to try some other possibilities beyond the specified objectives to see what else they can learn from the situation. The result is rather like herding cats, however 2 TAs and a faculty member can guide a section of 10 to 15 student groups through these activities in two to three hours per lab segment.

COSTS

Our typical classes are on the order of 150 to 180 students. In a traditional lab offering a faculty member would be responsible for reviewing the lab equipment preparations, briefing and supervising TAs and delivering an introductory lecture for that lab to place it in context. Two TAs would then supervise the class as they completed the lab (typically 1 TA to 3

groups at a time) and mark the lab reports. The sequence of six labs would be spread over 6 faculty to distribute the load. The result, in addition to preparing the labs, would be 12 to 18 faculty contact hours and 12 TA term contracts at 60 hours each for supervision and marking.

In this active learning model a single faculty member would be responsible for all six labs to maintain continuity, and would attend all lab sessions, typically with 8 to 12 student groups per 2 to 3 hour session and 5 or 6 sessions per lab. TAs would each support all six labs through the term to spread their load. The result, in addition to preparing the labs, would be 60 to 90 faculty contact hours and 6 TA term contracts at 60 hours each.

The active learning approach requires less total personnel time, but requires considerably more time from a faculty member or similarly qualified individual. The six additional TA contracts translate to about $15,000 in our environment, which is similar to the cost of hiring and adjunct faculty member to teach the lab portion of the course, but somewhat cheaper than the cost of assigning it as core teaching load to a tenure stream faculty member. TA budget is often seen partially as graduate student support and comes from a different funding stream, making it more attractive to use TAs. Additionally, in tight economic times the tendency is to eliminate as many flexible costs as possible, including adjunct teaching positions. Finally, splitting the task between 6 faculty only adds a minor load to each faculty member which may not show up in accounting resource requirements. The result can be a bias towards delivering labs in a traditional cookbook format with limited student engagement.

The simplicity and intentional crudeness of some of the measurement devices allows assembly of many sets of equipment at minimal cost. Although a purpose built lab plaza provides a wonderful venue for this and other activities, this approach was first developed in large empty room with simple plywood benches and it worked very well there.

CONCLUSION

A sequence of labs can be delivered in a more activated form with more faculty involvement if the institutional will is there. The actual cost is similar, especially if the faculty member involved is an adjunct or other teaching focussed instructor. Student engagement is increased by adding obstacles to simple measurement tasks, however timely intervention is necessary to keep challenge from spilling over into frustration. Further assessment is required to determine formally if this active approach produces the better learning outcomes we observe anecdotally.

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ACTIVE AND EXPERIENTIAL LEARNING OF STATISTICS @ LIBRARY

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ABSTRACT

This project was a collaborative effort by the Department of Mathematics and Science, the Library and the Educational Development Unit of Singapore Polytechnic. The primary objective was to help students sharpen their research skills and rectify statistical misconceptions through clarification of ideas. The secondary objective was to develop their confidence in interpreting and synthesizing information for classroom sharing. A total of 51 students from the Diploma in Information Communication Technology and the Diploma in Computer Engineering participated in the project. The study adopted a team-based approach whereby learning activities were designed around a common theme and the whole learning process took place within the library. Upon the completion of the learning tasks, the students then gathered in the library's Media Viewing room to present their findings. After the sharing session, students were asked to blog about their experiences. All these activities were candidly captured on video so that students could reflect on their learning. The whole exercise not only reinforced their fundamental knowledge in data collection and data analysis, it also enhanced their interest in learning statistics. Most importantly, the students enjoyed learning in a new environment and they were able to relate mathematical learning to real life applications.

KEYWORDS

research skills, statistical misconceptions, team-based approach, library, real life applications

INTRODUCTION

This project involved an integration of active and experiential learning, which was in line with CDIO™ Standard 8 on Active Learning. Active learning differed from traditional teaching in that students were required to do meaningful learning activities and in the process, learnt to think about what they were doing [1]. The benefits of active learning could be two-fold [2, 3]. First, it allowed students to examine questions that were both fundamental and pragmatic. Second, it eliminated the need to study the effectiveness of every instructional technique. The essence of active learning lay in the introduction of student activity to promote student engagement so that they could develop a deeper understanding of important ideas [4]. According to Soh [5], students learnt better through exploration, interaction and working collaboratively with others. Engaged learning could be carried out through active involvement, especially if students were given the opportunity to show what they had learnt. The role of the teacher was more to generate maximum participation, and to encourage them to search for solutions by getting them to ask questions. In sum, active learning helped learners gained ownership of their learning experience and made them aware of the desired learning outcomes.

CREATING WORKSPACE FOR ACTIVE LEARNING

The creation of an active learning experience at the library also satisfied CDIO™ Standard 6 on Workspaces. Educational pedagogies described the creation of spaces as a tool for empowerment and liberating student voices. Based on this epistemology, Povey [6], a British mathematical educator, identified three characteristics for creating a good mathematics classroom. They were:

1. The learners made the mathematics.
2. Mathematics should involved thinking about a problem-centered curriculum.
3. Learners' difference and individuality should be respected.

On the discussion of student voice and participation, Gustavson [7] proposed the concept of creating classroom as "spaces of mutual work" (p. 151) to develop authentic relationships of living mathematics. This shift required teachers to share their mathematical passion with students as in our everyday lives. One way to do this was to integrate mathematics with issues in our communities and help students develop the mathematical skills and concepts necessary for their applications in real life [8]. Helfenbein [9] also addressed the importance of finding new ways to support the creation of mathematical place so that students could engage in meaningful and purposeful exchanges while they spent their time there. According to Lefebvre [10], we could think of the concept of space as not in the space itself, but more on what was particularly important about this space of learning and teaching that we were creating with our students. To enact and create meaningful space, we could focus our thinking on some critical features of this space that would make the experience metaphorically analogous to the space itself. Lefebvre [10] reckoned that student participation could take on different forms. For example, we could divide students into small groups and leave what and how they produce it to the group to decide themselves. Alternatively, we could structure the space into class time periods where students take responsibility for their learning without the teacher directing the experience. In either way, the challenge was to ensure that learners were engaged in creating their understanding of the workplace itself.

DESIGNING AN ACTIVE LEARNING EXPERIENCE

How we relate to the space would determine how we would be experiencing that space. Hence, a major part of the design process was in finding a workplace so that students' interest in learning statistics could be heightened. According to Freeman [11], the library functioned as an extension of the classroom for students to engage in collaborative learning and refine their critical thinking. The library was also chosen for the following reasons:

1. It allowed students to take on learning assignments that were modelled after a real life environment.
2. It had a rich source of information and ideas which could facilitate the teaching of descriptive statistics.
3. The ready stream of library users created opportunities for students to engage in meaningful dialogue and conduct face-to-face interviews.
4. The Media Viewing zone provided a good setting for reflective critique and feedback from both peers and facilitator without disturbing other users.

To ensure that learning activities could be completed within the planned curriculum hour, students were divided into four groups and each group comprised four to five members. Since the venue for data collection varied according to task, the groups were assigned to different levels within the library to conduct their surveys. Each group was advised to collect at least 10 sets of data. At the end of the data collection, each group must justify why they chose to use mode, median or mean to draw their conclusions. The learning tasks for each group was specified below (details were provided in Appendix A).

1. Group A – the most preferred library materials used by students which included periodicals, DVDs and music CDs.
2. Group B – the most preferred library facilities used by students which included PC facilities, study facilities and loan facilities.
3. Group C –the number of hours spent weekly in the library by male students.
4. Group D –the number of hours spent weekly in the library by female students.

After the briefing, the students were naturally excited as the thought of learning statistics in the library was a novel idea to them. The Media Viewing zone was soon abuzz with enthusiasm as each group presented their findings and blogged about their learning experiences. The whole learning process was captured on video to allow students to review one another's work. The students were delighted to watch themselves in action. They were at ease in sharing problems they had encountered in the learning process. Interviewing the students thereafter also injected new ideas on how to make the whole learning process more meaningful.

LEARNING THEORY AND CONCEPTUAL MODEL

To facilitate a common understanding, the theory of action/reflection introduced by Dilworth [12] was incorporated as a conceptual model for statistics at the library (see figure 1). According to Dilworth [12], action/reflection learning employed the following formula:

L (Learning) = P (Programmed Knowledge) + Q (Questioning) + R (Reflection)

L (Learning) was built around the principles of active learning and reflective dialogue. Each tutorial class was assigned to a specific time slot at the library. Students then organized themselves into groups of 4 or 5 members and the lecturer briefed every group on its specific learning tasks. P (Programmed Knowledge) focused on strengthening the fundamental knowledge of the measures of central tendency and the construction of stem-and-leaf diagrams. Q (Questioning) emphasized the importance of inquiry-based learning and the techniques of conducting interviews with library users. R (Reflection) helped students rectify their statistical misconceptions and blogging the experience allowed them to document what and how they had learnt in the process.

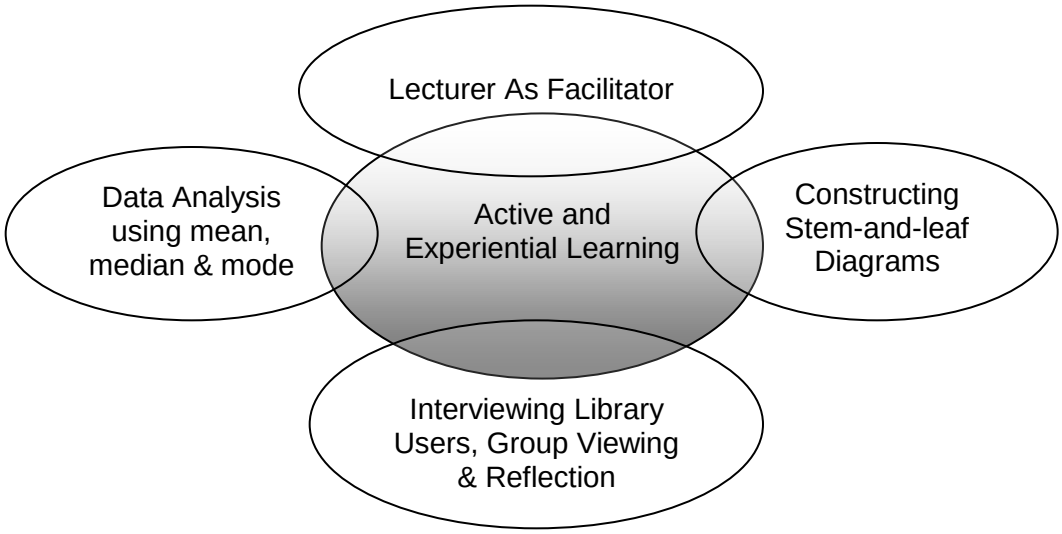

Figure 1 – A Conceptual Model of Statistics @ Library

AN OVERVIEW OF THE STUDENTS' FINDINGS OF LIBRARY

Group A was asked to approach library users for their preference of the library's collections of periodicals, music CDs and DVDs. Group B was asked to interview library users for their ratings on library's facilities. Group C and D were asked to gather feedback on library usage patterns and compare their findings in a back-to-back stem and leaf diagram for the number of hours male and female students spent weekly at the library. The findings were summarized below:

- **Library Materials**

  Students chose DVDs as their most preferred library materials as videos were more entertaining, the range of DVDs was wide and they were well organized. Most importantly, they were easily accessible at Level 2 near the library entrance.

  Music CDs was the second preferred choice although sometimes they had difficulties in finding them from the shelves. In addition, some respondents also said that they never borrowed music CDs as they were not keen in listening to music.

  Periodicals were the least preferred choice as participants found that these materials were not as entertaining as DVDs and Music CDs.

- **Library Facilities**

  Study facilities was the most preferred library facilities as respondents felt that the library provided an environment conducive for learning. In addition, they expressed that there were not enough study facilities in their school and they would like to have more project rooms in the library.

  PC facilities was the second preferred choice as most of the students had their own laptops and did not need to use the PCs in library PC labs. Loan facilities were the least preferred choice among the three options as respondents commented that they did not have time to read books due to their busy schedule. Some respondents said that when they study in the library, they would use the books in the library instead of borrowing them home.

- **Usage Pattern of Female and Male Students**

  The usage patterns of male and female students were similar as both genders spent an average of 3 hours per week in the library. However, for female students, their main activity was study and for male students, they would normally visit the library during their break time. Interestingly, this finding was similar to Group B's finding that library study facilities were their most preferred choice.

Misconceptions and Post Quiz Results

Although the learning experience at the library presented some misconceptions regarding the appropriate use of mean, median and mode, it was necessary to correct these misconceptions as they could lead to faulty thinking or poor understanding. Misconceptions could surface in many forms, particularly with regard to statistical decisions and interpretations of data-based findings. According to Mevarech [13], sometimes misconceptions were so deeply ingrained in a student's underlying knowledge base that mere exposure to a more advanced course in statistics was insufficient to overcome them. In the article entitled *"How students learn statistics"*, Garfield [14] found that students were resilient and slow to change their misconceptions even though they were confronted with evidence that their beliefs were incorrect. Callaert [15] reckoned that to eliminate students' misconceptions, teachers could design instructional interventions to generate a deeper understanding of these misconceptions.

To validate these concerns, a post quiz (see Appendix B) was conducted to test students on their analytical reasoning of data presented in a case study and stem-and-leaf diagrams. Students had to (i) compute mean, median and mode; (ii) comment on each company profile based on the salary distribution survey of three companies; (iii) complete a concept map on organizing data and the appropriate use of the measures of central tendency; and (iv) go through a checklist of questions to indicate if they had understood and achieved the desired learning outcomes. Surprisingly, there was a vast difference in the performance for each item. Although 100 percent of the students was able to compute mean, median and mode as well as analyse data presented in stem-and-leaf diagrams; only 20 percent could give accurate accounts of the profile of each company. Despite affirming that they had understood and were able to achieve their expected goals, 43 percent still could not distinguish the purpose and use of mean, median, mode. These results supported earlier evidence that some students were resilient and slow to change their misconceptions.

Conclusion

This project was successful in that it added an innovative and refreshing dimension to learning statistics outside the classroom. Student feedback indicated that such learning experience not only reinforced their fundamental knowledge in data collection and data analysis, it also stimulated their interest in learning statistics and raised their awareness of the real-life application of descriptive statistics. The survey findings revealed that students used the library for their projects and assignments. They viewed the library as a space conducive for independent study and collaborative learning. Although the project achieved the desired outcomes, designing an active learning curriculum required careful planning and a substantial amount of time and resources. Future work could build on the conceptual model and extend its applicability to other faculties of learning. The authors hoped that the teaching and learning of statistics at the library would motivate more teaching staff to explore the library for collaborative learning. The new library extension would be an interesting communal teaching and learning space as it offers a magazine reading lounge, board games room, Media theatre, Media Viewing booths and a café.

Acknowledgements

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Biographical Information

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Appendix A

Active and Experiential Learning of Statistics @ Library

In this lesson, students will gather at the library's Media Viewing room to learn how to interpret and analyze data using mean, median and mode. They will also learn to present their findings using stem-and-leaf diagrams.

Objectives

1. To encourage students to reflect on subject content and to deepen their understanding of the use of statistics.

2. To help students sharpen their research skills through clarification of ideas and group learning.

Learning Tasks

Students are briefed on how to carry out their learning tasks before they are divided into four groups. Each group consists of 4 - 5 members. They are given an hour to carry out their learning tasks and another half an hour to share their findings and blog about their learning experiences.

Group A & B

Group A and B will watch a 10-min video on "Distribution Curves". Group A will have to carry out a survey to gather feedback on library's periodicals, Music CDs and DVDs. Group B has to conduct a survey to gather feedback on library's facilities. Both groups have to complete the survey within 20 minutes and come back to the Media Viewing room to interpret the data using mean, median and mode.

Group C & D

Group C will conduct a survey to find out the number of hours that **male** students spent weekly at the library. Group D will conduct a survey to find out the number of hours that **female** students spend weekly at the library. They have to complete their survey within 20 minutes and meet at the Media Viewing room to watch a 10-min video on the techniques of creating a stem-and-leaf diagram. They then use a Back-to-Back stem-and-leaf diagram to compare the data collected for male and female students.

Constructing a Back-to-Back Stem-and-Leaf Diagram

A back-to-back stem-and-leaf diagram is useful when comparing distributions of two sets of data simultaneously. Using the two classes of data:

Class A					Class B				
5	7	48	18	30	22	11	6	9	44
19	31	27	35	12	23	39	28	32	26
44	4	29	16	23	14	46	8	17	41
41	25	39	9	21	45	6	21	38	485

Step 1: Decide which place values are to be used as the stems and leaves.

Identify the lowest score and highest score (e.g. 5 and 48).

Hence the stems are the tens digits 0 to 4 and the leaves are the one digits.

Step 2: Draw a vertical stem-column in the centre and label the 2 classes as the leaf-columns on each side of the stem in proper order. Provide a key for each class.

Class A						Class B				
	9	7	5	4	0	6	6	8	9	
	9	8	6	2	1	1	4	7		
9	7	5	3	1	2	1	2	3	6	8
	9	5	1	0	3	2	8	9		
		8	4	1	4	1	4	5	6	

Key: Class A: 8 | 4 means 48

Class B: 2 | 1 means 21

Learning Task for Group A

Name of Group Leader:

Name of Members:

Collect data from at least 10 polytechnic students to find out their preference of library's periodicals, music CDs and DVDs. Based on the data, calculate the mean, median and mode for each category. Identify which is the most preferred choice based on appropriate use of the three measures.

***Use tally count to record participants' response**

1- Least Preferred ----------5- Most Preferred

Rating Scale	1	2	3	4	5
Periodicals					
Music CDs					
DVDs					

Results	Mean	Median	Mode
Periodicals			
Music CDs			
DVDs			

Conclusion & Justification:

Learning Task for Group B

Name of Group Leader:

Name of Members:

Collect data from at least 10 polytechnic students to find out their preference of library's facilities. Based on the data, calculate the mean, median and mode for each category. Identify which is the most preferred choice based on appropriate use of the three measures.

***Use tally count to record participants' response**

1-Least Preferred ----------5- Most Preferred

Rating Scale	1	2	3	4	5
PC Facilities					
Study Facilities					
Loan Facilities					

Results	Mean	Median	Mode
PC Facilities			
Study Facilities			
Loan Facilities			

Conclusion & Justification:

Learning Task for Group C

Name of Group Leader:

Name of Members:

Conduct a survey to find out how many hours MALE students spend weekly at the library. Using the data, construct a stem-and-leaf diagram and provide a key for reading. Identify any gap or cluster.

No. of Hours Spent Weekly	Tally	No. of Male Students

Stem-and-Leaf Diagram

Comment on Your Findings:

Learning Task for Group D

Name of Group Leader:

Name of Members:

Conduct a survey to find out how many hours FEMALE students spend weekly at the library. Using the data, construct a stem-and-leaf diagram and provide a key for reading. Identify any gap or cluster.

No. of Hours Spent Weekly	Tally	No. of Female Students

Stem-and-Leaf Diagram

Comment on Your Findings:

Appendix B

POST QUIZ

1. Which of the following is the best representative of the data set: 1, 1, 2, 3, 3, 10 and 1?

   (a) mean (b) median (c) mode (d) all of them ( )

2. For the stem-and-leaf diagram given, find the mean, median and mode.

Stem	Leaf
1	3 5 7 7
2	1 2 2 3 3 5 5 6 7 8
3	0 1 4 5 9
4	2 3 8
5	1

   Key: 1 | 3 represents 13

3. The back-to-back stem-and-leaf diagram represents the test scores of Tom and Jane:

Tom		Jane
2 1	1	*3*
2 5 6	2	2 5
1 1 1	3	3 4 5
x	4	5 5 7

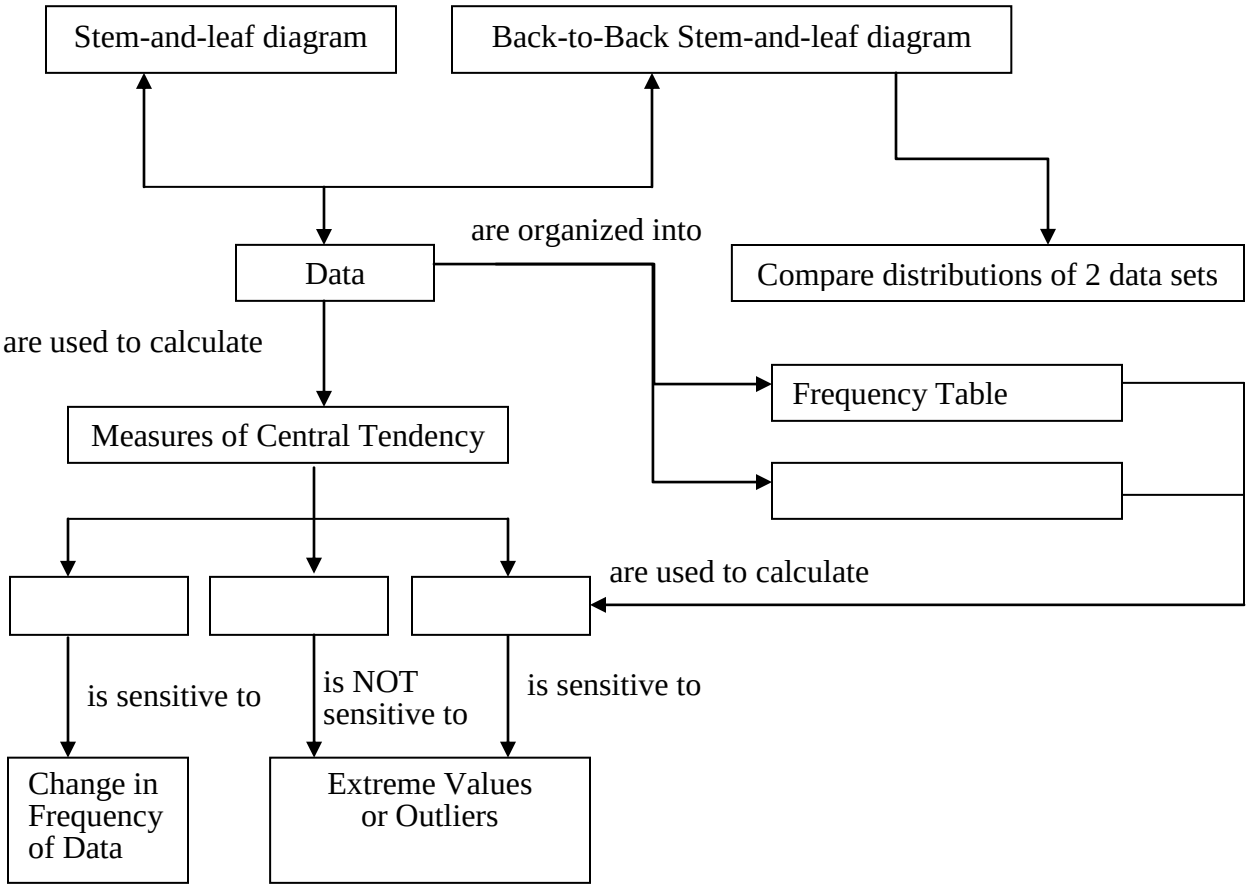
   Key: Tom - 2 | 1 represents 12 marks
   Jane - 2 | 5 represents 25 marks

   (a) How many tests did they each participate in?
   (b) If Tom's highest score was 3 less than Jane's highest score, find the value of *x*.
   (d) Which score occurred most often?

4. The mean, modal and median salary of a salary distribution survey conducted on three companies are displayed as follows. Study the results carefully and comment on the profile of each company.

Salary Range	Number of Employees		
	Company A	Company B	Company C
< $20 000	0	1	16
$20 000 - $30 000	2	46	21
$30 000 - $40 000	93	31	22
$40 000 - $50 000	5	18	15
$50 000 - $60 000	0	2	8
$60 000 - $70 000	0	2	5
>= $70 000	0	0	12
Mean	$35 000	$35 000	$45 000
Median	$35 000	$33 700	$37 400
Mode	$35 000	$31 100	$25 900

5. Fill up the missing boxes in the Concept Map below:



6. Complete the checklist with a tick.

I understand and am able to		Yes	No	Not sure
(i)	interpret and analyse stem-and-leaf diagram			
(ii)	find the mean, median and mode from a set of values			
(iii)	find the mean, median and mode from a frequency table			
(iv)	calculate the mean and standard deviation for group data			
(v)	distinguish the purpose and use of mean, median and mode			
Comments (if any)				

ACTIVE LEARNING IN LARGE INTRODUCTORY CLASSES IN MATHEMATIC

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ABSTRACT

The teaching-learning process has been a constant target of studies, particularly in Higher Education, in consequence of the annual increase of new students. The concern with the maintenance of a certain quality level in the training of these students, conjugated with the will to widen the access to all of those who finish Secondary School Education, has triggered a greater intervention from the education specialists, in partnership with the teachers of all Higher Education areas, in the problem analysis.
Considering the particular case of Sciences and Engineering, it is witnessed a rising concern with the active learning strategies and forms of assessment.
Research has demonstrated that students learn more if they are actively engaged with the material they are studying. In this presentation we describe and present the results of an active learning strategy in an Algebra course of the Informatics' Engineering Bach., with nearly 430 students and a team of 5 teachers.
The students start to study a subject with some help from the teachers, and they have to prepare a presentation on the studied subject. They make the presentation to their colleagues and after that they are evaluated. During this year we notice that students have shown a deeper interest in Algebra classes and also improving overall results.
This paper helps us answer the following questions: Who evaluates the presentations? How is this done? What other forms of assessment are there in this subject? What was used to assess that students showed deeper interest?

KEYWORDS

Teaching-learning process, learning strategies, assessment.

INTRODUCTION

The acquisition of experimental competences is fundamental for the students of sciences and engineering [1].

The article is structured in the following manner: section 2 presents a brief reflection about the present theoretical currents of the teaching-learning process; section 3 deepens the teaching components of sciences and engineering, particularly the experimental component; the following section describes the experimental learning; section 5 describes the assessment in the cognitive domain and finally, section 6 concludes the document.

PRESENT THEORETICAL CURRENTS OF THE TEACHING-LEARNING PROCESS

We initiated this reflection assuming that the teacher must know the tendencies that influenced the teaching-learning process, to be able to understand the present context and reflect on the pedagogical performance with the goal to optimize it. The pedagogical reflections that have been produced over the last few years are convergent in the analysis of the systemic character of the components in the teaching-learning process.

It can also be said that there is no effective pedagogy without having a precise idea of what the students are required to learn in the end. If we know where we are heading, the right path to get there will be taken [2], [3], [4], [5]. The previous definition of the pedagogical goals or expected learning outcomes, as well as the analysis of the pedagogical methods and means, which makes clear what is required to achieve with the pedagogical actions that are projected and undertaken, and in the end analyze the whole process. Through the definition of the goals, it becomes possible to eliminate the ambiguity that so many times surrounds a pedagogical moment defined in terms of content or acquisition of generic and diffuse knowledge [5].

The pedagogical goals offer the teacher a line of action for the learning activities planning, the conducting of a class and evaluation of the outcome. Knowing what are the goals to achieve, the way to achieve them will be easily known. With well defined goals, the teacher has of a point of reference which allows and guarantees more rigour in the selection and structuralization of the information to be provided, activities to be developed and the most suitable methods to apply. Thus, the goals will make the teacher care more about what the student should learn, rather than what it is supposed to be taught, assuring a higher adjustment and pertinence to the assignments that need to be executed. Finally, through the attainment, or not, of the scheduled goals it will be possible for the teacher to determine the degree of success of strategies and pedagogical behaviors, therefore obtaining an important mean of evaluation and action control. The student's knowledge of the goals is perhaps one of the most effective means for the attainment of learning. According to Mager (1976) [6], "... if you tell a student the goals of his or her learning, maybe you don't have to do anything else". In fact, the knowledge of the goals allows the student to:

- know where to stand concerning the purpose to be obtained;
- take conscience of what it is going to be demanded;
- distinguish the essential from the accessory;
- have a point of reference to evaluate and control the progresses.

SCIENCES AND ENGINEERING TEACHING COMPONENTS

Concerning experimentation, the integration between theory and practice assumes special relevance.

> "Activity by itself is not enough. It is the sense that is made of it that matters."
> Driver (1983)

About experimentation in an educational context, Lopes (2004) [7], highlights the following aspects:

- The experimental work cannot be isolated from the theoretical approach;
- The experimental work is a theoretical and empirical effort in the sense of answering to a problem of the physical knowledge, relevant to the student;

- The planning of experimental work is a task that is in need of an explicit model of physical situations, concerning experimental systems;
- The theories and empirical information can be enriched with experimental work. The theoretical approach, disregarding how rich and profound it may be, does not run out by itself. Every theoretical project can only be complete if it is prepared to face the experiment and be completed by it. In the same way, the empirical information has only true meaning if it is gathered and/or produced in the context of a theoretical approach.

Lopes (2004) widens the definition of experimental work presented previously, mentioning four important aspects:

- Questioning is part of the experimental work, as to unchain it, as well as to (re)-orientate it or even to consider it finished (it is necessary to look in the right direction, know how to look and be prepared to make the correct interpretation);
- The use/construction of a model is a fundamental characteristic of experimental work, because it is through it that it is possible to make decisions, go forward with knowledge, and make sure the relevant variables are being considered and even change the model itself or reformulate it. On the one hand, experimental work connects the theoretical models with reality and on the other, the theoretical models can only be used on models of physical situations and not on the physical situation;
- The activity concerning the empirical relation is a constant and it can belong to several types: assembly, observation, measurement, use of equipment, use of techniques, manipulation, perfecting the experimental system, etc. This activity can, in several circumstances, bear the use of computer systems for data acquisition, allowing the students to focus on the interpretation of data and less on the attainment and process of that same data;
- The interaction with the community (peers, teacher and accepted scientific knowledge) has the role of confronting ideas, clear up reasoning; communicate results and conclusions, as well as the way how it has come to them.

The conditions for the experimental work to promote the conceptual development are:

- The experimental activity has to be well thought of by the teacher and the subjacent conceptual aspects must be explained;
- The conceptual exploring must be focused on the experimental activity itself and not on its relationship with the previously mentioned subjects;
- It is necessary to invest time in experimental activities in order to deepen the conceptual aspects of the experimental activity, discuss and interpret the experimental results in light of the used models.

In this context, Lopes (2004) considers that the activities of the experimental work type are as follows:

- Activities of the predict-observe-explain type (FOE);
- Experimental verification (EV);
- Computational simulation/model (CS);
- Oriented experimental activity (OEA);
- Experimental problem (EP).

On the following table, the educational characteristics and functions of each activity are included (Lopes, 2004).

Table 1
Characteristics and educational functions of experimental work activities

Type of activity	Characteristics	Educational Functions
Predict-observe-explain	In presence of a problem and/or physical situation, it is requested to make a written prediction by presenting a justification. The teacher executes the experiment and, at the same time the students register what they observe. After that, they compare what they registered with what they predicted and explain the agreements and disagreements. The table can be used to register the synopsis of the predictions and observations. The mediation of interpretation and the conclusions must be very careful to the manifested disagreements.	Relate the theoretical approach with the experiment, based on questions. Use theoretical models and experimental systems to predict and explain discrepancies on what it is observed. Perform a scientific observation. Identify and control relevant variables. Initiate the students in competences of experimental work.Reformulate/structure/enrich a conceptual field.Widen/develop/precise sensitive experiment of physical phenomena.
Experimental verification	It is about verifying a law experimentally, or a theoretical model with an experimental system that is close to the ideal. Generally, it is guided by an experimental protocol. Considering that it has a strict protocol and the experimental system is close to the ideal (and conceived by the teacher), the experimental execution can be made by the students without the teacher's supervision. The interpretation needs to be mediated by the teacher. It will only have characteristics of experimental work if the question dimension is kept intact.	Illustrate theory (and/or study the conditions of the theory use). Study a law (and/or its limits of validity). Observe and describe a produced phenomenon in the frame of a scientific theory. Develop the competences of the data treatment. Develop competences of the experimental work. Reformulate/structure/enrich a conceptual field. Widen/develop/precise sensitive experiment of physical phenomena.
Computational Model Simulation	It is about using software to produce models or perform simulations by using previous computational models. In the sense that the perform dimension in a empiric relation is not present, it may not be considered as an experimental work. Even still, there is a manipulation component that consists in interacting with the software and see what happens. If the remaining dimensions are present, particularly the questioning dimension, there is a good proximity with advantages and flaws concerning the traditional experimental work. In any dimension of experimental work, the teacher must mediate.	Study in depth a theoretical model: its limits of validity, pertinent variables, relevant parameters, temporal evolution of the physical systems that can represent the change of physical systems with the alteration of initial conditions and parameters, the consequences of the alteration of parameters, functional relations and its visualization, etc. Test all mentioned aspects referred in a theoretical model more quickly. Reformulate/structure/enrich a conceptual field.
Oriented experimental activity	This emphasis is placed in a question (which can be a problem) and in its theoretical framing. The question must be relevant for the students, adjusted by them (obstacle identification and reformulation of its wording without changing the meaning) and properly framed by the teacher. The experimental planning and its execution is the students' responsibility. However, they're discussed and supervised by the teacher, in order to be	Study the functional relations between variables. Deepen the relations between theory-experience by deepening the conditions of the use of a theoretical model, or studying the questions that arose by the experimental results. Develop competences of experimental work, in students, involving all the

	completed by the students without problems or delays. The interpretation is made by the students and with the teacher's mediation. Finally, it is necessary to evaluate what was learned and what mistakes were made.	dimensions (problem, variable identification/control, experimental planning and execution, registration of observations, data attainment, production of results, physical situation model and experimental system, use of theoretical models to relate predictions with results, obtain conclusions, communicate the results). Reformulate/structure/enrich a conceptual field. Widen/develop/precise sensitive experiment of physical phenomena.
Experimental resolution of the Problem	The experimental task that is initiated with an experimental problem, which is explicit within a certain context. The problem must be relevant for the students, adjusted by them (obstacle identification and reformulation of its wording without altering the meaning) and properly framed by the teacher. It is a small investigation conducted by the students and oriented by the teacher with a greater control of the timing and means by the students. It culminates with the presentation of a product and/or results. It may be used in a curricular manner in 3 ways: i) Task connected to classes but not using classes for the execution. Classes are used to discuss the development of the problem solution and communication of results; ii) Task independent from classes, integrating extra-curricular activities, allowing the interested students to indulge their intellectual pleasure; iii) Project.	Develop competences of experimental work, in students, involving all the dimensions (problem, variable identification/control, experimental planning and execution, registration of observations, data attainment, production of results, physical situation model and experimental system, use of theoretical models to relate predictions with results, obtain conclusions, communicate the results). Build/study/use theoretical models. Build/study/use experimental systems. Subject a theoretical model to a wider empiric relation.. Investigate under the teacher's guidance. Develop communication and argumentation competences. Reformulate/structure/enrich a conceptual field. Widen/develop/precise sensitive experiment of physical phenomena.

The analysis of table 1 allows us to conclude that the questioning and the right mediation coming from the teacher are still two essential and indispensable elements, which will bind the possibility of development of the competences in the psychomotor domain.

EXPERIENTIAL LEARNING

In the book of Experiential Learning (1984), David Kolb [8] presents a theoretical and practical study of learning, in which he defends that, in an adult, learning represents a focus on the relation between the environment and the individual, in the dimensions of: acquisition, specialization and integration. According to Kolb (1984) experimental learning is the product that proves that the adult experiences the world and changes through means of man-mean interaction, in his work, education and personal development relationships.

Kolb took to himself the contributions of Vygotski, non-explicitly, to consolidate the idea of learning as a process of interaction between the internal and external characteristics, the personal and social knowledge. According to Kolb (1984), there is an acquisition of feeling or experience. This stimulus and repertory interact and direct the specialization of knowledge.

The information is adapted according to the needs, to finally occur formulation or reformulation of the experiment. Each person, by means of interpretation of their own experience, structures the building process of knowledge. Learning travels through these axes: capturing and transforming. Capturing is "apprehension", it occurs through an opening to experience, through the right path or through the comprehension of concepts. Transforming is "grasping", decoding the perceptions or the concepts and getting them closer to reality, using the repertory or the application of experience. Information gains meaning through reflection, in a path of intention or through the new exposure to experience, in the extension path.

According to Kolb (1984), learning is the alteration of behavior as the result of an experiment. Experimental learning values the interaction of the students' way of living and the environment (concepts, experiences of masters and colleagues). First of all there is an acquisition of information, skill or experience. This external stimulus and internal repertory of the individual interact and direct learning to another moment, when there is a specialization of knowledge. The information is adapted in accordance to the needs and interests of the students, to finally occur the moment of interaction, when learning is finalized. It is the intersection between theory and practice, individual and social needs. Life experience learning, as a process, travels between two axes: capturing and transforming. Capturing or grasping something intellectually in the act of learning, is to "learn". Transforming is to internalize what was learned, "understanding". Capturing is exercising perception, decoding external information and coming closer to life experiences, along with the stored repertory. In the process of transformation, information, that was once isolated, gains now significance through reflection and critical analysis. Capturing and transforming are permanent actions of the human mind. But all the theorists, in the Educational area, somehow unfolded them and compose these two dimensions in other dimensions in order to explain the construction of the apprenticeship.

Kolb uses the teachings of Lewin, Dewey and Piaget, valuing a sequence of stages that compose the Learning Styles. Learning, according to Kolb, is a cycle of interaction, allowing information to be experimented, observed, reflected and appraised, permitting four stages or phases in the construction of learning to be observed:

1. Concrete Experience: there is an emphasis in the relationship of two individuals, in daily situations; information is captured in the environment. The apprentice focuses more on his or her feelings, rather than on the systematic focus of problems. Learning is the result of a specific experiment and the relationship between people. The apprentice is predisposed to a new experiment.
2. Reflective Orientation: there is a commitment to ideas and situations deriving from different points of view. The apprentice trusts in objectivity and in careful judgment; in his or her own thoughts and feelings to formulate opinions. Observing and reflecting simultaneously allows the transformation of previous ideas into new ideas through internal mechanisms.
3. Abstract Conceptualization: the result of reflective orientation, with the captured experiment allows us to create schemes, theories and abstract interpretations. The apprentice uses logic more, trusts in systematic planning to develop theories and ideas to solve problems. The performance is based on the intellectual comprehension of a situation. On this stage the intellect captures what is new, exclusively by mental processes.

4. Active Experimentation: setting the created schemes, theories and abstractions. The apprentice performs with the goal of influencing and modifying. There is an interest in finding how theories and schemes work in practice, as opposed to a simple observation of a situation. The apprentice appreciates the accomplishment of tasks and results by taking risks. It is skillful to accomplish tasks and influences through actions. For Kolb (1984; 101) "life experience learning is based on a theory of dual knowledge: the Concrete Experience of the empiric grabbing reality by the direct process of learning, and the Abstract Conceptualization of the rationalist analyzing reality by mediating through the abstract conceptualization process".

This author defends an experiential approach, with the help of the interaction between concrete experience and the abstract conceptualization. Learning is seen as cyclical process, constituted by four phases: concrete experience, active experimentation, conceptual abstraction and reflective observation. The four types of aptitude are considered necessary, in order for learning to be effective, in spite of believing that the majority of people have only one or two more developed due to their former experiences, like the scholarity level and other social and cultural factors.

Kolb presupposes that all knowledge results in the interaction between theory (abstract concepts) and experience, and the LSI (Learning Style Inventory) is based on this concept of experiential education. The LSI defines the experiential learning process. To understand the learning process based on Kolb's experiential learning model, we can analyze the following situation:

> When we come across with the task of determining a procedure, first we formulate a theory about the solution for the problem (abstract conception). Taking it from there we test this theory (concrete experience); we reflect about it and possibly make some alterations on the original theory (reflection and observation) and from there we test our modified plan, based on the accumulated experience from the execution of our first plan (active experimentation). Each time this cycle is complete, we gain more knowledge, and therefore we are going through a process of experiential education.

ASSESSMENT IN THE COGNITIVE DOMAIN

In 1956, Benjamin Bloom headed a group of educational psychologists who developed a classification of levels of intellectual behavior important in learning. This taxonomy contained three overlapping domains: the cognitive, psychomotor, and affective. Within the cognitive domain, he identified six levels: knowledge, comprehension, application, analysis, synthesis, and evaluation. These domains and levels are still useful today as you develop the critical thinking skills of your students. Verb examples that represent intellectual activity on each level are listed here.

1. **Knowledge**: arrange, define, duplicate, label, list, memorize, name, order, recognize, relate, recall, repeat, reproduce state.
2. **Comprehension**: classify, describe, discuss, explain, express, identify, indicate, locate, recognize, report, restate, review, select, translate,
3. **Application**: apply, choose, demonstrate, dramatize, employ, illustrate, interpret, operate, practice, schedule, sketch, solve, use, write.
4. **Analysis**: analyze, appraise, calculate, categorize, compare, contrast, criticize, differentiate, discriminate, distinguish, examine, experiment, question, test.
5. **Synthesis**: arrange, assemble, collect, compose, construct, create, design, develop, formulate, manage, organize, plan, prepare, propose, set up, write.
6. **Evaluation**: appraise, argue, assess, attach, choose compare, defend estimate, judge, predict, rate, core, select, support, value, evaluate.

The following tables present the subjects, assessment activities and results of an Algebra course at ISEP.

Table 2
Assessment Subjects

2004/05	**1º Test** – Determinants and matrices operations **2º Test –** Linear systems and geometry in space **Final Exam –** All subjects
2005/06	**1º Test** – Determinants and matrices operations **2º Test –** Linear Systems and geometry in space **Final Exam –** All subjects
2006/07	**1º Test** – Matrices operations, determinants and Linear Systems **Final Exam –** Vectorial space and geometry in space **Laboratory Project – M**atrices operations and Gauss Seidel method to solve Linear Systems.
2007/08	**Final Exam –** Operations with matrices and Gauss Seidel method to solve linear systems. **Laboratory Project -** Operations with matrices, Determinants, matrix inverse and rank matrix.
2008/09	**Group work assignments:** - Matrix operations (1 Group Work) - Matrix Rank (1 Group Work) - Matrix inverse by the method of condensation. (1 Group Work) - Vectorial space R (2 Group Works) - Geometry in space (2 Group Works) **Laboratory Project -** Geometry in space **Final Exam –** All subjects.

Table 3
Laboratory Project

2006/07
One of this year's projects was about matrices operations, in a close relation with the Algebra course. In the project the students, in groups of 2 or 3 elements, had to implement a Java application to: • add and subtract matrices • multiply two matrices and a vector by a matrix • solve linear systems by the Gauss-Seidel method
2007/08
From this year on there is only one project in this course. This year project's theme was closely related to the Algebra course. The students had to develop, in groups of 2 or 3 elements, a Java application to implement matrix operations: • matrix addition and subtraction • matrix product and vector by matrix product • matrix transpose • matrix rank • matrix inverse • calculate the determinant of a matrix
2008/09
This year project's theme was also closely related to the Algebra course, but focused on Geometry in space (3D). The students had to develop, in groups of 2 or 3 elements, a Java application to: • obtain the equations of a straight line given two points or a point and a vector

• given a straight line's equation, obtain a point and the line's vector • given the equation of a straight line, obtain the other line's equations • obtain the equations of a plane given three points, two points and a vector or two vectors • given the equation of a plane, obtain the other plane's equations • given a plane's equation, obtain a point and the plane's normal vector • calculate the distance between a point and straight line between a point and a plane • graphically represent a straight line (using two 2D graphs) • graphically represent a plane (using a 3D graph)

Table 4
Work Assessment

Project	Formal presentation of the group's work to a 3 element jury (3 teachers), logbook and project's report assessment.
Group work	Oral presentation, individual class attendance information, individual assessment exercises in some classes, logbook assessment, Annex 1.

Table 5
% of each Assessment and Successful Rate Results*

2004/05	2005/06	2006/07	2007/08	2008/09
2 Tests - 20% Final exam–80%	2 Tests - 25% Final exam–75%	1 Test – 40% Final Exam–45% Laboratory Project – 15%	Final Exam– 100% Laboratory Project on other course	7 group works – 30% Laboratory Project on other course Final Exam–70%
40% Success rate	37% Success rate	57% Success rate	57% Success rate	58% Success rate

* all students were evaluate

We found that most of the students have better results, with significant improvement of classification, when required to think only at the lowest possible level - the recall of information or recognition of facts, not having noticed improvements with the introduction of practical work in the area of geometry, a subject that requires more complex and abstract mental levels, to the highest order which is classified as evaluation.

To support the evaluation process, surveys were used to allow teachers to discipline access to the perception that each of the elements of the groups had in relation to their own performance and the performance of colleagues in pursuit of the tasks.

CONCLUSION

The study must follow the guide lines centered in the teaching-learning process, particularly in the components of sciences and engineering teaching and assessment of HOTS "higher-order thinking skills" which are concentrated on the top three levels of Bloom's Taxonomy: analysis, synthesis, and evaluation.

Based on the provided results, is our intend to provide strategies that may potentiate for technicians cover knowledge, comprehension and application, but not concern itself with analysis and above, whereas full professional training may be expected to include this and synthesis and evaluation as well.

We will seek to maintain strategies in which one cannot effectively — or ought not try to — address higher levels until those below them have been covered (it is thus effectively serial in structure). In the end it is expected the attainment of a basic sequential model for dealing with topics in the curriculum, and a way of categorising levels of learning, in terms of the expected ceiling for a given programme.

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ANNEX 1

isep instituto superior de engenharia do porto	**DEPARTAMENT:** Mathematic

LOGSHEET ASSESSMENT

On some classes

Assessment subjects
Information on the project logsheet
Accuracy of language
• Identification of individual tasks and performance • Tasks assigned • Date of end of work • Progression documented • Compilation of working hours

TYPES OF CONTENT TO FIND IN THE PROJECT LOGSHEET

	Title	Descrition
Texto	Group Identification	Name of the elements of the group Group ID (CLASS+Number) **Exemple:** A2 –Group number 2 - Class A
	Handwritten notes	Notes made during the individual and collaborative work.
	Meeting notes	Notes taken during a meeting
	Meeting dates	
	Hand calculations	Hand calculations to evaluate a complex situation
	Tables and pictures	Hand made table and pictures

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ACTIVE LEARNING IN NAVAL ARCHITECTURE

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ABSTRACT

Knowledge of naval architecture is a fundamental requirement for those working in the marine industry. The ability to design and construct marine vehicles requires the understanding of many theoretical principles. In a naval architecture course, the breadth and depth of content to be covered is very broad. There is always a danger that educators will resort to delivering every lesson in transmission mode, adopting a “tell-all” approach that focuses only on the development of theoretical knowledge. This paper describes the changes made to the learning design of a module, Naval Architecture I, offered by the School of Engineering in Ngee Ann Polytechnic to enhance learning. This module is a foundational module taken by learners without background knowledge in this area of discipline. The key change involved a shift from the traditional “tell-all” approach to one that is more constructivist and experiential. Lessons were re-designed to include activities that encouraged active engagements from learners in learning. Opportunities to develop learners in their personal and professional skills such as e-competency, teamwork and communication were also woven into the lesson. The paper will describe (1) a change in laboratory experience to support theory-to-practice progression by getting learners to physically construct a model of the hull-form, verify their computations and discuss any variations observed. (2) the use of a ship simulation tool to stimulate learners’ interest and more importantly help them visualise various parts of a marine vehicle, an important experience that brings in the context for what they are going to study in the rest of the module. (3) an activity to encourage self-directed learning and reflection through concept maps. The paper will also discuss learners’ feedback and response to the changes.

KEYWORDS

E-competency, simulation tools, concept maps, active learning

INTRODUCTION

"...the *sine qua non* of deep learning in any complex domain is the creation of such motivation for extended engagement."

Dr. James Paul Gee (Gee J.P., 2005)

Given the breadth of knowledge to be ‘covered’ in engineering education, the most-used teaching approach tends to be a lecture-based, ‘tell-all’ approach where information is transmitted and instructions are given to learners. Learners would then be expected to have the maturity and strong foundational knowledge, skills and concepts in mathematics and the

physical sciences to synthesise and transform the information, and to transfer and apply the knowledge appropriate to the various engineering situations they face.

Learning characteristics and preferences that lend themselves to this approach tend to be primarily cognitive and meta-cognitive in nature and include a high tolerance for theoretical information and for learning discrete bytes of knowledge over time, coupled with the discipline for drill and practice. Good auditory skills and the ability to imagine and visualise are also critical for effective learning. Learner motivation, discipline, and drive are expected and needed for success in this approach.

The Diploma for Marine and Offshore Technology (MOT) at Ngee Ann Polytechnic, established since 1975, also adopted a lecture-tutorial-practical approach where the curriculum was essentially content-centered and instructor-led.

However, given a changing educational landscape, many of MOT's students now have a strong visual and kinaesthetic learning preference and tend to prefer more applied approaches to learning such as undertaking projects and experiments where they can explore, do and discover rather than be told how to, what to know and how to do. Being of the digital age, many display low tolerance for 'tell-all' situations and prefer 'when-I-need-it' information. Many also may not have a strong foundation in mathematics and the physical sciences. Motivation and drive tend to be characteristics they expect the teaching approaches and the learning design to help them develop.

This paper discusses the changes made in the teaching approaches and learning experiences that have been made to Naval Architecture I to make the learning effective for this changing profile of learners.

NAVAL ARCHITECTURE I: ORIGINAL APPROACH TO TEACHING AND LEARNING

The module adopted the typical lecture-tutorial-laboratory approach to learning where lectures were events where the lecturers told all and showed how. The Tutorials offered students the opportunity to be drilled in and practice the cognitive operations necessary to work through the exercises they had been shown how to do in the lecture. The laboratory practice is an enhanced tutorial session where students get the opportunity to work on tasks such as visualising the linesplan (how the 2-D linesplan would look like as a 3-D hullform) and conducting the hydrostatic calculations by hand from the lines plan (which is a 2-D drawing of the hullform).

Teaching and Learning materials were continuously made more visual and interactive with the use of short computer animations, illustrations and interactive calculation exercises. However, these changes and modifications have tended to focus on the medium and presentation of the content while the approach still remained largely content-focused and instructor-led.

NAVAL ARCHITECHTURE 1: KEY CHANGES NEEDED

Changes to the module in the last two years have focussed on re-thinking the design for learning – how the students learn - rather than on the content and on the medium and presentation of the content. 3 key needs were identified:

a) The need to gain attention and interest in the module as many of the students expected that the learning design and activities should motivate and engage them.

b) The need to bring the 'feeling' dimension into the learning experience as many students lacked the sailing experience and were therefore unable to imagine the ship's behaviour while in motion when learning about ship construction.

c) The need to use more active, experiential and collaborative learning strategies to cater to students who were more visual, kinaesthetic, and social in their learning preferences.

In CDIO terms, these needs are synonymous with what is articulated in Standard 8 - **Active Learning**

"Teaching and learning based on active experiential learning methods"
Active learning methods engage students directly in thinking and problem solving activities. There is less emphasis on passive transmission of information, and more on engaging students in manipulating, applying, analyzing, and evaluating ideas. Active learning in lecture-based courses can include such methods as partner and small-group discussions, demonstrations, debates, concept questions, and feedback from students about what they are learning. Active learning is considered *experiential* when students take on roles that simulate professional engineering practice, for example, design-build projects, simulations, and case studies."

NAVAL ARCHITECTURE I: EXAMPLES OF CHANGES

This section details 3 key examples of the changes made.

The use of ship simulation tools

Ship Simulation tools were introduced in the module to provide students with the opportunity to see and 'feel' ship behaviour. Without the luxury of time and resources of going aboard a marine vessel, the learner would be brought into this marine world through this simulation software - Ship Simulator 2008 (http://www.shipsim.com/home.php).

Introduced right at the start of the module, the highly graphical and interactive tools and the hands-on nature of the learning activities using the ship simulation tools were able to engage students in a way that an introductory lecture on naval architecture was not able to do.

The strategy for infusing the use of this simulation software in T&L is:

1. grabbing the attention of the learner at the start of the module

2. introducing the various types of platforms (Figure 1)

3. showing the various parts of the marine platforms (Figure 2)

4. introducing dynamics of marine vehicles through the actual playing of the game itself. The platform and mission selected should be high-speed and exciting to create maximum positive impact on the learners.

Figure 1. Various Types of Marine Platforms

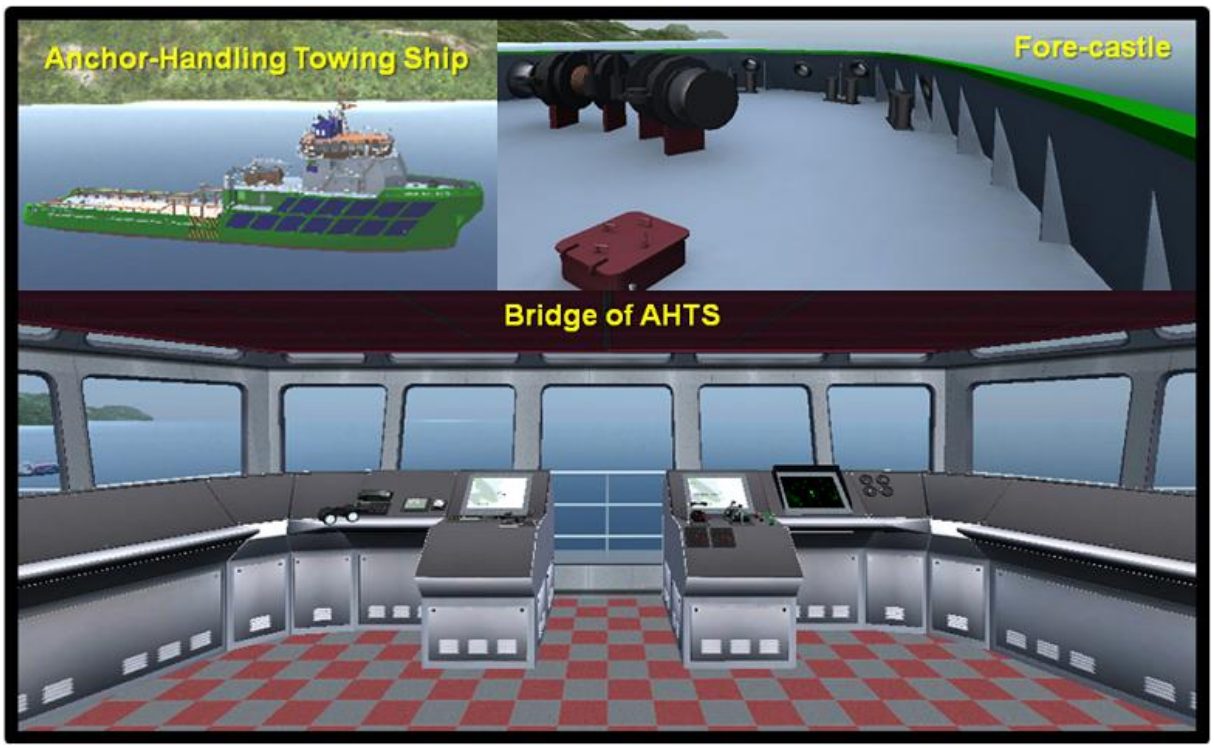

Figure 2. Various Parts of the Platform

The change in Laboratory Practice

In the new laboratory practices, an experiential learning approach is adopted that engages the learner in model construction and analysis/evaluation of the model data instead of the previous arrangement where learners looked at 2 linesplans and calculate the hydrostatics data (that basically exemplifies a prolonged tutorial session). The change enables the learners to have a hands-on collaborative learning session which also enhances the learner's e-competencies through the use of software such as Delftship (a freeware: http://www.delftship.net/) for hydrostatics purpose as shown in Figure 3 and Microsoft Excel spreadsheet (to replace laborious hand computations).

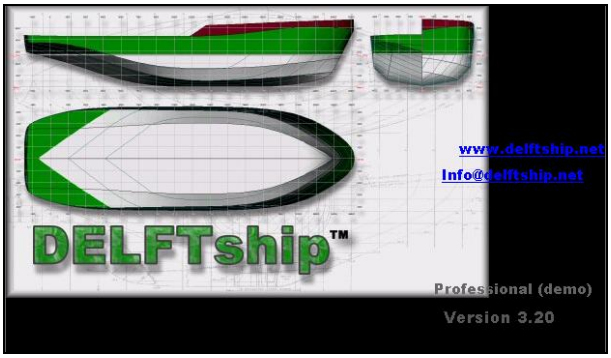

Figure 3. Delftship Software

The laboratory practice still consists of two sequential sessions (of 2 hours) for this topic (the first lab experience must come before the second). Prior to these experiential sessions, the lectures and tutorials would introduce and build up prior knowledge of the concepts needed. Table 1 shows the sequence of introducing the topics.

Table 1
Sequence of Topics

S/N	Topics	Remarks
1	Lecture & Lab - Linesplan & mini-lab	To introduce the learners the concept and the use of the linesplan
2	Lecture/Tutorial - Ship Geometry	To familiarise the learners with the hullform and ship terminology
3	Lecture/Tutorial - Ship Floatation (Archimedes Principle)	
4	Lab 1 – Visualising Linesplan through team learning 1	To appreciate the hullform generation from the linesplan – learner teams would construct a polyform hull model Learners would conduct a Archimedes Principle experiment to determine the underwater volume of the hull and displacement of the vessel model
5	Lecture/Tutorial - Ship Hydrostatics	Learners learn the application of linesplan in calculating the underwater volume of the hull and other Hydrostatics parameters
6	Lab 2 – Visualising Linesplan through team learning 2	Learners would be given the model's linesplan to calculate the model's underwater volume through Simpson's rules in Excel (instead of hand calculation) The calculated volume is then compared with that obtained from Lab 1(Archimedes Principle) to derive lessons learnt

Conduct of Lab 1

The first session enables them to recap and experience the constructed 3-D hullform on their own. During the first session, the learners form 3 to 4-person teams in a workshop setting. They are given the profile view of the lines plan (generated from Delftship) to build a simple

ship's hull out of Styrofoam board. Construction materials required are: styrofoam board, glue, cutter, cutting board and ruler.

A brief on the line's plan is given. After studying the lines plan, each group will have to build the model. After building the model, the learners would have to conduct an Archimedes Principle experiment to determine the underwater volume of the hullform. Figure 4 shows the conduct of the laboratory session. At the end of the session, the learners will need to log into Blackboard for a post-experience discussion and to reflect on the learning activity.

Figure 4. Conduct of Laboratory Session 1

Conduct of Lab 2

The learners would have learnt the basics of calculating the hull volume from lectures & tutorials using an approximation method i.e. Simpson's rule. In this lab session, the task is to calculate the underwater volume using Simpson's rule.

The learners are provided the linesplan to generate the table of offsets where the values would be used to approximate the volume. The learners would then need to compare the results obtained in this session and from the previous session where the volume was obtained through the Archimedes method.

Instead of traditional manual calculations, the learners are introduced the use of computational methods to approximate the volume. Excel is used in this session. A spreadsheet template shown in Figure 5 is provided to the learners and they would be guided through the use of the creating formulae for the volume approximation exercise. At the end of the lesson, the learners will need to log into Blackboard for discussion and reflection on the learning activity.

From this package of learning activities, the learner is able to Conceive-Design-Implement-Operate (CDIO) the basic concept of ship linesplan and hydrostatics in ship design and modelling.

NA1 LAB CALCULATIONS (WATERLINE AREA & SUBMERGED VOLUME)

Names: Ng Xiao Tong
Nursyahidah
Jackie Low
Siti Radiah

Hull Data

LPP = 36.2 cm Station Spacing (hx)= 3.6 cm
DWL = 4.4 cm Waterline Spacing (hz)= 1.1 cm

TABLE OF OFFSETS

HALF-BREADTHS ARE IN CM FROM THE CENTERLINE

STATION NUMBERS

WL	AP 0	1	2	3	4	5	6	7	8	FP 9
4	2.95	3.05	3.10	3.10	3.10	3.00	2.70	2.20	1.20	0.15
3	1.90	2.80	3.00	3.00	3.00	2.90	2.50	1.90	1.00	0.10
2	0.00	1.60	2.70	2.90	2.90	2.65	2.15	1.50	0.70	0.00
1	0.00	0.00	0.90	2.00	2.20	2.00	1.50	0.90	0.35	0.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Submerged Volume

(Do this when complete WL areas)

WL	Area	SM	f(V)
0	0	1	0
1	70.3	4	281
2	125	2	250
3	153	4	612
4	166	1	166
		sum f(	1309
	volume	540	cm^2

Area of Waterline 1 (Example)

Stn No	1/2 B	SM	f(a)
0	0	1	0
1	0	3	0
2	0.9	3	2.7
3	2	2	4
4	2.2	3	6.6
5	2	3	6
6	1.5	2	3
7	0.9	3	2.7
8	0.35	3	1.05
9	0	1	0
		sum fa	26.05
	area =	70.3	cm^2

Area of Waterline 2

Stn No	1/2 B	SM	f(a)
0	0	1	0
1	1.6	3	4.8
2	2.7	3	8.1
3	2.9	2	5.8
4	2.9	3	8.7
5	2.65	3	7.95
6	2.15	2	4.3
7	1.5	3	4.5
8	0.7	3	2.1
9	0	1	0
		sum fa	46.3
	area =	125	cm^2

Area of Waterline 3

Stn No	1/2 B	SM	f(a)
0	1.9	1	1.9
1	2.8	3	8.4
2	3	3	9
3	3	2	6
4	3	3	9
5	2.9	3	8.7
6	2.5	2	5
7	1.9	3	5.7
8	1	3	3
9	0.1	1	0.1
		sum fa	56.8
	area =	153	cm^2

Area of Waterline 4

Stn No	1/2 B	SM	f(a)
0	2.95	1	2.95
1	3.05	3	9.15
2	3.1	3	9.3
3	3.1	2	6.2
4	3.1	3	9.3
5	3	3	9
6	2.7	2	5.4
7	2.2	3	6.6
8	1.2	3	3.6
9	0.15	1	0.15
		sum fa	61.7
	area =	166	cm^2

Figure 5: Spreadsheet Template for Laboratory Session 2

The use of concept maps

The use of concept maps for T&L is applied on the Ship Construction topics. The learners would have some basic understanding of forces and stresses on hull structure and also, seen the ship structure models in the marine workshop. The subsequent Ship Construction topics require the learners to go a little more in depth to discover the construction and detailing of various parts of the ship.

CMap, (http://cmap.ihmc.us/) from the Institute for Human and Machine Cognition (IHMC), USA is used as a reflective tool in a constructivist approach. The exercise is done as a group mini-project which requires students to build knowledge, connect concepts, and construct new understanding which they are required to represent graphically as a concept map rather than in text or PowerPoint presentations. In this active learning experience, no lecture is given on the topic (which is a part of the ship detail and construction) and the learners are required to research online and at the workshop. At this point in the module, the learners are equipped with some basic ship construction knowledge to scaffold them in this assignment. Through the exercise, the learners are able to build on their prior basic knowledge of ship construction and construct knew knowledge and understanding for themselves. They use the CMap tool to construct and present a graphical representation of their new concepts, connections and knowledge. In addition to the group exercise, each learner is required to do an individual reflection on what they have done by summarising it in a separate concept map. A sample of the concept map is shown in Figure 7.

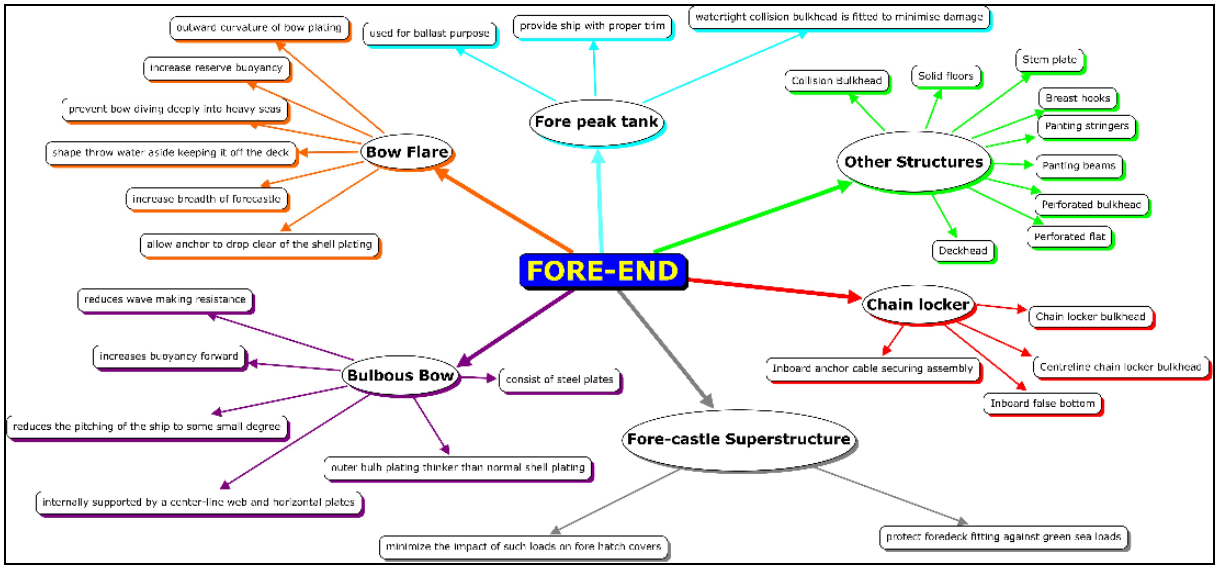

Figure 7. Sample Concept Map

NAVAL ARCHITECHTURE 1: STUDENT FEEDBACK

After these changes were implemented, student feedback was obtained in November 08.

Table 2 shows the results for the module survey conducted for 69 learners (55 responses) in Nov 08. Feedback by learners on the module is detailed in Table 3. From the module survey results, the learners had a good learning experience in the module as compared with student feedback on modules with a more traditional approach to teaching.

Table 2
Module Survey Results

Dimension	Rating
The module helped me to develop useful skills and knowledge	5.25
This module stretches my thinking	5.16
The teaching and learning approaches are appropriate for this module/project	4.95
I received timely and useful feedback in a group/individually on my progress in this module/project	4.53
The module materials including online resources were useful	4.85
The module activities enhanced my overall learning	5
Overall, this module provided a good learning experience	5.29

Scale: 1-Strongly Disagree, 2-Disagree, 3-Disagree somewhat, 4-Agree somewhat, 5-Agree, 6-Strongly Agree. Rating above indicates students who have selected “Agree somewhat”, “Agree” and “Strongly Agree”.

Table 3
Module Survey - Student Comments

S/N	Feedback
1.	This module is an essential module if you are planning to work in marine industry.
2.	very interesting module.you get to know about ships,measurements and many more.is a really good module to be prepared in this industry
3.	INTERESTING!!!!!!!!!!!!!!!!!
4.	interesting module. enhance my knowledge on ships and stuffs.
5.	Great module, very interesting.
6.	tough but interesting. whole new learning.
7.	created a more pleasant practical workshop

Table 4 shows the survey results for the Laboratory sessions conducted for 50 (25 responses) learners in Apr 08. Comments from the 3 questions were also obtained as detailed in Table 5. The qualitative feedback was very encouraging.

The feedback also indicated more time may be provided for certain aspects of the laboratory session, in particular, the learning of the use of EXCEL might be conducted separately and prior the laboratory session 2 so that there is sufficient time for the learners to consolidate the learning then.

Table 4
Survey Result for Laboratory Session

S/N	Question	Yes	No
1	Have you benefitted from the Labs?	25	0
2	Are you able to visualise and understand the lines plan, table of offsets and its application on calculating waterplane area and underwater volume better?	24	1
3	Overall, was it a good and engaging learning experience within your group?	25	0

Table 5
Laboratory Session Survey Feedback

Q/n	Comments
1	Overall it was a fun experience to get hands on activity rather than sticking to the books. We get to work in teams and got to know each other better. We also got to learn while having fun, I believed that the labs session made the understanding of details (eg. calculation of waterplane area) much easier. Learn some very interesting stuff thro. practical instead of theory. Yes. I guess it was pretty enriching as its something not from the textbook. as in we get to do a hands on kinda thing. through this i can visualise and understand more about the offset table.
2	It was clearly explained by you :) and furthurmore with the activities carried out. It was fairly easy to understand and visualise the information. Constructing a ship hull enables us to visualise better it makes me understand it more with the models. The practical helps as its something that is verbally explain and some ship objects to help us understand and visualise.
3	It was a fun and enjoyable time at lab sessions and not to forget that it was a good learning experience. We each had our flaws and niche areas. Therefore, when my group worked together, we each get to point out each other's mistakes and also get to learn from each other. One example was that my team mates' handwriting and organisation of details were very neat. I believed that i have improved on my presentation of work after working with him in the lab. In overall, i think that working in groups is definitely a good and engaging learning experience. it has helped me to understand my team mates better. From this i have learned on how they complete the assignments which will help me to work better with them in the future. we had fun as well as achieved learning at the same time. greaT learning experience...!

CONCLUSION

Student feedback indicates that the move to rework the learning design of the module Naval Architecture I is a move in the appropriate direction.

While the more active, experiential and collaborative T&L strategies have been well received by students, further review is needed to build in sufficient time and proper sequencing of learning activities to ensure that students have sufficient opportunity to synthesise the knowledge and skills and reflect on and evaluate their learning.

Problem-based learning is one approach that is being considered in the next stage of enhancement for the laboratory sessions.

A more immersive ship simulation laboratory experience is also being designed for the next stage of enhancements.

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Biographical Information

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Active Learning of Creativity through Clay-Modelling

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ABSTRACT

Creativity is a key part of the teaching curriculum for product design students. A special one and a half day creativity workshop was organized for a group of postgraduate students in product design who were more used to conventional computer-aided design techniques. This pilot project was developed with the sculptor-in-residence who had conducted such exercises for other groups of students. The purpose of this project was to study the value and effectiveness of active learning of a creativity process through clay model making. The first exercise required the building of a part without direct visual contact, i.e. blind modelling. The second one was building the same part in a normal way with full eye contact. The remaining three exercises were group work for building the tallest structure with given clay material, representation of an engineering discipline and a car for the future. Discussions were held with students at the end of each exercise and feedbacks were received from each individual student through a standardized questionnaire. Results of this active learning project are discussed in details with supporting quantitative and qualitative data.

KEYWORDS

Active Learning, Creativity, Clay, Modelling

INTRODUCTION

Creativity is absolutely essential for product design. For students on the Masters programme in Product Design and Management at Liverpool University, creativity is taught and practiced using a variety of methods and tools. Lectures on innovation, techniques for creative thinking and seminar on TRIZ by industrial practitioner are given. Practical sessions on the use of creativity tools in groups also take place. All such methods share a common characteristic, i.e. use of words or a sketch. In other words, the results of such creative processes do not produce a physical object directly. However, it has been a long history for sculptors to create a 3D object directly without any intermediaries. Such methods are rarely used in Engineering Schools in the study and practice of creativity. This paper reports the experience and findings of a one and a half day workshop on creativity using clay-modelling though 5 exercises.

Sculptor in Residence Project

At Liverpool University, a new initiative on 'Sculptor in Residence' was launched by Dominic Dickson as part of 'Liverpool- European Capital of Culture 2008 Project'. A part-time sculptor, Rodney Harris, was recruited for this project for one year. The main objectives of this project entitled 'EXCESS- Exploring Creativity in Engineering and Science with Sculpture' are as follows:

- To encourage creative collaboration across disciplines by providing opportunities to allow this to happen.
- To develop creativity and creative thinking in science and engineering students and staff through art.
- To promote new approaches to collective and individual learning in science and engineering.
- To explore fundamental aspects of science and engineering subjects by producing pieces of sculpture (three dimensional visual art) to illustrate these aspects (such as the relationships between structure and function).

The entire project ran for 8 groups of students in science, engineering and medicine and one interdisciplinary forum for a total of 327 participants. After realising the existence of such a project in the university, a discussion took place on the essence, the contents, earlier results and the relevance to Product Design students. With the intent to stimulate participants to think laterally, to gain cross fertilisation in a group working environment and to use one medium to explore another, it was decided to run a pilot workshop which could help product design students to see things in a different and hopefully enlightening way.

CREATIVITY WORKSHOP

A pilot run on the use of clay-modelling as a creativity exercise was arranged for a group of 15 MSc students in Product Design and Management in the first month of Semester 1 in 2008. They had various academic backgrounds which are summarized in Table 1. They were all familiar with the use of Pro-E CAD package for product design. More than 60% of students had no previous experience of clay modelling and 20% of them were female students.

Table 1: Background of Participants.

Subject of First Degree	No of Student
Electrical & Electronic Engineering	1
Industrial Design	1
Industrial Engineering	2
Machine Design	1
Mechanical Design	1
Mechanical Engineering	8
Product Design	1

The one and a half day Creativity workshop took place in the Design Studio. The Sculptor in Residence and one instructor were in attendance throughout the workshop. Five exercises

were conducted in the workshop and they consisted of both individual and group work. In this workshop, creativity entails the basic 3Ps: a *person* engaging in a creative *process* which produces a creative *product* [Barron, 1999].

Before the first exercise, every student was given a lump of clay to get familiar with the properties of the material. As an unstructured material which requires little technical ability to manipulate, everyone was ready for the first exercise after a short while.

Exercise 1: Creation of a Clay Elephant Behind the Back

The first exercise was in fact a familiarity exercise and an elephant was selected for the modelling because it had very distinctive features. This exercise was performed behind the back with the purpose of maximising the sensory touch to create a mental 3D image through clay manipulation as shown in Figure 1. After the completion of this exercise, all elephant models were placed on a worktable as shown in Figure 1.

Figure 1. Modelling an elephant behind the back in exercise 1.

Figure 2. Results of clay modelling exercise 1.

With a variety of accurate and less accurate models, it lightened the atmosphere immediately and this exercise achieved an unexpected by-product of ice-breaking. Only 80% of the models had the characteristic feature of a trunk and it was also difficult to identify at least 20% of the models as elephants as shown in Figure 2. However, the main purpose of this exercise was to build up confidence in modelling with clay and not entirely concerned with accuracy. In a feedback session, it was noted that one student had never seen an elephant in real life.

Exercise 2: Creation of a Clay Elephant in sight

Exercise 2 represents the normal way of creating a clay model as shown in Figure 3. A few observations could be made in this case. First, use of eye does not necessarily mean that the resultant model is more accurate as shown in Figure 4. Second, there is a tendency to take more time to complete the task as participants are keener to improve the model. The maximum time taken for exercise 2 was 22 minutes compared with 18 minutes for the previous exercise. Finally, expression of originality started to appear as one model was a symbolic representation of an elephant instead of an accurate mock up. In this case, it was strongly influenced by the traditional African culture.

Figure 3. Modelling of a clay elephant in sight.

Figure 4. Comparison of results of exercise 1 (inner circle) and exercise 2 (outer circle).

Exercise 3: Creation of the Tallest Tower

In this exercise, the 15 students were divided into 5 groups. The aim of this exercise is to construct the tallest tower they could make based on the materials given. Although the aim is simplistic, this will require students to think about the form of the structure, agree on the right form, build the structure without drawings, analyse the problems encountered and optimise the structure to reach a greater height. While a conical shape was common, the final structure created by each group was different as shown in Figures 5 and 6. During the feedback session, discussions were focussed on the question of an optimum structure, i.e. the existence of only one single tallest structure with a given amount of clay.

Figure 5. Example of a tall tower.

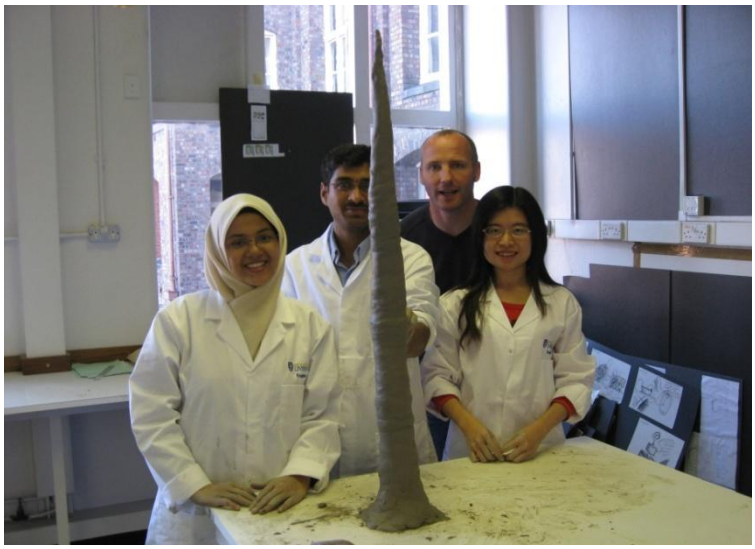

Figure 6. Another example of a tall tower.

Exercise 4: Representation of an Engineering Discipline

Students were asked to produce a model which was a representation of their previous discipline. This exercise, unlike the previous ones, was entirely open-ended and students were given full freedom to express themselves. Some of the models produced were conventional, for instance, a set of gears to represent mechanical engineering. Other examples were more sophisticated, for instance, a hand to represent design and the hand broke free from shackles implying unbounded space for innovation for design as shown in Figure 7. One example departed from the given remit, i.e. linking the previous discipline of mechanical engineering with the current discipline of product design as shown in Figure 8. This symbolises the single facet of mechanical engineering to multi-facet product design.

Figure 7. Representation of design discipline.

Figure 8. Representation of mechanical engineering discipline.

Exercise 5: A Car for the Future

This is the final exercise of this workshop. As every student is familiar with a car, the theme of this exercise is to model a future car, 30 years from now. A number of imaginative features were introduced in this exercise, for instance, detachable modular structure, new forms of fuel energy, energy saving profiles, etc. Two examples are chosen as a demonstration of the creativity process. First, students use tools to add features to the clay model as shown in Figure 9. This is entirely based on their own initiative. Second, some students used lateral thinking. They propose a new form of transport 'transport gate' instead of a car as shown in Figure 10.

Figure 9. Example of a future car.

Figure 10. Future model of transport through a 'Transport Gate'.

DISCUSSIONS

This series of five exercises allows students to build up experience and confidence in using clay and progress to total freedom of expression as a creative process. Exercises 1 and 2 serve as skill acquisition and ice-breaking. Exercise 3 is quite different as it covers the whole spectrum of idea generation, design, build and re-think, re-build due to the collapse of the tower structure mid-course. Exercises 4 and 5 are more directly related to creativity as there are open-ended questions.

After the completion of the workshop, every student completed a simple questionnaire including both numerical and qualitative assessment of the overall activity. Each exercise, except 3, was rated from 1 (most boring) to 10 (most interesting). The averages for Exercises 1, 2, 4 and 5 were 9.07, 8.00, 8.13 and 7.80 respectively. The fact that the future car has a relatively lower rating is probably because this is a well known topic and some students feel that the level of creativity is more constrained. The histograms of the satisfaction ratings of the clay modelling are given in Figures 11 to 14.

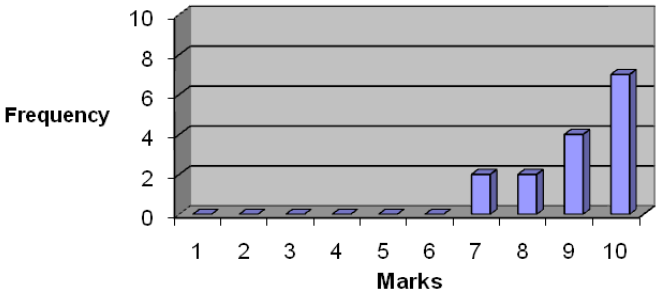

Figure 11. Questionnaire results for Exercise 1.

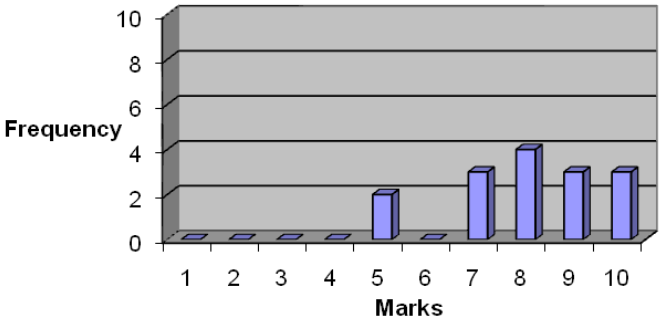

Figure 12. Questionnaire results for Exercise 2.

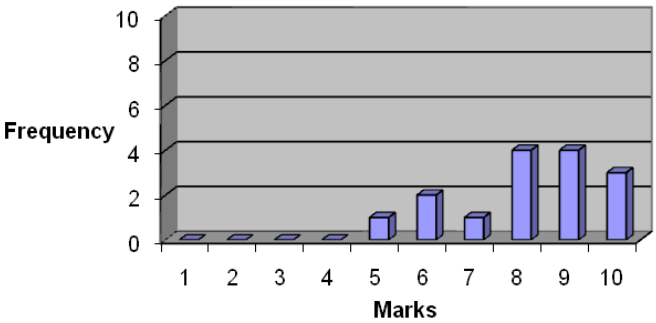

Figure 13. Questionnaire results for Exercise 4.

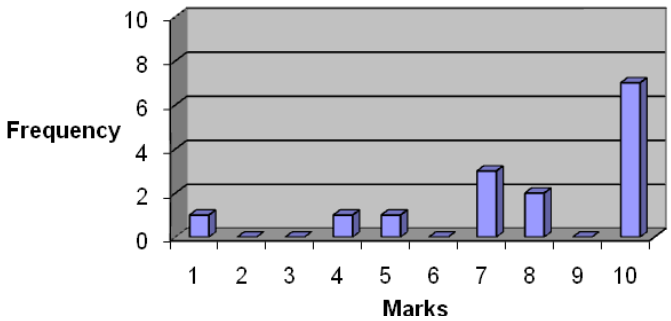

Figure 14. Questionnaire results for Exercise 4.

In terms of the relevance of this workshop to product design, the results show a bi-modal distribution with two peaks at 7 and 10 and an average of 8.67 as given in Figure 15. Responses on the best aspects of the workshop include: innovative thinking, creative skills, teamworking and wider perspective. On suggestions for the next Clay Modelling workshop, 4 students suggested that more time should be allocated while one opted for less. Other suggestions include the provision of more tools and more challenging tasks. There was a clear majority supporting the idea that this should be part of the core curriculum in the future.

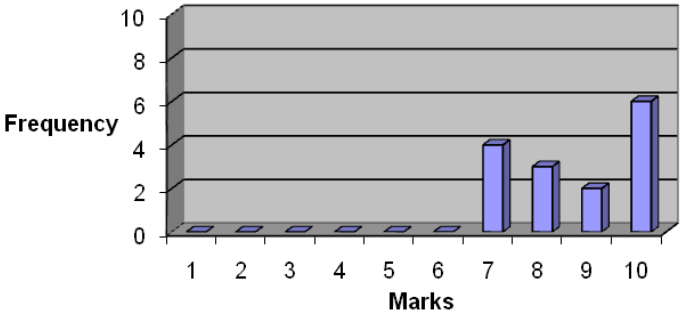

Figure 14. Overall relevance of the workshop to product design.

CONCLUSIONS

As an unstructured material, unlike lego or meccano, clay is a very versatile, low cost and reusable material for modelling. Clay modelling is more common with students in arts or design schools but much less common in engineering schools. This case study of a pilot workshop in an engineering school has demonstrated that clay modelling is also attractive to engineering product design students because of its simplicity and ease of use.

Unlike normal CDIO activities where a full detailed design is required before making the parts, clay modelling has a shortened process chain from the mind to direct fabrication of an 3D object. This has a positive impact on the creative process as students are not diverted on the fine details of engineering. Clay modelling also enhances active learning as demonstrated by exercise 3 in building a tall tower. Building a tall tower with clay is entirely different from sketching a tall tower as one has to cope with the properties of material and gravity effect.

Finally, based on positive student feedbacks, it is planned that this workshop will extend to more MSc programmes in engineering to stimulate the creative process.

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ACTIVE LEARNING TRAINING FOR THE FACULTY: A CASE STUDY

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ABSTRACT

The faculty of Telecommunication and e-Business in the Turku University of Applied Sciences wanted to lower the risk factors of student withdrawal relating to motivation, poor quality of student experience and lack of student engagement. The CDIO standard number 8 – Active Learning – provided some solutions to these risks. In addition, the faculty wanted to increase and support the use of active experiential teaching and learning methods. Therefore a training program was started in the autumn of 2008. The training was finished in January 2009. The main goal of the training was that teachers get to know, begin the experiments and usage of active learning methods. In addition, the training should provide new viewpoints for the role of a teacher and tools for assessment with active teaching and learning. The content of the training was divided into four topics: a) active learning methods, b) managing groups, c) different teacher roles and d) new tools for assessment. The training had four contact days and between the contact days study groups of four to six teachers were supposed to work with the agreed topics. There were altogether 10 study groups which all had a different development focuses. The training used a web-based learning environment for distributing materials and providing a discussion platform for teachers for example. The faculty gave very positive feedback over the training and several experiments were developed and many were implemented as well. The training fulfilled its' main goals and we can warmly recommend this kind of training to others as well. However, the implications for student retention remain to be seen.

KEYWORDS

Active learning, Faculty development, Case study, CDIO Standard 8

INTRODUCTION

According to a recent OECD publication, about 27 percent of students enrolling to higher education institutes leave without a degree in Finland [1]. There are many different risk factors affecting student withdrawal [2-5]. Identified risk factors are for instance: low motivation [2], poor quality of the student experience [4] and lack of commitment to educational objectives[5]. Students expect to have interesting and challenging courses. Furthermore, students expect to have versatile teaching with advanced learning methods. [6]

One of the basic requirements of the CDIO initiative is to make engineering more interesting, to increase students' motivation and retention [7]. Active learning is one answer to support this. Standard 8 of the CDIO initiative focuses on active learning. It defines that teaching and learning should be based on active and experiential learning methods. Active learning methods engage students in activities that support deeper approach to learning. [8] The

standard describes what this mean and rationalizes the use of active and experiential learning methods following:

- ***Description***: Active learning methods engage students directly in thinking and problem solving activities. There is less emphasis on passive transmission of information, and more on engaging students in manipulating, applying, analyzing, and evaluating ideas. Active learning in lecture-based courses can include such methods as partner and small-group discussions, demonstrations, debates, concept questions, and feedback from students about what they are learning. Active learning is considered *experiential* when students take on roles that simulate professional engineering practice, for example, design-build projects, simulations, and case studies.
- ***Rationale***: Students remember less than a fourth of what they hear and only about half of what they see and hear. By engaging students in thinking about concepts, particularly new ideas, and requiring some kind of overt response, students not only learn more, they recognize for themselves what and how they learn. This process of metacognition helps to increase students' motivation to achieve program learning outcomes and form habits of lifelong learning. With active learning methods, instructors can help students make connections among key concepts and facilitate the application of this knowledge to new settings.

The faculty of Telecommunication and e-Business in the Turku University of Applied Sciences wanted to enhance the use of active experiential teaching and learning methods and to lower the risk factors of student withdrawal. Therefore early 2008 a training program was planned and potential educators were analyzed. The training program started autumn 2008 and it finished in January 2009. Altogether 55 teachers and experts participated in the training.

In this paper, we describe the overall structure of the active learning training program, the content and activities in training, the results of the training and finally conclude with the discussion.

THE ACTIVE LEARNING TRAINING PROGRAM

The training program was designed to support and enhance our faculty in the use of active and experiential learning methods. The main aim of the training was to learn new methods for active and experiental learning. In addition, the training aimed at new viewpoints to teacher’s role, new tools for assessing active learning and concrete and practical ideas for instant use in teaching.

The training program started in the August of 2008 and finished in the February of 2009. Altogether 55 teachers participated in the training. The training had four contact days and between the contact days study groups of four to six teachers were supposed to work with the agreed topics. Before first contact day, a pre-assignment was sent to the participants. This assignment had two functions. First, it provided basic information on the participants’ skills, knowledge and expectations for the educators. Second, it served as an orientation for the forthcoming training program.

Table 1
Contact days and topics

Contact days	**Topics**
21.8.2008 – 4 h	Orientation to the training Active learning vs. traditional learning Forming the study groups
4.11.2008 – 8 h	Focus on active learning methods
26.11.2008 – 8 h	Focus on learning assessment Presentations of the study groups
5.2.2009 – 8 h	Focus on tutoring the learning Presentations of the study groups

There were altogether 10 study groups which all had a different study and development focus. The focus of each group was supposed to be as concrete as possible. The aim was that the study groups actively test and try the ideas they are working on in their teaching. The topics of the study groups were following:

- Self-assessment and peer-assessment
- Virtual learning and tutoring
- Active learning with large student groups
- Assessment and feedback
- Motivating independent learning
- Continuous assessment in courses
- Moving to experiental learning
- Enhancing student cooperation in learning
- From competences to assessment
- co-operative learning in practise.

The training utilized a web-based learning environment for distributing materials and providing a discussion platform for teachers for example.

At the end of the training feedback was collected with a web-based questionnaire. The questionnaire had following questions:

1. How the training succeeded to fulfill its' goals?
2. What was your own role in making the training to succeed?
3. What support and tools you received for your teaching?
4. How are you going to use the active and experiental methods?
5. How was the training organized?

Altogether 41 participants answered the feedback questionnaire.

Day 1

Day one started with short orientation to the training. After that the aims, content and schedule of the training was introduced and discussed. At the same time, the results of the pre-assignments were discussed too. The pre-assignment showed that there are many active learning methods that are not so familiar to our faculty – at least by the names. However, it confirmed that we have already quite many active and experiential learning methods in use.

In the first contact day the main idea was settling active learning and experiential learning into the pedagogical field. Finally, at the end of the day study groups were formed. The

groups formulated their own study question using the so-called double-team method. Every team was supposed to work with their topics before the next contact day.

Day 2

The second contact day focused on active learning methods, but before it we discussed about the change from the traditional teacher's role to a guiding and tutoring teacher's role. During the day, several active learning methods were studied as listed below. The methods were learned using gallery walking.

Table 2
Active learning methods learned

Method	**Short description**
Creative problem solving: 8 * 8	• the problem is written on a paper and around this paper eight papers are set • in each of these eight papers a viewpoint raising from the problem is written • after the viewpoints are set eight ideas are generated from each viewpoint
Creative problem solving: brainstorming	• every member of the group writes one idea on a paper and puts the paper on the table to his right side • this continues as long as new ideas come to mind • when new ideas are finishing, you take the first paper from the pile on your left side and develop this idea further and put the paper to your right side on top of the pile • at the end the idea papers are sorted and assessed • the rotation of the idea papers is meant to give new views to idea generation
Gallery walking	• a form of cooperative group work • make free riding quite difficult • there are home groups and walking groups • one topic is learned in each home group and a poster is prepared • each walking group is made of one member from each home group • the posters are set up in a "gallery" and walking groups study each poster one by one • each student teaches own group's poster to other members of the walking group • at the end results are discussed and unclear topics are clarified
Puzzle	• cooperative group work • basic idea is presented in Figure 1 •
6-3-5 – method	• also known as brainwriting [9] • With this method 108 new ideas can be generated. • A group of six peoples write three ideas in five minutes. • The papers are forwarded to next member of the group, who reads the papers and adds three new ideas in next five minutes. • The papers are circulated every five minutes until the round is finished.

Table 2 continues
Active learning methods learned

Debate	• effective way to support information adoption and usage
	• traditional debate is the most common form of debate in education
	• phases of traditional debate are following
	  ○ chairman, secretary, referees, two teams of debaters and public are selected
	  ○ theme of the debate is selected; other team is against it and other team is for it
	  ○ teams prepare their arguments
	  ○ debate last 10 to 20 minutes and each address is 1 to 3 minutes (both sides have as much time to speak)
	  ○ at the end of the debate closing speeches are given
	  ○ finally the referees assess which team won (based on relevance of arguments, presentation, entertainments and credibility)

Six hats
[10]
	• idea of six different hats is to have six different viewpoints and roles for looking at the problem
	• the six hats are
	  ○ white:
	  ▪ “let’s look this objectively”
	  ▪ facts and figures are important
	  ○ red:
	  ▪ “let’s listen our feelings and intuition”
	  ▪ emotional arguments are allowed without rationale and explanations
	  ○ black:
	  ▪ ”let’s look at the risks and weak points
	  ▪ logical and relevant arguments why something is not working or not succeeding
	  ○ yellow:
	  ▪ “let’s think about the advantages”
	  ▪ things are supposed to progress logically
	  ▪ constructive suggestions are provided
	  ○ green:
	  ▪ ”let’s develop new ideas, let’s fool"
	  ▪ traditional thinking is forgotten
	  ○ blue:
	  ▪ “let’s think how we have progressed so far and how we should continue towards the goal”
	  ▪ observing and planning action and timing
	  ▪ make conclusions
	• there are three different ways to use this method
	  ○ In a group with all hats in use at the same time
	  ○ In a group with one hat in use at the same time
	  ○ By yourself

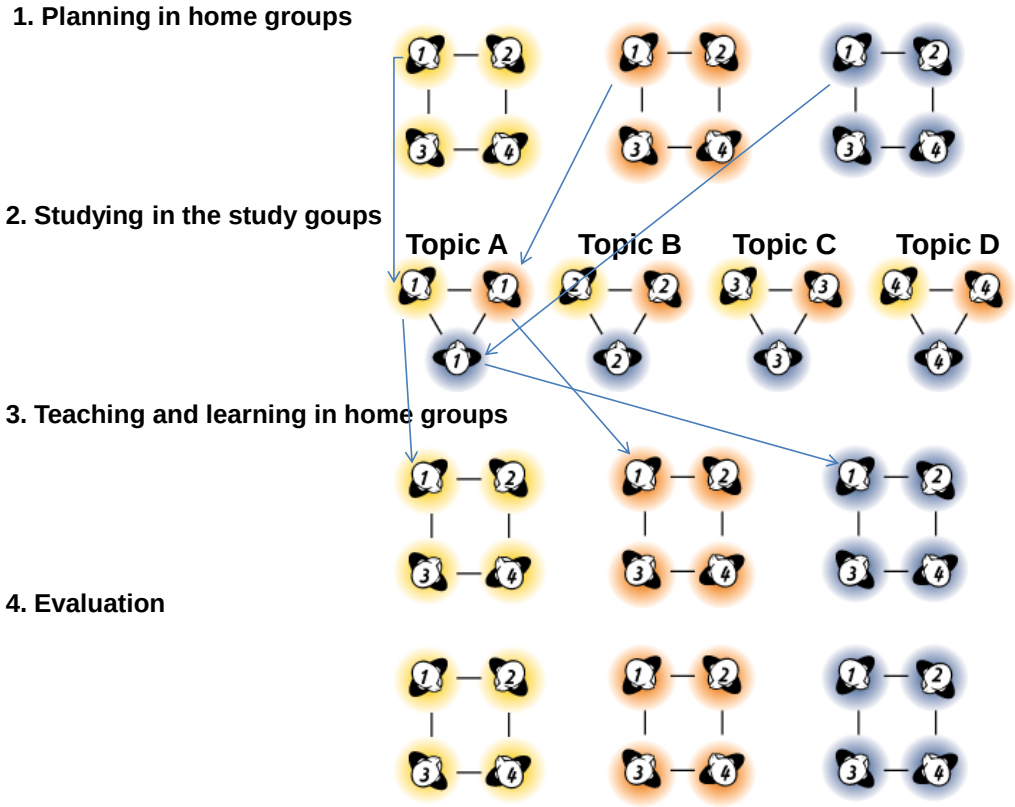

Figure 1. Puzzle method.

At the end of the day, guidelines for independent group work were given. Every group should study different sources and try to form a common understanding about the pedagogy that is involved in the topic they are working on. Furthermore the group should have the practical part of the group work i.e. test the developed ideas in a real teaching setting/course. Finally, the groups should start planning the presentation part of their group work for the other member of the faculty.

Day 3

The third contact day focused on assessment. There were three presentations by the study groups too: From competences to assessment, Self-assessment and peer-assessment and Assessment and feedback.

The assessment was studied from many different viewpoints, but the main idea was all the time to rationalize the need for new kind of assessment for active and experiental learning. The message was that we have to move from a “red assessment house” to a “blue assessment house”. We should change assessment from traditional students’ classification and comparison to students’ guidance and development. Students’ skills and competences should be understood as functional packages. Students’ skills and competences are a continuously improving relationship between a student and the assignment.

Day 4

The final contact day focused on the presentations of the study groups. In addition, we learnt tutoring related topics such as different learning styles and their features and students’ motivation. Finally, final discussions and preliminary feedback we gathered. The web questionnaire was delivered later for collecting more precise feedback.

RESULTS

The feedback of the training shows positive results. Most of the participants (30/41) answered positively to the question how the training succeeded in fulfilling its' goals. Typical positive comments were following for example:

- I received a lot of new ideas to active learning
- The training offered time to truly understand active learning methods
- I got new ideas to teach my topics
- The training refreshed old thoughts of active learning.

The critical comments mentioned following for example:

- I didn't get anything new out of the training
- I was expecting a more innovative approach by the trainers
- I hoped more concrete information and experiences of active learning methods
- The timing of the training was bad – too hurry period in teaching.

The participants saw that the training had given them support and tools for their teaching. The following comments confirm this interpretation:

- I had to actively evaluate my own way of working/teaching
- Active discussions with the colleagues were very fruitful
- I now have the courage to truly use active learning methods
- Pedagogy is now official and accepted discussion topics in coffee rooms.

Most of the participants said either that they have already used active learning methods or they have plans for using active learning methods in the next courses.

The results of the study groups are presented in the table 3.

Table 3
Active learning methods learned

Study group focus area	**Group results**
Self-assessment and peer-assessment	• Self- and peer- assessment was tested in Information services course at the Degree programme in Library and Information services. • Thesis seminars developed peer assessemt practices
Virtual learning and tutoring	• Study on virtual learning and better understanding of the virtual learning environment • Implementation of virtual learning and tutoring in work placement management practices
Active learning with large student groups	• No results
Assessment and feedback	• Every member of the study group rewrite the assessment descriptions of at least one of their courses • Test different assessment methods in own courses • How to manage a group exam? • How to manage an oral exam?

Table 3 continues
Active learning methods learned

Motivating independent learning	• Every member of the study group tries some new way to motivate students and evaluates the effects
Continuous assessment in courses	• New possibilities for assessment and evaluation were developed for the Practise Enterprise course • Different evaluation methods utilized: 1. Self Evaluation 2. Peer Assessment 3. Process Evaluation 4. Consortium Evaluation 5. Rotation Evaluation 6. Outcome Evaluation
Moving to experiental learning	No results
Enhancing student cooperation in learning	• A special testing focused week was arranged • New implementation of Customer focused marketing
From competences to assessment	• Plan for improved assessment practise to whole faculty was developed • New curriculums are required to describe competences and assessment better and more understandable way than earlier
Co-operative learning in practise	• A small survey among first year students relating their study methods • New group assignments were introduced in Electronics • New optional exercises were introduced • Lectures have more active learning parts that they used to have

DISCUSSION

The training program was quite intensive and suffered little from the other responsibilities the faculty had parallel to the training. Still, the faculty was very active and committed to the training as the results described earlier showed. The training resulted in new ideas and plans to implement teaching. Some of the plans are already tested and some are still to come. Besides the information on active learning, the training provided time for discussion and networking for faculty members. The training has initiated several discussions over pedagogical choices and solutions.

The active learning methods learned were not totally new to our faculty, but this training refreshed the methods in our minds and hopefully encouraged our faculty to use these methods more. A very helpful matter was that the training was arranged in a way where we studied the active learning methods with active learning methods. While learning active learning methods we gained experience from these methods at the same time. This teaching method worked for us because the level of knowledge with active learning methods was quite good at the beginning.

Based on our experience we can recommend similar training programs for other faculties as well.

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AN EXTENDED CDIO SYLLABUS FRAMEWORK WITH PREPARATORY ENGINEERING PROFICIENCIES

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ABSTRACT

The CDIO Initiative has been globally recognised as an enabler for engineering education reform. With the CDIO process, the CDIO Standards and the CDIO Syllabus, many scholarly contributions have been made around cultural change, curriculum reform and learning environments. In the Australasian region, reform is gaining significant momentum within the engineering education community, the profession, and higher education institutions. This paper presents the CDIO Syllabus cast into the Australian context by mapping it to the Engineers Australia Graduate Attributes, the Washington Accord Graduate Attributes and the Queensland University of Technology Graduate Capabilities. Furthermore, in recognition that many secondary schools and technical training institutions offer introductory engineering technology subjects, this paper presents an extended self-rating framework suited for recognising developing levels of proficiency at a preparatory level. The framework is consistent with conventional application to undergraduate programs and professional practice, but adapted for the preparatory context. As with the original CDIO framework with proficiency levels, this extended framework is informed by Bloom's Educational Objectives. A proficiency evaluation of Queensland Study Authority's Engineering Technology senior syllabus is demonstrated indicating proficiency levels embedded within this secondary school subject within a preparatory scope. Through this extended CDIO framework, students and faculty have greater awareness and access to tools to promote (i) student engagement in their own graduate capability development, (ii) faculty engagement in course and program design, through greater transparency and utility of the continuum of graduate capability development with associate levels of proficiency, and the context in which they exist in terms of pre-tertiary engineering studies; and (iii) course maintenance and quality audit methodology for the purpose of continuous improvement processes and program accreditation.

KEYWORDS

CDIO Syllabus, Graduate attributes, Learning outcomes, Integrated curriculum, Engineering in Schools

INTRODUCTION

Curriculum and cultural reform in engineering education is very much on the agenda internationally. An immediate driver for this is the global professional engineering skill shortage. Engineering skills contribute directly to the global economy, environment, security and health. In Australia, there is a current reported shortfall of some 20,000 engineers to undertake *known or available* engineering work [1]. Engineering businesses seek engineers with abilities and attributes in two broad areas – technical understanding and generic graduate attributes. The first of these comprises: a sound knowledge of disciplinary fundamentals; a strong grasp of mathematics; creativity and innovation; together with the ability to apply theory in practice. The second is the set of attributes that enable engineers to work effectively in a business environment: communication skills; team working skills; and business awareness of the implications of engineering decisions and investments. [2]

Over the past decade, Australian engineering schools have been innovative and responsive to students' needs, while meeting the requirements of industry and the professional accreditation bodies. The Engineers Australia (EA) accreditation process assesses programs against the delivery of graduate attributes, the educational environment, assessment and the quality systems used to ensure program delivery. The graduate attributes are also elaborated in the accreditation system as *professional competencies* that may be used for program design. The real test of the professional competencies for most graduates will be their fit to employers' requirements, and the rate at which they can progress through work-place experience to gain the required competencies for practice as independent professionals and gain full Chartered status. Despite progress made by institutions worldwide, it remains a challenge to integrate these professional outcomes in engineering programs in a manner that prepares students for the professional complexities of their careers. This is due to traditional thinking about engineering curricula, and in a sense holding onto past messages [3]. Felder and Brent point out that equipping students with necessary skills (graduate attributes) is much harder than determining whether or not they have these skills [4].

The Australian accreditation process is benchmarked formally as producing "substantially equivalent" outcomes as those of the other 12 signatory jurisdictions of the Washington Accord (for professional engineering qualifications) and the six other signatory jurisdictions of the Sydney Accord (for engineering technologist qualifications). Each accord has developed a set of program outcome standards (otherwise called *graduate attribute exemplars*) that are reviewed periodically by the accord signatories to ensure that they are in step with on-going changes to national higher education systems. The accord standards and processes demonstrate a powerful means of international benchmarking of professional qualifications. [1]

Australian engineering schools have maintained good international educational standards by a combination of mechanisms, including international benchmarking, international staff recruitment, student and staff exchanges, and participation in international curriculum networks such as the CDIO model, strong academic participation in international engineering education conferences, and foundation membership by Engineers Australia of the International Engineering Alliance.

The CDIO concept promotes the notion that "*learning activities are crafted to support explicit pre-professional behaviour*" [5]. Much of the CDIO philosophy is in line with the expressed focus of most Australian engineering schools with the CDIO Standards and self-rating framework providing a methodology for evaluating the effectiveness of engineering program initiatives at the tertiary level.

The Australian Learning and Teaching Council (ALTC) sponsored report by Robin King, *Engineers for the Future: - Addressing the supply and quality of Australian engineering graduates for the 21st century* [1], has made a number of recommendations to stimulate the agenda for engineering education for the next decade, and at a time when the demand for engineers significantly exceeds the supply of graduates. This paper focuses on two of the recommendations.

1. **Raise the public perception of engineering** ("…including within primary and secondary schools …")
2. **Implement best-practice engineering education** ("…define curricula more strongly around engineering problem solving, engineering application and practice, and develop the themes of design...")

These recommendations are intended to be a 'roadmap' for the next decade of development of Australia's engineering education system.

Two nationally funded projects which are addressing, in part, these recommendations are:

(i) **Design Based Curriculum Reform within Engineering Education** (Australian Learning and Teaching Council)

(ii) **Australian Technology Network (ATN) Engineering in Schools** (Collaboration and Structural Reform)

With respect to the CDIO Standards, a significant aspect of these projects in addressing the two recommendations is the development of integrated curriculum (CDIO Standard 3), design-implement experiences (CDIO Standard 4), active learning (CDIO Standard 8), and enhancement of faculty skills competence (CDIO Standard 9), in the context of both senior secondary school and tertiary engineering curricula. [5]

This paper makes two key contributions which casts the CDIO Syllabus and an extended self-rating framework with preparatory proficiency levels into the Australian engineering qualification context.

1. The CDIO Syllabus topics are linked to the Engineers Australia Graduate Attributes, Washington Accord Graduate Attributes and QUT Graduate Capabilities, the former to provide Australian professional association mapping and the latter to demonstrate an institution mapping. This mapping was based on the same principles used to map the CDIO Syllabus to the ABET Student Outcomes by Crawley et al [5].
2. The self-rating framework introduced by Crawley et al [5] is extended to include levels of proficiency within the context of pre-tertiary engineering technology learning at secondary school and technical training institutions. Bloom's Taxonomy was employed to inform the different levels of cognitive ability to produce learning outcomes and preparatory levels of proficiency. A particular example is given of rating the Queensland Studies Authority senior secondary school Engineering Technology syllabus based on the proposed preparatory levels of proficiency.

CDIO SYLLABUS AND ENGINEERING CAPABILITIES

The CDIO Syllabus is expressed in levels which range from a broad set of competency statements to finer grained syllabus topics. Each syllabus topic is expressed in terms of proficiency levels based on Bloom's Educational Objectives in the cognitive domain:- *Knowledge* (Levels 1 and 2), *Comprehension* (Level 3), *Application and Analysis* (Level 4),

Synthesis and Evaluation (Level 5) [5][6]. Conceptually, this relationship is illustrated in Figure 1 (below). Greater detail of proficiency levels is given in Table 6.

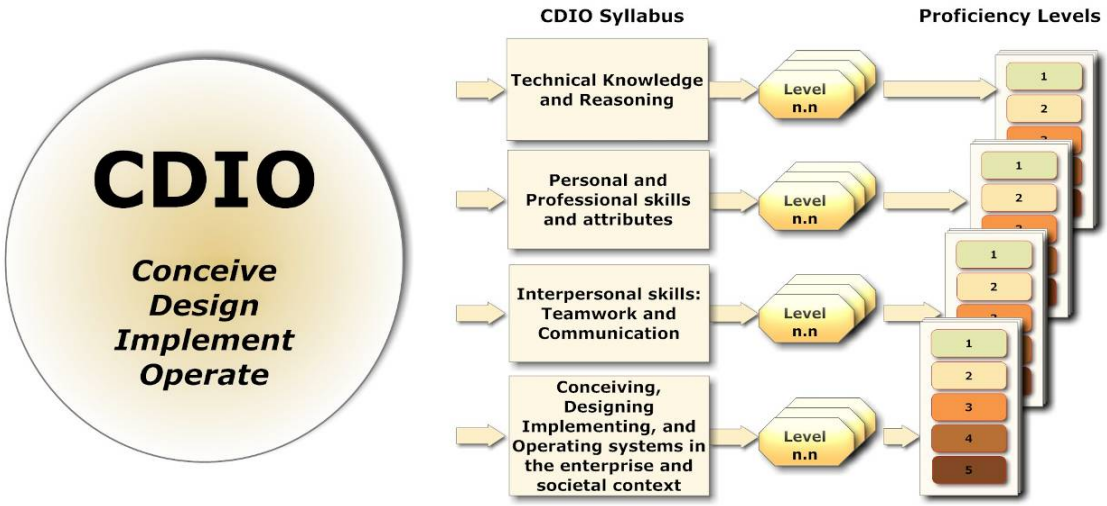

Figure 1. Conceptual overview of the CDIO Syllabus and topic linkage with proficiency levels [5].

The three levels of the CDIO Syllabus can be represented in terms of *n*, *n.n* and *n.n.n*. The top level (*n*) comprises the four broad ranging statements as shown in Figure 1. The top two CDIO Syllabus levels (*n* and *n.n*) have the greatest alignment with commonly stated graduate attributes, graduate capabilities and (key) learning outcomes from accrediting bodies and syllabus stakeholders. The mapping to ABET Student Outcomes [7] has been performed previously by Crawley et al [5].

CDIO Syllabus Mapping in the Australian Context

With a growing community of practice throughout the CDIO Australia and New Zealand Regional Group, and the Australasian Association for Engineering Education (AAEE) via the CDIO Special Interest Group, there is a need to map the CDIO Syllabus within the Australian context. In this exercise, the mapping exercise was applied to the graduate attributes/capabilities published by Engineers Australia (the professional accrediting body in Australia) [2], the Washington Accord (an international alliance of accrediting bodies to which Engineers Australia is a signatory) [8], and the Queensland University of Technology (QUT) (to give an institutional example of graduate capability mapping) [9].

These mappings are tabulated along with the previously published mapping against the ABET Graduate Outcomes in Table 1 (below). This mapping is an initial proposition based on the same principles stated for the ABET mapping. Linkages are indicated where attributes have a “strong correlation” and those with a “reasonable correlation” (bracketed). Alignments are subjective, however, this initial proposed mapping is intended for use and refinement by the growing CDIO community.

The mappings relate the CDIO syllabus topic to the relevant graduate attribute or outcomes as listed in Table 2 to Table 5.

Table 1
CDIO Syllabus topics mapped against ABET Student Outcomes (Table 2) [5], Engineers Australia Graduate Attributes (Table 3), Washington Accord Graduate Attributes [8]) and QUT Graduate Capabilities (Table 5).

	CDIO SYLLABUS TOPIC	ABET GRAD. OUT.	EA GRAD. ATT.	WA GRAD. ATT.	QUT GRAD. CAP.
TECHNICAL KNOWLEDGE AND REASONING	1.1 KNOWLEDGE OF UNDERLYING SCIENCES	A	A	B	A
	1.2 CORE ENGINEERING FUNDAMENTAL KNOWLEDGE	A	A	B	A
	1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE	K(A)	C	B	A
PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES	2.1 ENGINEERING REASONING AND PROBLEM SOLVING	'E'(K)	D	C	B
	2.2 EXPERIMENTATION AND KNOWLEDGE DISCOVERY	B	-	E	-
	2.3 SYSTEM THINKING	C,'H'	E,G	D	-
	2.4 PERSONAL SKILLS AND ATTITUDES	I	F,(J)	G,(N)	E,G,(D)
	2.5 PROFESSIONAL SKILLS AND ATTITUDES	F,(K)	I,(J)	J(N)	F,(D)
INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION	3.1 TEAMWORK	D	F	G	E,G
	3.2 COMMUNICATIONS	G	B	H	C
	3.3 COMMUNICATIONS IN FOREIGN LANGUAGES	-	-	-	-
CONCEIVING, DESIGNING, IMPLEMENTING AND OPERATING SYSTEMS IN THE ENTERPRISE AND SOCIETAL CONTEXT	4.1 EXTERNAL AND SOCIETAL CONTEXT	H,(J)	G	I	F
	4.2 ENTERPRISE AND BUSINESS CONTEXT	-	-	L	-
	4.3 CONCEIVING AND ENGINEERING SYSTEMS	C	E,H	F,K	B,F
	4.4 DESIGNING	C	E,H	F,K	(A),(B)
	4.5 IMPLEMENTING	C	E,H	F,K	(A),(B)
	4.6 OPERATING	C	E,H	F,K	(A),(B)

Mappings indicated as "strong correlation". *(X)* indicates reasonable correlation. *'X'* is the contention of these authors for mapping against ABET and not mentioned in the original reference.

For example, **CDIO Syllabus topic, *Advanced Engineering Fundamental Knowledge***, maps to:-

- **ABET Graduate Outcome K**, *An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice* (strong correlation)

- **ABET Graduate Outcome A**, *An ability to apply knowledge of mathematics, science, and engineering* (reasonable correlation)
- **Engineers Australia Graduate Attribute C**, *In-depth technical competence in at least one engineering discipline* (strong correlation)
- **Washington Accord Graduate Attribute B**, *Knowledge of Engineering Sciences*, (strong correlation)
- **QUT Graduate Capability A**, *Knowledge and skills pertinent to a particular discipline or professional area*, (strong correlation)

Institutional, Professional and Syndicated Graduate Capabilities

Table 2
Accreditation Board for Engineering and Technology (ABET) Student Outcomes [7].

A	An ability to apply knowledge of mathematics, science, and engineering
B	An ability to design and conduct experiments, as well as to analyze and interpret data
C	An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
D	An ability to function on multidisciplinary teams
E	An ability to identify, formulate, and solve engineering problems
F	An understanding of professional and ethical responsibility
G	An ability to communicate effectively
H	The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
I	A recognition of the need for, and an ability to engage in life-long learning
J	A knowledge of contemporary issues
K	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Table 3
Engineers Australia (EA) Graduate Attributes [2].

A	Ability to apply knowledge of basic science and engineering fundamentals;
B	Ability to communicate effectively, not only with engineers but also with the community at large;
C	In-depth technical competence in at least one engineering discipline;
D	Ability to undertake problem identification, formulation and solution;
E	Ability to utilise a systems approach to design and operational performance;
F	Ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be a leader or manager as well as an effective team member;
G	Understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development;
H	Understanding of the principles of sustainable design and development;
I	Understanding of professional and ethical responsibilities and commitment to them; and
J	Expectation of the need to undertake lifelong learning, and capacity to do so.

Table 4
Washington Accord Graduate Attributes [8].

A	Academic Education	Completion of an accredited program of study typified by four years or more of post-secondary study.
B	Knowledge of Engineering Sciences	Apply knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the conceptualization of engineering models.
C	Problem Analysis	Identify, formulate, research literature and solve complex engineering problems reaching substantiated conclusions using first principles of mathematics and engineering sciences.
D	Design/ development of solutions	Design solutions for complex engineering problems and design systems, components or processes that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.
E	Investigation	Conduct investigations of complex problems including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.
F	Modern Tool Usage	Create, select and apply appropriate techniques, resources, and modern engineering tools, including prediction and modelling, to complex engineering activities, with an understanding of the limitations.

G	Individual and Team work	Function effectively as an individual, and as a member or leader in diverse teams and in multi-disciplinary settings.
H	Communication	Communicate effectively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
I	The Engineer and Society	Demonstrate understanding of the societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to engineering practice.
J	Ethics	Understand and commit to professional ethics and responsibilities and norms of engineering practice.
K	Environment and Sustainability	Understand the impact of engineering solutions in a societal context and demonstrate knowledge of and need for sustainable development.
L	Project Management and Finance	Demonstrate a knowledge and understanding of management and business practices, such as risk and change management, and understand their limitations.
M	Life long learning	Recognize the need for, and have the ability to engage in independent and life-long learning.

Table 5
Queensland University of Technology (QUT) Graduate Capabilities [9].

A	Knowledge and skills pertinent to a particular discipline or professional area	encompassing: coherent theoretical and practical knowledge in at least one discipline area at the level of entry to a profession; technological skills appropriate to the discipline
B	Critical, creative and analytical thinking, and effective problem-solving	including: the ability to critique current paradigms and contribute to intellectual inquiry; the capacity to exhibit creative as well as analytical ways of thinking about questions in at least one discipline; the ability to identify, define and solve problems in at least one discipline area
C	Effective communication in a variety of contexts and modes	including: effective written and oral communication with discipline specialists and non-specialists and in cross-cultural contexts
D	The capacity for life-long learning	including: searching and critically evaluating information from a variety of sources using effective strategies and appropriate technologies
E	The ability to work independently and collaboratively	including: managing time and prioritising activities to achieve goals; demonstrating: the capacity for self-assessment of learning needs and achievements; being a cooperative and productive team member or leader
F	Social and ethical responsibility and an understanding of indigenous and international perspectives	encompassing: active contribution to intellectual, social and cultural activities; understanding and appreciation of indigenous perspectives; recognition and appreciation of gender, culture and customs in personal and community relations; valuing and promoting truth, accuracy, honesty, accountability and the code of practice relevant to the discipline or professional area
G	Characteristics of self-reliance and leadership	including: the ability to take the initiative, to embrace innovation, and to manage change productive

SENIOR SCHOOL ENGINEERING CURRICULUM AND LEARNING OUTCOMES

There is evidence that many graduate attributes can develop, at least to a limited extent, through studies prior to tertiary engineering degree programs [10]. Feedback from industry representatives on the Queensland Studies Authority (QSA) senior secondary school Engineering Technology curriculum has been positive in terms of the rigour in the curriculum and identifies the major strength as developing problem solving skills and producing tangible outcomes.

> "*It was only after studying Engineering Technology that I understood the importance and relevance of mathematics and science to everyday life. The problem solving skills I learnt in this subject has helped me in getting through first year engineering at university and better understand how engineers work together.*" Student, Kelvin Grove State High School, now studying Engineering at QUT.

An examination is made of an engineering technology syllabus within secondary school senior years (years 11 and 12). The QSA senior Engineering Technology Curriculum [11] states a number of key learning objectives, such as:-

- *apply knowledge to unfamiliar and/or complex engineering problems*
- *use mathematical concepts and techniques in preparing and interpreting engineering data*
- *investigate and analyse engineering problems, and identify and prioritise their critical elements*
- *propose and validate possible solutions to engineering problems*
- *select suitable engineering solutions by drawing conclusions based on the evidence gathered*
- *evaluate proposed solutions in terms of their capacity to solve engineering problems, meet environmental and societal needs, and comply with appropriate benchmarks and standards.*

To read these learning objectives, it is not immediately clear that they are cast within the context of a senior secondary school syllabus. Indeed, one could have difficulty discerning these from professional graduate capabilities. This context may be defined, relative to the tertiary level proficiencies, as one:-

1. That is highly controlled in a highly supervised environment
2. That has limited scope and context of topics, and learning activities
3. That has outcomes which are generally aligned with graduate attributes, however the levels of proficiency are somewhat limited in comparison

With the contention that engineering proficiencies can indeed start for those who take pre-tertiary engineering related subjects, it is beneficial to recognise and identify these preparatory proficiencies cast within the CDIO framework. This process will inform application to other preparatory pathways to undergraduate engineering programs.

EXTENDED CDIO FRAMEWORK FOR PREPARATORY CAPABILITIES

The CDIO framework bases the levels of proficiencies on Bloom's Educational Objectives (in the cognitive domain). It is proposed here to extend this framework to include sub-levels, or preparatory levels of proficiencies. This is done with the same sets of verbs, however within the preparatory context characterised in the previous section. The established CDIO proficiency levels, linked to Bloom's Educational Objectives is tabulated below (Table 6) and extended to include the proposed preparatory sub-levels.

Table 6
CDIO levels of proficiencies link to Bloom's Educational Objectives and expanded to include preparatory proficiencies.

Bloom's Educational Objectives	CDIO Proficiency	Preparatory Proficiency
Knowledge	**1** To have experience or been expose to … **2** To be able to participate in and contribute to …	**Prep1** To have elementary knowledge and basic awareness of … **Prep2** To be able to participate in and contribute in controlled situations
Comprehension	**3** To be able to understand and explain …	**Prep3** To be able to understand and explain elementary principles.
Application **Analysis**	**4** To be skilled in the practice or implementation of …	**Prep4** To have preparatory skills in the practice and implementation of …
Synthesis **Evaluation**	**5** To be able to lead or innovate.	**Prep5** Beyond the scope of preparatory proficiency.

Using Bloom's verbs and associated proposed preparatory proficiencies to determine the level of skill, this extended framework was then applied to the QSA senior secondary Engineering Technology Syllabus as follows.

The stated general objectives of the Engineering Technology Syllabus are expressed in terms of *Knowledge and understanding*; *Reasoning*; and *Communication* as listed below [11]. An assessment is made in terms of proficiency level (Prep1 through to Prep4) within the extended framework. The linked broad CDIO Syllabus topic is indicated in square brackets.

QSA Engineering Technology - Knowledge and understanding

By the conclusion of the course students should have acquired knowledge and understanding of:

Prep1	• *interdependence that occurs among technology, industry and society [4.1]*
Prep1	• *nature and diversity of engineering materials, their properties and applications [1.1]*
Prep2	• *methods for testing and modifying the properties of engineering materials [1.2]*
Prep2	• *principles of engineering mechanics and their applications [1.2]*
Prep2	• *statics and dynamics involved in machines, structures and components [1.2]*
Prep2	• *control systems in industry and society [4.1]*
Prep2	• *mathematical concepts and techniques [1.1]*
Prep1	• *conventions used to communicate engineering information [3.2]*

QSA Engineering Technology – Reasoning

By the conclusion of the course students should be able to:

Prep4	• *apply knowledge to unfamiliar and/or complex engineering problems [2.1]*
Prep2	• *use mathematical concepts and techniques in preparing and interpreting engineering data [2.1]*
Prep4	• *investigate and analyse engineering problems, and identify and prioritise their critical elements [2.1]*
Prep3	• *propose and validate possible solutions to engineering problems [2.1]*
Prep3	• *select suitable engineering solutions by drawing conclusions based on the evidence gathered [2.1]*
Prep4	• *evaluate proposed solutions in terms of their capacity to solve engineering problems, meet environmental and societal needs, and comply with appropriate benchmarks and standards [4.3]*

QSA Engineering Technology - Communication

By the conclusion of the course, students should be able to:

Prep2	• *select suitable modes and genres for the communication and presentation of engineering information, whether oral, written, graphical, multimedia or using models [3.2]*
Prep1	• *organise and present information in the selected mode and genre [3.2]*
Prep2	• *demonstrate technical literacy through the use of appropriate symbolic, graphical, engineering, language and referencing conventions [3.2]*

DISCUSSION AND CONCLUSION

The CDIO Syllabus mapping and extended proficiency framework presented in this paper provides a transparent connection between engineering education communities within Australia and the CDIO global community of practice. It is the intention that a more fluid pathway now exists for sharing of ideas, processes, resources and initiatives in global efforts of engineering curriculum reform. Through these contributions, a further mechanism now exists for globalisation of the curriculum, and to foster student mobility.

Through this extended CDIO framework, students and faculty have greater awareness and access to tools to promote (i) student engagement in their own graduate capability development, (ii) faculty engagement in course and program design, through greater transparency and utility of the continuum of graduate capability development with associate levels of proficiency, and the context in which they exist in terms of pre-tertiary engineering studies; and (iii) course maintenance and quality audit methodology for the purpose of continuous improvement processes and program accreditation.

In summary of the relationship between the CDIO Syllabus and the extended proficiency levels (with Bloom's verbs) a chart has been produced (Figure 2). This chart is best printed in at least A3 portrait style.

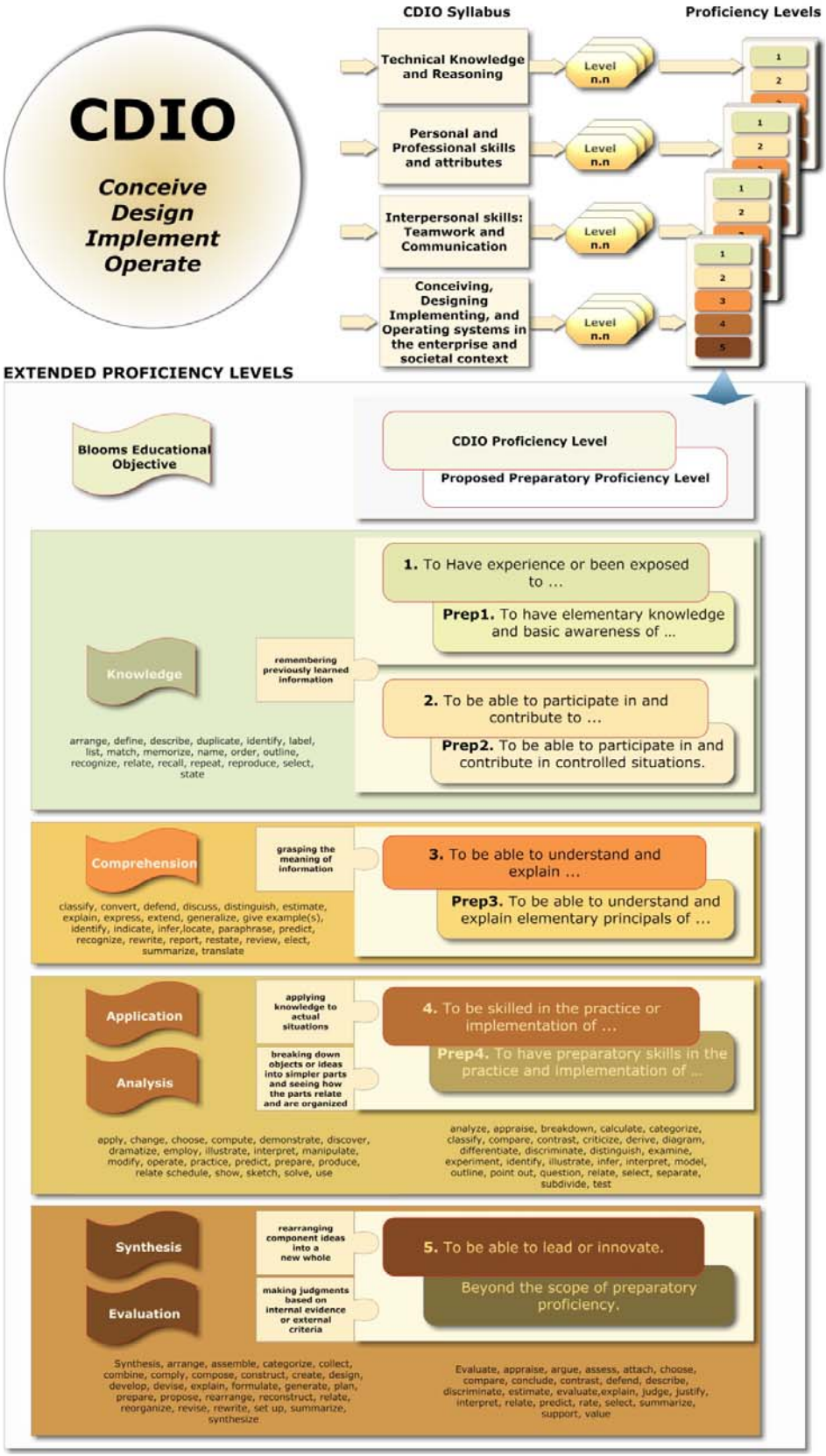

Figure 2. Conceptual representation of the CDIO Syllabus with extended proficiency levels.

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Biographical Information

Duncan Campbell is an Associate Professor of Engineering Education with the School of Engineering Systems at the Queensland University of Technology, Brisbane, Australia. He leads a number of engineering education initiatives related to engineering curriculum reform. Duncan is Co-Chair of the CDIO Integrated Curriculum Committee, Chair of the Australasian Association for Engineering Education (AAEE) CDIO Special Interest Group, and is Deputy-Chair of the CDIO Australia and New Zealand Regional group. He has received a number of engineering education awards, the most recent being the AAEE *Citation for Outstanding Contribution to Student Learning and Engineering* (2008).

Les Dawes is a senior lecturer in Civil and Environmental Engineering at Queensland University of Technology and Director of Domestic Relations for the Faculty of Built Environment and Engineering. He has been involved in developing design based activities and learning environments incorporating experiential learning and community outreach for over 10 years. He is also the editor for the Australasian Journal of Engineering Education.

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Sam Wallace is a Senior Electronics Engineer and Manager of Electronics R&D for Auslog – Weatherford Wire-Line Manufacturing in Australia. He has a Master's Rating from Microchip (PIC) in embedded processors and has more than 25 years experience in microprocessor and electronics design across a broad range of areas. Sam is passionate about engineering education and is currently doing a Master of Engineering designing an embedded processor platform to inspire life-long learning in our undergraduate electrical engineering students. He spends one day a week at QUT mentoring students and contributing to scholarship in engineering education.

Carl Reidsema is a mechanical design engineer with over 12 years industry experience. He is the founder of the newly proposed Centre for Design Research and Learning at the University of New South Wales. Dr. Reidsema has led the Faculty development of the University of New South Wale's first year common course in engineering design "ENGG1000 - Engineering Design and Innovation" which was largely based on his educational research and development. He was an invited speaker at several Australian Universities showcasing this innovative approach towards engaging first year engineering students and received the Faculty Teaching Award in 2006 and the Vice Chancellor's Teaching Excellence Award in 2009.

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AN INTEGRATED APPROACH TO DESIGN TEACHING IN A GENERAL ENGINEERING DEPARTMENT

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ABSTRACT

Design teaching is widely recognised as the core activity in engineering education, which integrates the subject specific technical contents with the social and technical needs. Design is the creation and development of products or systems to meet the needs and it involves significant technical and intellectual challenges. Integration of all engineering understanding, knowledge and skills are needed to solve the real problems. This paper describes an integrated approach to design teaching in a General Engineering department. The integrated approach emphasizes the need for systems and product design approach, and aligns the CDIO approach in the design teaching, involving: (1) the generation of general product concepts, (2) the selection of concepts between competing design solutions, (3) the application of engineering principal for detailed mechanical, electrical and software specifications and (4) the integration of the product designs. The exercise provides students with a platform to think across discipline-specific engineering fundamentals and to integrate technologies in product and system design. It also provides an opportunity to integrate technical fundamentals with personal and interpersonal skills for developing professional and leadership skills.

KEYWORDS

Design teaching, CDIO, Integrated approach, Design-implement experience

INTRODUCTION

There is a general recognition that design should be at the heart of the engineering curriculum, based largely on the observation that design is one of the core activities that professional engineers undertake [1]. Design is the creation and development of an economically viable product, process or system to meet a defined need. It involves significant technical and intellectual challenges and can be used to integrate engineering understanding, knowledge, know-how and skills to the solution of real problems. The requirement for design at the core of the education of professional engineers was enshrined in the UK-SPEC of Engineering Council's Standards [2], which stated, "the course must be taught in the context of design, which provides an integrating theme".

Design has become the central or core activity in our teaching and acts as a bond between various subject specific contents in our teaching. The Department of Engineering at Leicester is a Department with a general engineering philosophy; it offers a wide range of accredited undergraduate engineering courses, including aerospace engineering, communications and electronic engineering, electrical and electronic engineering, software and electronic engineering, general engineering and mechanical engineering. The broad base of our degrees aims to provide students with the skills to meet the technical challenges, enabling students to adapt to the changes in advanced technology and giving students a wider range of career options. Research and development in our design teaching follow our aim that our engineering programmes should graduate students who can design effective solutions to meet the current social and customer's needs.

The traditional model of engineering education is discipline specific, with a strong emphasis on the engineering science of that discipline. It was previously expected that graduates would work within their specialism. The reality of today's workplace is that employers (particularly the larger ones) expect graduates to join multi-functional teams engaged in the development of complex system projects. Even amongst smaller companies, there is still a need for graduates who can work across disciplines and who can integrate technologies allied to different disciplines. A unique feature of the design teaching at Leicester is the way in which 2nd and 4th year students interact in the solution of a multidisciplinary design problem. Our design teaching started from the so-called "partial design" approach [3] for a mechanical component, such as water bucket transporter, in 1990s, and then changed to a "total design" approach [3] for an integrated system, such as a robot, in early 2000s in which different disciplinary technologies were integrated into a system or product. Recently, we incorporated CDIO [4] concepts in our design teaching through (1) introducing active learning in design and (2) integrating technological and non-technological training in the design including communication, team work, and the awareness of social and society needs.

In this paper, we will explain the integration of design throughout our undergraduate curriculum, then introduce our project based 2nd year design learning using CDIO concepts, and finally we will address some ways of strengthening the active learning and the integration of technical and integrate technical fundamentals with personal and interpersonal skills in our design learning.

INTEGRATION OF DESIGN THROUGHOUT THE UNDERGRADUATE CURRICULUM

In the traditional curriculum, knowledge of each discipline is taught via a series of courses, and students become proficient at solving well-defined problems by the end of these. However, in reality, most of engineering problems are complex, open-ended problems that require synthesis of the knowledge gained in inter-disciplinary courses. For economic considerations, the best overall solution is not necessarily the best solution for each individual component of the problem. A good paradigm for design education is the integration of design throughout the undergraduate curriculum. Design is one of the five specific learning outcomes that graduates from accredited engineering programmes must achieve (see table 1). The five learning outcomes in the table were defined by broad areas of learning. Design has become the core of the 5 specified learning outcomes since design involves significant technical and intellectual challenges, is the creation and development of an economically viable product to meet custom's needs and can be used to integrate all engineering understanding, knowledge and skills to the solution of real problems.

Table 1 Specific learning outcome in Engineering Degrees [2]

1	Underpinning science and mathematics, and associated engineering disciplines, as defined by the relevant engineering institution
2	Engineering Analysis
3	Design
4	Economic, social, and environmental contexts
5	Engineering Practice

To fulfil the requirement for Professional Accreditation and to fulfil customers' needs, design education forms the spine of our curriculum and runs across the whole duration of undergraduate training, as illustrated in Table 2.

Table 2 Design teaching at the Engineering Department at Leicester

Year 1	First year design	10 credits
Year 2	Second year design	10 credits
Year 3	Third year research project on design	20 credits
Year 4	Fourth year project on design	20 credits
Year 4	Design management study	15 credits

In the first year of our course, the design module has 7 lectures, 40 hours practical drawing classes and 27 hours private study. Students are continuously assessed throughout the semester. During this period, design courses emerge as a means for students to be exposed to some flavour of what engineers actually do while enjoying an experience where they could learn the basic elements of the design process by doing case studies. At the end of first year training, students are able to demonstrate competence in the use of drawing conventions and standards, computer aided design and design methodology, and are able to convey basic information about engineering components and circuits. Through a few open-ended case studies near the end of the semester, students learn to break down a task into sections which can be analysed numerically, allowing a complete working system to be designed to meet a performance requirement.

In the second year of our course, the design module contains 6 lectures and 28 hours design classes and 45 hours private study and group work. This year, students will be grouped into design teams and all the teams will be assigned a design task. Students will design, manufacture the product or systems and compete with other design teams at the end of semester. Second year students will meet and report to their customers. They will be organised by a line manager, a role taken by a 4th year student, and apply their course work knowledge to make design decisions. Communication skills within a group environment are experienced together with the pressures of producing results and tasks on time, to budget and to specification. At the end of this module, students will have experienced a real-life scenario, which a design team might experience in industry. The format of second year design teaching follows the “Total Design” approach initially, but now incorporates “CDIO” concepts. The second year design teaching and the application of CDIO initiative will be presented in more detail in the next section.

In the third year, a design project can be chosen as a student’s project. This will be an individual project, which will occupy approximately one quarter of the student’s time. The project may be initiated by the student or selected from a list of topics offered by staff members. The design projects usually consist of the development of either a piece of equipment or a system. The third year design project covers application of the content of all courses taken. Oral presentation and written report are required. In a typical 3rd year design project, students shall be able to analyse existing designs such as troubleshooting and debottlenecking and more importantly to apply the knowledge of their discipline to the design of new processes or products.

In the fourth year, MEng students will have training in design management in the first semester and act as a line manager for the second year design teams in the second semester. In the 4th year design management study, students will experience the full design cycle, starting from market/social needs and technical drive for a new product, then market survey and profit margin for the new product, developing product specifications and selecting of design concept, and risk and fault tree analysis of the product. By the end of the 4th year, students will have a good appreciation of the skills required in managing the design of product or process from marketing to product release together with the skills and techniques required to manage and lead a design team.

In conclusion, we have integrated design teaching throughout our undergraduate curriculum to ensure that our undergraduate will be well prepared for an industrial career, without compromising the intellectual rigour of a single discipline course. Through the design training, we expect our graduates to have an understanding of the importance of systems thinking and a whole product holistic appreciation to meet the society and customer's needs. In the next section, we will introduce our implementation of the integrated approach design teaching as an example.

IMPLEMENTING PROJECT BASED LEARNING USING CDIO CONCEPTS

Evolution of Project Based Learning in Leicester

We have implemented project based learning in design since early 1990. In the second year of our course, students will be grouped into design teams and will be assigned an open-ended design task. Design teams will perform design, manufacture the product or systems and compete for the performance of the product with other design teams. As listed in Table 3, our project based design teaching started from so-called "partial design" approach [3] for a mechanical component in 1990s, and then changed to "total design" approach [3] for an integrated system in early 2000s through integrating different disciplinary technologies into a system or product. Recently, we incorporated CDIO concepts in design teaching through (1) introducing active learning in design and integrating technological and non-technological training including communication, team work, and the awareness of social and society needs.

Table 3 Design tasks in the Engineering Department at The University of Leicester since 1995

Year	Design task
1995	Container transporter
1996	Water bucket transporter
1997	A wheel-less locomotive device (plc based straight track)
1998	A wheel-less locomotive device (plc based wall obstacle on track)
1999	A moving autonomous transporter - rice collector with 2 walls)
2000	A moving autonomous transporter - block collecting from 3 locations
2001	Robot tug-of-war
2002	CD jukebox
2003	Ball bearing size sorter & distributor
2004	"Mars" rock sample collection system
2005	Autonomous Sled Transporter Vehicle
2006	Path Following Robot
2007	Wind Turbine
2008	Solar Panel
2009	Water turbine

Composition of Design Teams

The composition of the design team is shown in Table 4. The role of the MEng students is to manage the design project. As project managers they shall not be involved in executing the design, sourcing, building or testing the design. Rather, (s)he is responsible for: meetings, planning, progress monitoring, budget, technical guidance, presentations, audit and internal assessment. By doing these, the design module provides the 4th year MEng students with a real life experience for applying management principles.

Our department currently has 4 Visiting Professors in Principles of Engineering Design. The initiative of the Visiting Design Professor was supported by the UK Royal Academy of

Engineering. It enables distinguished, senior engineers in business to work with their academic colleagues to provide a bridge for undergraduates from education to industry. Their role is to demonstrate and transmit to students and staff that design is the integrating theme in all the engineering disciplines within the university. In our design teaching, Visiting Design Professors act as customers of the design by interviewing students and assessing their design at various design stages and give design lectures from an industrial point of view.

Table 4 Composition of design team at Engineering Department at Leicester

Team Managers (1-2)	4th year MEng students
Customer (1)	Visiting Design Professor
Team Supervisor (1)	Staff member
Technical support (2)	Mechanical technician
	Electrical and software technician
Team Members (6-10)	Mechanical sub-team
	Electrical sub-team
	Communication and software sub-team

The team supervisor is a staff member of the Department who provides technical advice to the team and oversees the design activities in the team.

Team members are 2nd year students who carry out the design. Typically the team consists of 2-3 mechanical students, 2-3 electrical and 1-2 software or communication students. They work together as a team while each member has his/her unique contribution.

Key Activities in Our Second Year Design

Our design teaching followed the “Total Design” concepts initially [total design] and we adapted CDIO concepts in our design teaching recently. Total Design is the systematic application, from the identification of the market/user need, to the selling of the successful product to satisfy the need. We used the product component of total design to achieve the integration of technical subject material in our design. Total design may be constructed as having central core activities – the design core, consisting of market (user need), product design specification, conceptual design, detail design, manufacture and sale. Though the adoption of CDIO concepts in our design we enhanced active learning in design and integrated technological and non-technological subject material in the 2nd year design including communication, team work, and the awareness of social and society need. The active learning and the integration of technological and non-technological will be discussed in details in next section. In this section, we will present key stages/steps in our 2nd year design.

Figure 1 illustrates the key stages in our design. Design starts, or should start, with a need that will fit into an existing market or create a market of its own. In the first semester of the second year, a staff member will meet with visiting design professor to plan/select a design task. Then the selected task will be passed to 4th year MEng students for them formulate a Product Design Specification (PDS) – the specification of the product to be design. At this stage, the 4th year student will assess the market/society needs, and ensure the PDS will meet the market/society needs. The PDS is usually finalised before Christmas, so the 2nd year students will be informed about the PDS before the design semester starts. The PDS acts as the mantle for the total design activity because it places the boundaries on the subsequent stages of design.

Conceptual design is carried out in the first two weeks of the design semester after Christmas. The conceptual stage of the design is primarily concerned with the generation of solutions to meet the PDS. At this stage, each group member is expected to develop a

minimum of one design concept for a system or a part of the system. After two weeks, students will be interviewed by a Visiting Design Professor (VDP); each member will have 5 minutes to present his/her selected concept and receive feedbacks from the VDP. After the interview, members of design team will work together to write a concept selection report. The report will contain:

- a morphological diagram or mind-map showing the range of solutions or devices considered for concepts,
- a sketch of concept that was presented to VDP during the interview,
- the criteria derived from the PDS for the design to meet the system requirements and the rules,
- a requirement tree showing expanded criteria and their weightings as decided upon by the team,
- a completed synthesis chart showing: specifications considered, weightings for each criterion and marks for each design concept and the totals, and
- a summary stating the outcome of the selection process and giving outline details of the final design with the division of task to subgroups.

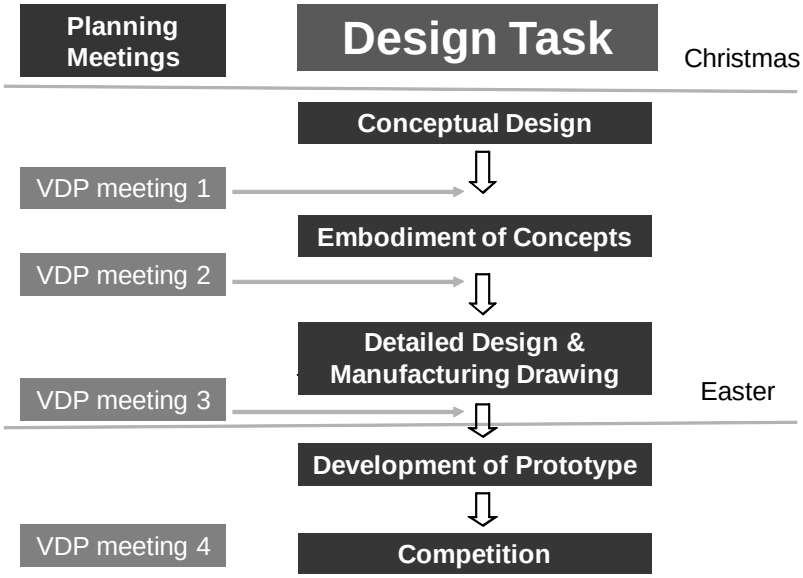

Figure 1. Flow chart illustrating the key steps in 2nd year design teaching at Leicester

In the **embodiment stage of the design**, students will have to expand concepts into more details in order to (1) better understand the concepts, (2) sort out the differences in technological approach, (3) define the component part of the whole system and (4) interface each component with those adjacent to it and its effect on the whole to ensure engineering compatibility. Students need to apply specific discipline-dependent techniques and technological knowledge such as stress analysis, thermodynamic analysis, properties of materials, electrical and electronic circuits, software, communication. After this design stage, students need to prepare a technical design report. A single design report is required from a team. The personnel authoring a section in the report must be named and a general section covering any predicted problem areas should be included. Only named contributors will be allocated report marks for their sections.The report shall contain:

- the details of the concept chosen with details of changes made as a result of *embodiment,*
- an assembly layout drawing, with items indexed, of the complete design,
- the selection of mechanical and electrical components,

- details of the sensing systems, etc.,
- the layout of circuit diagrams for printed circuit boards (PCBs) or/and a software flow chart for data-log and control,
- a list of problem areas that the group foresee in the production of a successful system using fault tree analysis of the system with ideas for overcoming critical faults

Design teams will be interviewed by a Visiting Design Professor (VDP) and the design will be modified according to the comments from VDP. When the design is approved by the staff member of the team, the design will progress to the **detailed design/manufacturing drawing stage**. In this stage, the technical support team work closely with the students to provide technical guidelines on component availability, local constraints in surrounding environment and interfacing components, testing, maintains and manufacturing facility, standards. Students will meet VDPs near the end of this stage to outline the current state of the prototype system, identify the problems experienced and discuss the feasibility of changes. Manufacturing drawings will be produced at the end of this stage and contain:

- an assembly sketch, with items indexed, of the complete design,
- detailed mechanical components and parts drawings using CAD printed full size,
- detailed circuit diagrams for PCBs,
- a detailed wiring layout for sensors, motors and actuators,
- a statement of departmental technical labour required by the various subgroups in parts manufacture and circuits together with the labour costs,
- a detailed parts list and sourcing, from internal stock or external companies to enable parts to be ordered together with the total estimated cost of the system including the labour.

The components will be either manufactured within the department or purchased from external resources. Each team has a budget of £200 to buy components from external sources and £400 for renting components and the cost for technician time in the Department. After Easter, the designed system/product will be assembled and demonstrated before the final competition. The demonstration will be the last chance to identify problems and consider the feasibility of modifications. A **Performance Competition** will be held in the last week of the summer term. This will be the final presentation of the system to the customers represented by all the VDP's who will be allotting a final mark, as a panel of judges, given in the light of all the required customer specifications and the appearance of the system.

The stages as depicted appear to have been gone through sequentially, but it must be emphasized that the design activities shall be operated **iteratively** at all stages**.** So the main design flow can and does reverse at any point in the design activity and some iteration is inevitable, but operating within the design rigorously and systematically will minimize unnecessary iteration.

Promoting Active Learning

Education is not just about the acquisition of knowledge, but the ability to apply that knowledge in a work force and ideally throughout all aspects of life. As engineering academics, we strive to impact real-world situations into our teaching and learning. Briggs (1999) [5] described four levels of thinking about learning and teaching as follows:

- Level 1: Learning is up to the students. A teacher's responsibility is to know the content well and to expound it clearly. When the students do not learn well, then it is due to something the students are lacking.

- Level 2: Teaching is treated as a performance. The teacher obtains an armoury of teaching skills. However, the teaching is focused on the skill itself, but the effectiveness of learning is dependent on the student learning

- Level 3: Teaching is seen as supporting learning. It recognises that learning can only be effective if it is engaged in an activity by the learner. The teacher's responsibility is to set up an environment of learning activities and assessments from which it is very difficult for the student to escape from without learning.

- Level 4: The level is the ultimate aim of higher education. Students take control. The focus is on how the student can manage what they do, initially within framework created by the teacher, but ultimately creating their own framework. There is no shortcut from level 1 or 2 straight to 4, a student cannot operate effectively at level 4 without having experienced level 3 teaching.

Levels 1 & 2 are usually termed as teacher-centred (transmissive) learning, while the levels 3 & 4 are termed as active (student-centred) learning. Active learning is a key element of CDIO concepts and it increases students' motivation, commitment, and retention [6]. Teaching in the Engineering Department at Leicester aims at levels 3 and 4, i.e. towards active learning. As described above, in our engineering design module, 2nd and 4th year students interact for a solution of a multidisciplinary open-ended design problem. Students make their own decisions on how to achieve the performance and to design their own product. This provides a unique opportunity for students at Leicester to reveal their changed conceptual understanding of the subjects and encourage students to restructure their existing knowledge in terms of the new way of thinking about the subject that they have learnt. This development was embodied by a statement from a 4th-year student who recently stated to one of us, "Were we really that bad when we were 2nd-years?"

Different students have different learning styles. To enable students to learn effectively we have tried to adopt approaches to teaching by designing our teaching with different learning opportunities to ensure that the learning is accessible to the largest number of students. In 1992-1994, a study was carried out at Leicester using the Approaches to Study Inventory [7] to measure Leicester students' learning styles, and the results are surmised as follows:

- Medical students most likely to take a deep approach to learning
- Law students differ in their reasons for study – largely external to subject matter
- Science (including Engineering) students are more likely to be surface learners

Comparing with students studying medicine and law, most engineering students are visual and sensing learners. Engineering students like to learn from the concrete experience, such as experiments, being the basis for observations and reflections, which allow them develop a 'theory'. This cycle is similar to so-called "Kolb's experiential learning cycle" [8]. As shown in figure 2, the cycle is a continuous process with the current "concrete experience" being the basis for observations and reflections, which allow the development of a "theory." The "theory" is then tested in new situations to lead to a more concrete experience. To enhance the learning effectiveness, Visiting Design Professors and invited practising designers will give a series of design lectures on presentation skills, design theory and practice using real design examples. Staff members of the design team have also tried to **link the design teaching with other disciplinary-relevant subjects**, such as solid mechanics, thermodynamics, programming and so on. In this way, students can reflect on their conceptual understanding of the subjects and restructure their existing knowledge in terms of the new way of thinking about the subjects that they have been taught.

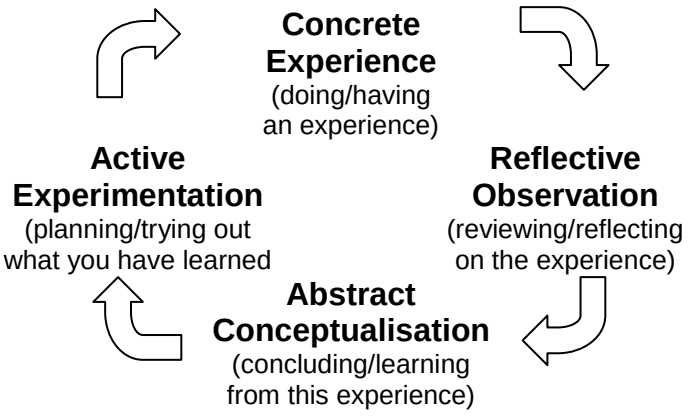

Figure 2. The Kolb learning cycle [8]

Integrating Technical and Professional Skill Training

Professional skill development is not a new concept, but it is becoming increasingly important. The engineering industry has been evolving rapidly, with the result that engineers are expected to have a wider range of skills [2]. Nowadays, engineers increasingly work in teams on projects and much of what we do is virtual rather than tangible. As one project ends, another begins, and so we move from project to project, from team to team, and from one workplace to another. As a result, engineering graduates need to have a solid grasp of disciplinary-relevant technologies, but they are also expected to have a good training in interpersonal skills such as communication, teamwork, and leadership. Indeed, it may be better to consider these “interpersonal skills” as necessary “professional competencies.”

Due to the multi-disciplinary nature of our Department, we integrated disciplinary-relevant technologies into our design teaching through the “Total Design” approach. Recently, some of the training in professional skills was integrated into our design teaching though the adaption of CDIO concepts through integrating technological and non-technological training in the design including communication, team work, and the awareness of social and society needs. In our design teaching process, communication skills within a group environment are experienced together with the pressures of producing results and tasks on time, to budget and to specification. Two lectures on presentation skills are given at the start of the design semester. Students will be interviewed by Visiting Design Professors 3 times during the design. Various presentation skills are required, such as formal presentation and around-the-table discussion with and without visual aids to describe, negotiate and defend the design.

A unique feature of our design teaching is the way in which 2nd and 4th year students interact in the solution of a design problem. The design team consists of mechanical, electrical, software and communication students and the design task contains mechanical, electrical, software and communication component. The overall design is a result of team work effort with clear individual contributions. The collaboration and team spirit is a key issue for the success for their design. MEng students act as line managers of the design team. They are responsible for the overall technical and people management together with budget control. At the end of design learning, students will have experienced a real-life scenario, similar to that which a design team might experience in industry.

For design teams, it is critical for members to hold frequent discussions to build consciousness among all members of the teams and styles of each person. These discussions are the foundation for **leadership development** for students during their university years. We encourage 4th year MEng to explore the importance of leadership and focus on ways that they can develop skills related to this vision, so that they can be of service to others in the design.

CONCLUDING REMARKS

An integrated approach to design teaching has been implemented in a General Engineering department. The integrated approach emphasizes the need for systems and product design approach, and adopts the CDIO concepts in the design teaching. The exercise of our design teaching provides students with a platform to think across discipline-specific engineering fundamentals and the adoption of CDIO concepts. It also provides students with an opportunity to integrate technical fundamentals with personal and interpersonal skills for developing professional and leadership skills.

ACKNOWLEDGEMENT

The Engineering Department at Leicester would like to thank the Royal Academy of Engineering for offering the Visiting Design Professorships and all our Visiting Design Professors. All authors thank the late Colin Morrison for his long time contribution to our design teaching.

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John Fothergill is Head of the Department of Engineering at the University of Leicester and has been Pro Vice Chancellor (Learning and Teaching). He is interested in on-line and campus-based learning, and has been a Member of the Melville Inquiry into the Changing Learning Experience.

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AN INTEGRATED APPROACH TO ENGINEERING AND DESIGN

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ABSTRACT

This paper describes the approach to integrate engineering and design where students learn the practice and application of engineering skills and foundation design skills in year 1 of their study. The design knowledge and engineering skills acquired by the students equipped them in the generation of ideas and implementing these ideas through team project activities. As part of the CDIO implementation plan for this module, a workspace is created to provide students to gain simple Design-Build experiences. This workspace allows each project team to realise their creative designs and develop them into models.

The paper also explains how the contents of the two modules, “Introduction to Engineering” and “IDEA” (Innovative Design and Enterprise in Action) are integrated. An example in the form of project will be described in detail to show the CDIO skills learned and experienced by the students. Finally, a summary of the evaluation this programme has in delivering the intended aims and conclusions are also outlined.

KEYWORDS

CDIO, workspace, design-build and integration

INTRODUCTION

The School of Mechanical and Manufacturing Engineering offers five diploma courses, namely Diploma in Aeronautical Engineering, Diploma in Bioengineering, Diploma in Mechanical Engineering, Diploma in Mechatronics, and Diploma in Resort Facilities Services and Management. The five courses, which have about 600 students, share the same first year curriculum and the students continue with their respective course of study from the second year.

CDIO [conceive-design-implement-operate] was implemented for the all the diploma courses in the first year of study. The objectives of implementing CDIO are to achieve the following goals:

- Improve the quality of the courses.
- Provide significant learning experiences for students which are more than foundational knowledge acquisition.
- Enhance the local relevance of our program.
- Enhance international recognition for the excellence of our courses.

A comparison between the current syllabus design methodology and CDIO is given in Table 1 below.

Current	CDIO
1. Learning outcome: heavy on "what we think students are capable of doing"	1. Learning outcome is determined by what the graduates are expected to do, example of which is the job competency.
2. Modules are still largely "independent", that is compartmentalized learning. Disconnect between C-D-I-O, not integrative	2. Modules are integrated to support the job competency.
3. Assessment: heavy on testing knowledge	3. CDIO elements are assessed mainly on application of knowledge

Table 1. Some shortfalls in current syllabus design methodology and how CDIO framework can address them

In determining these learning outcomes, there has also been an integrating of the two modules, and a subsequent alignment of the assessment system to the new outcomes.

The CDIO framework[1] consists of 2 broad categories: the 'WHAT' which are the skillsets that students need to learn and the 'HOW' which determine the method of getting it done.

A "Gap Analysis" for the Diploma courses was conducted to determine the missing and necessary skillsets to be introduced to the students. "Introduction to Engineering", which is Standard 4 of the 'HOW' was then introduced in year 1 of the course. This module is integrated and conducted together with another module, "Innovation, Design and Enterprise in Action" (IDEA) to fulfil Standard 3. In "Introduction to Engineering" module, students are engaged in the practice and application of engineering skills and knowledge in the manufacturing of a product. The skills acquired for generating ideas for the product was taught in "IDEA". The integration between these modules is achieved through team project activities. Students were awarded credit on Personal and Interpersonal skills through oral and written presentation.

To engage students in an active learning environment, a CDIO workspace, Standard 8, was built for students to gain simple Deign-Built experiences.

MODULES DESCRIPTION AND INTEGRATION

Two modules, "Introduction to Engineering" which is engineering in nature and "IDEA" which is design based were integrated and conducted as one module.

The objectives of ''Introduction to Engineering" are to:

- introduce students to engineering
- motivate them for engineering studies
- provide real experiences of engineering work
- support the learning of CDIO skills

The module starts by introducing the students to the world of engineering, understand the engineering behind how stuff work, understand machining processes and their applications and finally experience a simple design-build project. Students also have to demonstrate their ability to work individually and in groups to encourage teamwork, personal and interpersonal communication skills.

The objectives of "IDEA" are to:

- develop an attitude and skills in basic design creativity through an understanding of the experience design process
- enable students to question preconceptions, see things from multiple perspectives, and generate new ideas.
- enable students to generate new ideas
- provide students with the ability to work with and communicate effectively with the others for good teamwork and collaboration

Although the two modules are integrative in nature, other skills such as computer-aided drafting and oral communication are also taught. The core discipline knowledge complemented these two modules. Figure 1 shows how the modules are integrated.

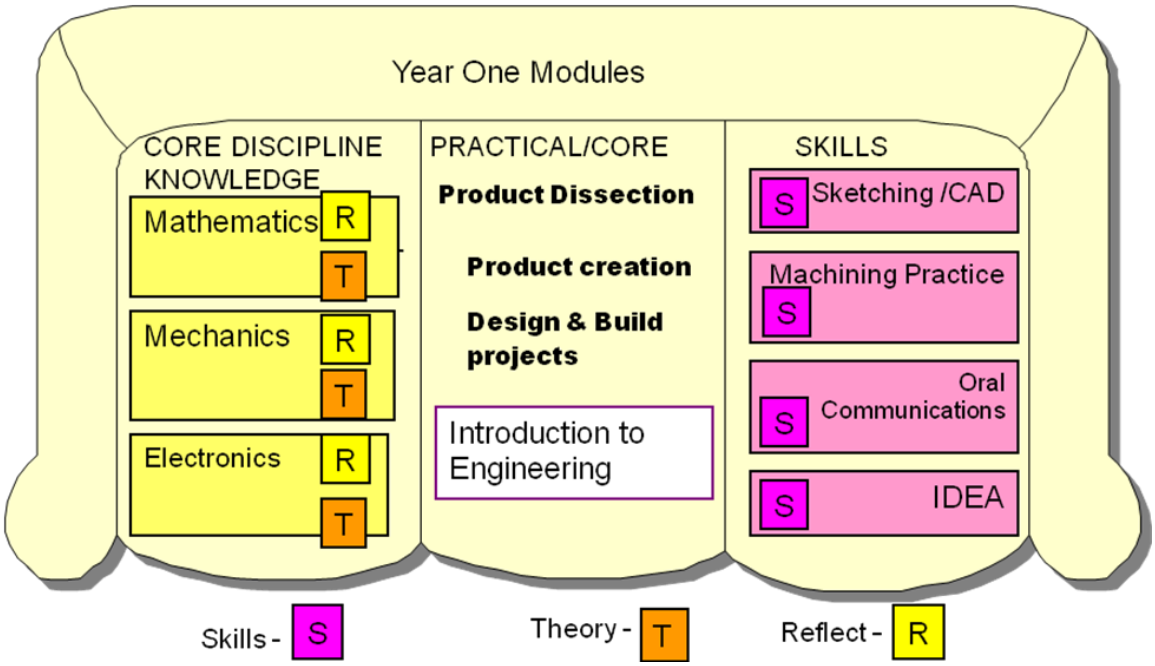

Figure 1. Integrated Curriculum

PROJECT DESCRIPTION

The design-build project is a Race Car comprises of two parts:

- Designing and modelling of the Race Car body which is conducted in "IDEA" module whereas
- Machining of the Race Car chassis is conducted under "Introduction to Engineering" module

Figure 2 shows how the two parts are assembled into a Race Car. Students complete the modules by participating in a CDIO Racing Challenge with the model racing cars that they have designed and produced.

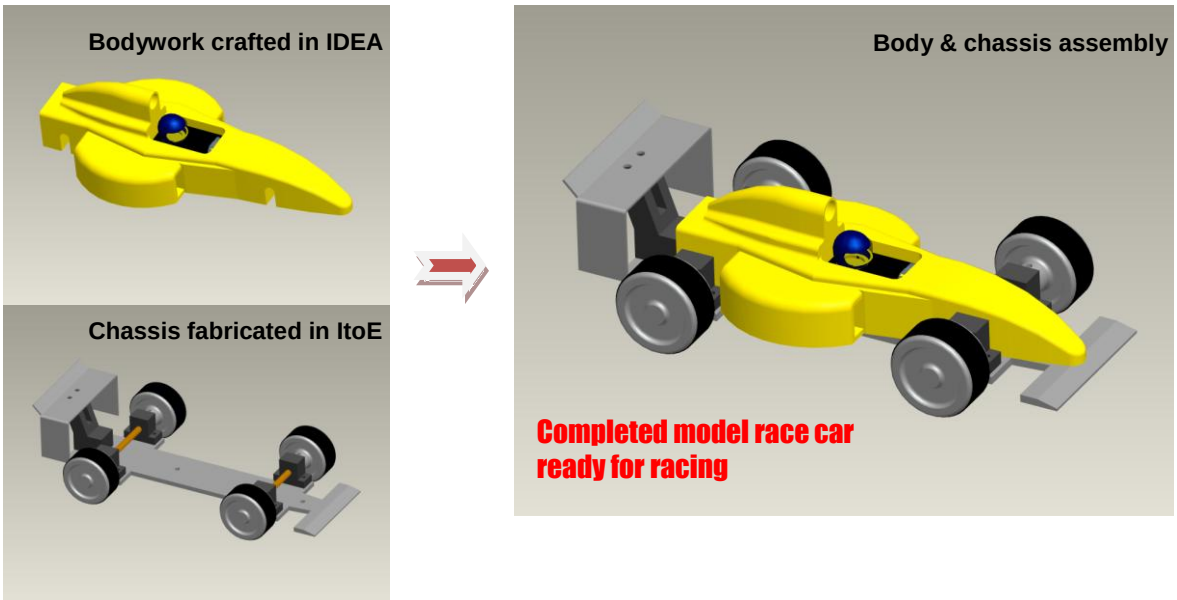

Figure 2. Design-Build Project

Figure 3 shows the detailed drawing of the chassis assembly.

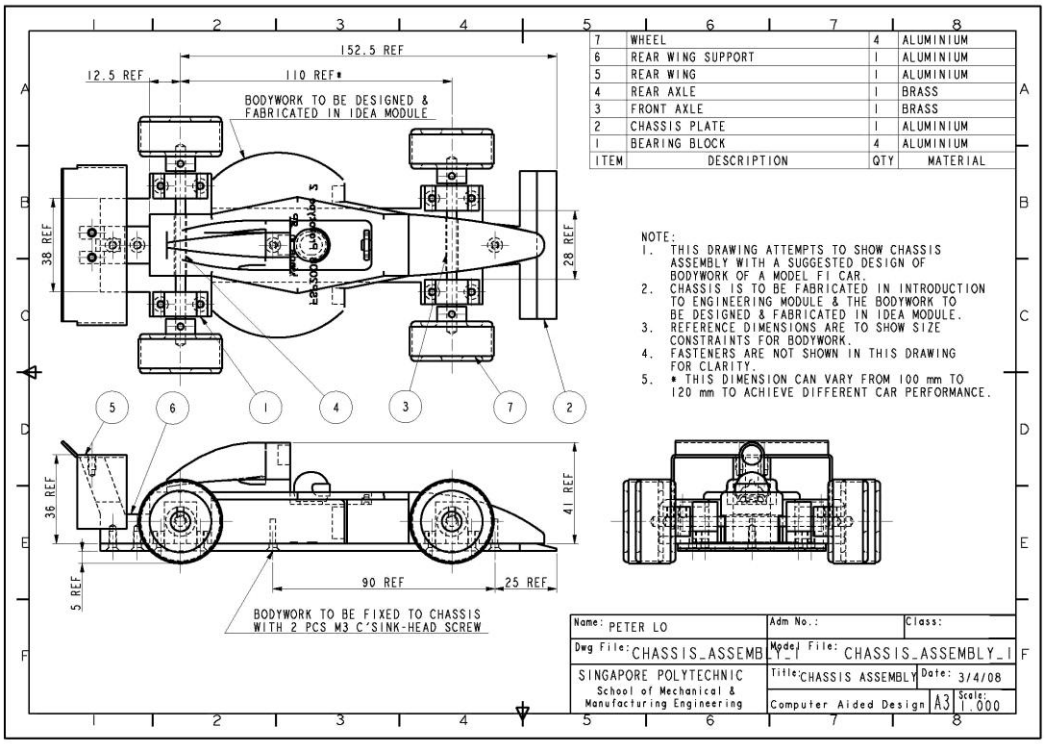

Figure 3. Chassis Assembly

Lecturers selected from each class two finalist cars (one to take part in the best performance category and the other in the most innovative design category).

Selection of the most innovative design cars was based on the following assessment criteria:

- form (innovative and functional)
- built quality, colour and decals

Selection of the best performance cars was based on time taken to race down the 6-metre long race track. In the 2nd CDIO Racing Challenge, as shown in Figure 4, the electronic timing readings ranged from 2.87 to 3.30 seconds among the 18 finalist cars.

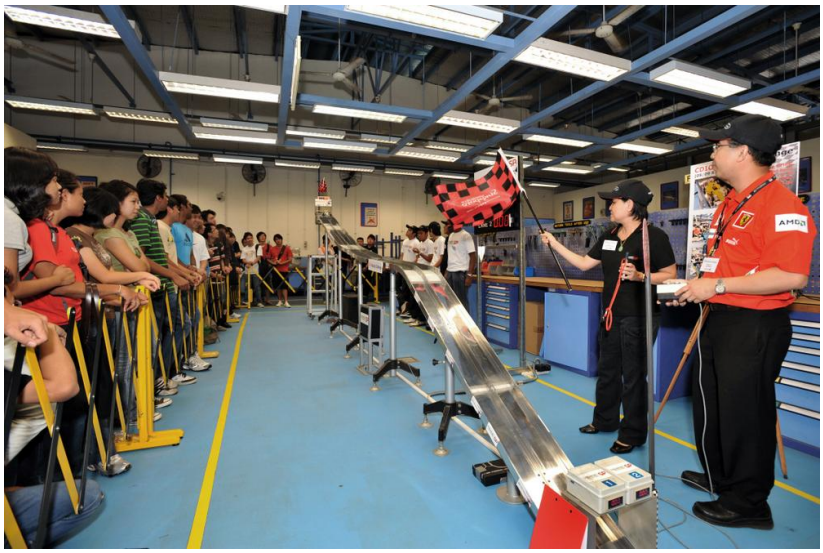

Figure 4. 2nd CDIO Racing Challenge

Figure 5 shows the winners of the most innovative design category and the best performance category.

Figure 5. Most Innovative Design and Best Performance Cars

WORKSPACE AND RESOURCES

The Instructions approaches for the two modules take place through a combination of tutorials and practical workshop. A CDIO Workspace, shown in Figure 6, was created for the students to design and produce their model race cars. Facilities such as foam cutter, saw and polishing machine were provided.

Figure 6. CDIO Workspace

A 6-metre long race track with two lanes and electronic timing system, as shown in Figure 7, was specially created for the CDIO Racing Challenge.

Figure 7. Race Track

MODE OF ASSESSMENT

The students were assessed on the process of designing and building the project. They are required to describe the various stages of team formation, select a project design from a collection of designs conceived during the "IDEA" design phase, manage the entire process of the project by appointing suitable members for the various tasks, apply machining skills to fabricate the parts and assemble the entire project and communicate group findings through a presentation.

The assessment consists of three components. The first component is on the design and modelling of the race car body which is conducted in "IDEA", the second is on the machining of the car chassis which is conducted in Introduction to Engineering and, the third is on the assembly, performance and presentation.

Students were assessed through critiques sessions on their ability to design and build their projects for the first two components. A rubric is designed for the assessment of the third component as shown in Table 2.

Grade **Criteria**	**Excellent**	**Good**	**Satisfactory**	**Needs improvement**
Final Assembly of Chassis and Car Body	Great effort was put into the assembly. The completed model is rigid and stable yet neat and attractive.	The completed model is technically sound and neat. All individual components are properly secured.	The final assembly were satisfactorily completed. But some details could have been refined to make it more presentable.	The final model appeared haphazardly assembled if not uncompleted. Many parts are still loose, not assembled properly and needed refinement.
Car Performance	Completed the race in the 95th percentile.	Completed the race in the 90th percentile.	Completed the race.	Unable to complete the race.
Presentation to Class	Clear, effective and well-organised, good visual aids. Displays excellent teamwork and good communication.	Good presentation with appropriate visual aids. Evidence of positive teamwork.	Satisfactory presentation with limited visual aids. Satisfactory cooperative work.	Presentation lacks effectiveness. Limited cooperation and communication.

Table 2. Rubric for the Final Assessment

MODULE EVALUATION

At the end of the semester, an evaluation was conducted to gather feedback on students experience, achievement and development of selected CDIO skills. A set of questions for interview was conducted for a selected group of about 103 students.

The evaluation is targeted at the students' ability to understand the skills and whether the skills help them in the tasks they were given. The following skills areas were evaluated:

- Thinking
- Managing your learning
- Communication
- Teamwork

A Rating scale of 1 to 5 is used where 1 being strongly disagreed to 5 being strongly agreed.

The % of Ratings of 3 or more were collected and the results of the evaluation are shown in Table 3.

Singapore Polytechnic **CDIO Evaluation Survey Results**	
Questions	% of Rating >=3
Q1a : I am aware that the following skills are being practised in my Introduction to Engineering lessons. (thinking)	98
Q1b : I am aware that the following skills are being practised in my Introduction to Engineering lessons. (teamwork)	96
Q1c : I am aware that the following skills are being practised in my Introduction to Engineering lessons. (communication)	95
Q2a : I understand the usefulness of these skills in my learning and development as a technologist. (thinking)	98
Q2b : I understand the usefulness of these skills in my learning and development as a technologist. (teamwork)	98
Q2c : I understand the usefulness of these skills in my learning and development as a technologist. (communication)	95
Q3 : The activities in my Introduction to Engineering module make my learning more interesting and motivate me to learn more about my course.	95
Q4 : I am participating more actively during my Introduction to Engineering lessons	95
Q5 : As a result of the activities in the Introduction to Engineering lessons, I am able to think more creatively and generate ideas.	93
Q6 : As a result of the activities in the Introduction to Engineering lessons, I am able to use a range of critical thinking skills more effectively in problem-solving (e.g. analyse, compare & contrast, evaluate).	94
Q7 : As a result of the activities in the Introduction to Engineering lessons, I am able to manage my learning effectively (e.g. keep to deadlines, organise notes and prioritise learning activities).	97
Q8 : In doing the project/s in the Introduction to Engineering module, I understand the importance of having initiative and the willingness to take thoughtful risks.	97
Q9 : The activities in the Introduction to Engineering module gave me a greater understanding of the importance of team roles and their impact on team performance.	95
Q10 : As a result of the activities in the Introduction to Engineering module, I am able to design and deliver more effective oral presentations	92
Q11 : I am able to see the linkages between the IDEA module and the Introduction to Engineering module.	93

Table 3. Results of Evaluation

CONCLUSIONS

The paper presented the integration between an engineering module, “Introduction to Engineering” and a design module “IDEA” and how the knowledge gained from one module is used culminating to the design and building of a Race Car,

Overall responses from the students were positive and majority felt that they have benefited from the integration of the two modules and the ability to understand and apply the CDIO skills effectively.

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Dr Linda Lee is the Deputy Director for the Product Engineering & Management Division. She is also the Course Chairman for the Diploma in Mechanical Engineering. She currently oversee the implementation of CDIO for the School of Mechanical & Manufacturing Engineering, Singapore Polytechnic. As Course chairman, she is responsible for the management of the course.

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AN INTERACTIVE PC-BASED ELECTRICAL POWER SYSTEM SIMULATOR FOR ENGINEERING EDUCATION

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ABSTRACT

The research scheme proposed in this article describes the development of a PC-based teaching/learning approach to power systems education. The paper describes an illustrative network system to be modelled and the software's capabilities and features, as implemented using MatLab. Simulation functions are introduced for teaching and learning purposes, in order to help students better understand complex electromagnetic transient phenomena of electrical power systems under various system fault conditions. The teaching impact of the simulator is discussed, with a focus on how students using this approach are supported with regard to developing their skill set, transferable knowledge and future career. The work demonstrates that adopting such an innovative simulation approach can allow for rapid simulation-based experimentation, and facilitates student learning in a safe and cost-effective environment, particularly where practical student experience is not otherwise feasible.

KEYWORDS

Power system modelling, digital simulation, computer programming, interactive, experiential learning

INTRODUCTION

Digital simulation has been applied in many fields e.g. aerospace [1], aeronautics [2] and chemical production [3]. A digital simulator is superior to an analogue simulator because of its high accuracy and software flexibility and also because of its low cost. Digital computer simulation is widely used in power system analysis. There have been a great number of well developed programs in various R & D and educational aspects of power systems [4 – 6].

One convenient and powerful approach is to use digital simulation tools to support teaching and learning, and to integrate these into power engineering courses. Such a power system simulation allows engineering students to understand the fundamentals of electrical power systems in an interactive way. Instead of using physical system components, the simulator configures circuit and component parameters freely, based on software models.

A Matlab-based electrical power system simulator is proposed in the paper. The simulator is designed to help students at different levels, to better understand and to provide detailed insight into complex electromagnetic transient phenomena of power systems under various fault conditions. In particular, it will provide engineering students with an effective and complementary learning method to understand power system responses and their dynamical characteristics. The paper starts with a description of an illustrative network system to be modelled and of the software's capabilities and features implemented. Simulation functions are subsequently introduced for teaching and learning purposes. The teaching impact of the simulator is discussed, with a focus on how students using this approach are supported in terms of their skill set, transferable knowledge and future career developments.

POWER SYSTEM SIMULATOR

Network Modeling

A simplified electrical power system to be simulated is shown in Figure 1. On the generation side (M) and the receiving side (N) there are two AC power sources which are connected via transformers, circuit breakers, a transmission line with local load, CTs and PTs. The current transformer (CT) and the potential transformer (PT) are instrumental devices used to measure high-range electric currents and voltages respectively, which are normally interfaced to power control equipment using signal conditioning hardware. The power sources are assumed as ideal 3-phase sources and the transformers have an ideal turn ratio with only leakage impedance being considered. The transmission line is represented by its positive-negative-zero sequence impedance by neglecting the capacity of phase-to-phase and the capacity of phase-to-ground. Nevertheless, the simplified system can adequately represent the right AC components and asymmetric DC components of voltages and currents in system fault conditions.

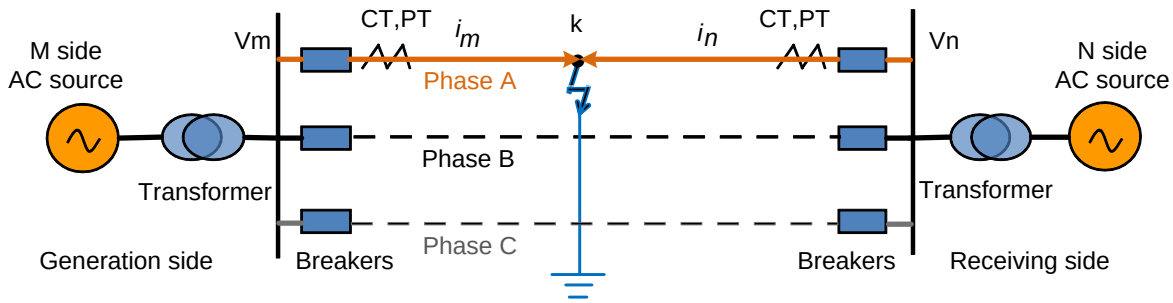


Figure 1 Simplified electrical power system

Table 1
Electrical Parameters of the Simulated System

X_{sm}, R_{sm}	Impedance of M side AC source
X_{sn}, R_{sn}	Impedance of N side AC source
X_{tm}, R_{tm}	Leakage impedance of M side transformer
X_{tn}, R_{tn}	Leakage impedance of N side transformer
X_1, R_1	Positive sequence impedance of the transmission line
X_0, R_0	Zero sequence impedance of the transmission line
E_{ma}, E_{mb}, E_{mc}, E_{na}, E_{nb}, E_{nc}	Phase voltages of power source at both sides
i_{ma}, i_{mb}, i_{mc}, i_{na}, i_{nb}, i_{nc}	Phase currents feeding from two sides of the line
V_{ma}, V_{mb}, V_{mc}, V_{na}, V_{nb}, V_{nc}	Bus voltages at both sides

The electrical parameters of the simulated system are given in Table 1. Take phase A as the example. Under normal conditions, i.e. no fault, the differential equation of phase A can be described by Eqn (1), where the boundary condition $i_{ma} = -i_{na}$ applies.

$$E_{ma} - E_{na} = \frac{X_{sm} + X_{tm} + X_1 + X_{tn} + X_{sn}}{2\pi f} \, di_{ma}/dt + (R_{sm} + R_{tm} + R_1 + R_{tn} + R_{sn}) i_{ma} \qquad (1)$$

When an AG (phase A grounded) fault occurs at location k, the electrical topology of the system changes accordingly. The differential equations of phase A can be described by Eqns

(2) – (7), where V_{m0} and V_{n0} denote the zero sequence voltage of the neutral connector of the transformers at M and N sides respectively and fault location k is represented by its percentage of the line.

$$E_{ma} + V_{m0} = \frac{X_{sm} + X_{tm} + kX_1}{2\pi f} \, di_{ma}/dt + (R_{sm} + R_{tm} + kR_1) i_{ma} \tag{2}$$

$$E_{na} + V_{n0} = \frac{X_{sn} + X_{tn} + (1-k)X_1}{2\pi f} \, di_{na}/dt + (R_{sn} + R_{tn} + (1-k)R_1) i_{na} \tag{3}$$

$$V_{m0} = \frac{kX_0}{2\pi f} \, di_{m0}/dt + kR_0 i_{m0} \tag{4}$$

$$V_{n0} = \frac{(1-k)X_0}{2\pi f} \, di_{n0}/dt + (1-k)R_0 i_{n0} \tag{5}$$

$$i_{m0} = -(i_{ma} + i_{mb} + i_{mc}) \tag{6}$$

$$i_{n0} = -(i_{na} + i_{nb} + i_{nc}) \tag{7}$$

If phases B and C work under normal conditions, their differential equations can be described similarly by Eqn (1) where only current and voltage symbols need to be replaced using those of phases B and C respectively. Therefore, three simultaneous differential equations are formed at each side with three unknown phase currents to be determined. The differential equations can be numerically solved using a suitable iterative algorithm such as a higher order RK (Runge-Kutta) method to minimise the round-off errors in calculation. Having obtained the phase currents, bus voltages can be calculated based on Eqn (8, 9) by taking phase A as the example.

$$V_{ma} = E_{ma} - \frac{X_{sm} + X_{tm}}{2\pi f} \, di_{ma}/dt + (R_{sm} + R_{tm}) i_{ma} \tag{8}$$

$$V_{na} = E_{na} - \frac{X_{sn} + X_{tn}}{2\pi f} \, di_{na}/dt + (R_{sn} + R_{tn}) i_{na} \tag{9}$$

By arbitrarily setting the initial load condition and fault situation, the system under various fault conditions can be simulated. The results show the dynamical changes of bus voltages and phase currents of the system under normal and abnormal operating conditions.

Software Implementation

A graphical user interface (GUI) which integrates with the simulation engine was developed in the MatLab programming environment. The interface allows students to configure freely initial power flows and fault conditions including location, type and status. The fault type can be one-phase grounded, two-phase short circuit, two-phase grounded, three-phase short circuit, three-phase grounded, phase breaks or complex faults. The GUI displays the steady state voltages and currents prior to the faults and their electromagnetic transient behaviours during the fault period.

The software structure is designed on a modular basis, enabling more functionality to be added to meet more flexible teaching and learning requirements. Apart from system fault simulations, the simulator also includes modules of electrical power system oscillation and

harmonics analysis. The addition of new modules provides students with an improved insight into power plant response and power system dynamical characteristics.

Simulation results can be exported into a file format which can be further processed by programs such as Excel. The data files can also be downloaded into a digital storage oscilloscope (DSO) via an internet link for waveform replay when required.

SIMULATOR FUNCTIONS FOR TEACHING DELIVERABLES

System Operation and Fault Analysis

The main function of the simulator is to simulate various types of short circuit fault occurring in the transmission line including faults evolving from a simple one to a more complex one. Fault location k can be set arbitrarily at any position on the line. The fault can be transient or permanent. The fault resistor can be zero (directly grounded) or a specific value that is defined by program.

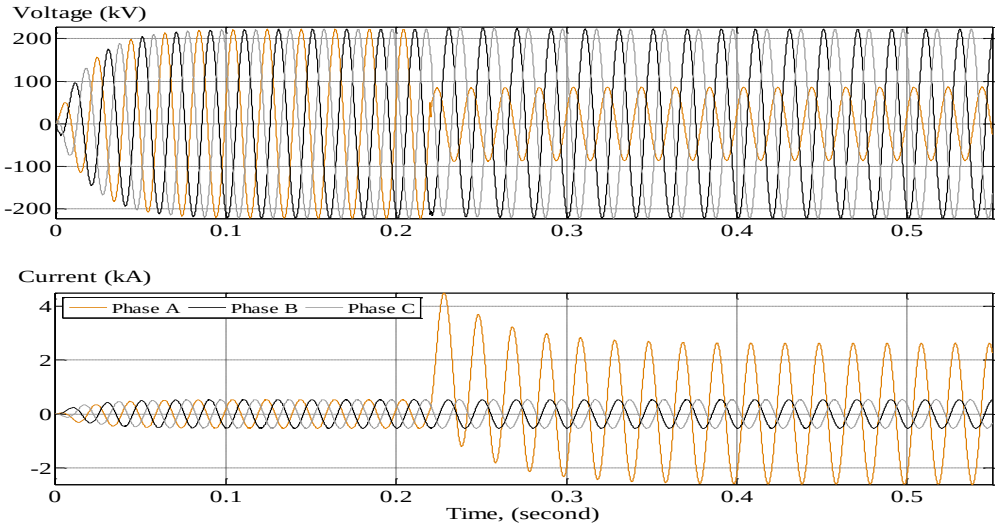
A case study is considered in this paper to simulate two substations connected via one 100 km transmission line. Table 2 gives the main parameters used to configure the case study system. Two fault positions are chosen; k1 is defined as midpoint on the line whereas k2 the point between transformer and breakers at M side. Breakers at both sides are independently timed controlled and default status is closed. System voltage of 275 kV is chosen since this is a popular voltage level in the UK transmission system. By adjusting phase angle between two power sources, the correct power flow can be obtained. In this case, M side power source leads N side 20 °, which means that substation M is a generation side and substation N is a receiving side.

Table 2
Case Study System Configuration

	Substation M	Substation N
Power source	100 MVA, 275 kV, 20°, 50 Hz	100 MVA, 275 kV, 0°, 50 Hz
Voltage setup time	0.2 s	0.2 s
R_s, X_s	1 Ω, 0.1 Ω	1 Ω, 0.1 Ω
R_t, X_t	1 Ω, 0.1 Ω	1 Ω, 0.1 Ω
Breaker	Default is closed	Default is closed
AG	Phase A grounded fault	
AB	Short circuit fault between phase A and phase B	
ABCG	Three-phase grounded fault	

As an example, Figure 2 shows bus voltages and phase currents at M side when a permanent AG fault at position k1, AB fault at position k2, and ABCG fault at position k1 occur respectively. The waveforms of the first 0.1 second simulate the time duration for the system to stabilise, which is determined by the source voltage setup time configured for the system. The faults start at 0.22 s as controlled resulting in a significant change in both voltages and currents on fault phases. The voltages become small whereas the currents are larger due to the short circuit nature compared to their steady state levels prior to the fault.

The fault can be transient, which implies that it disappears after a time period. Figure 3 shows the voltages and currents of the examples given in Figure 2 with a fault time duration of 0.15 s being applied. After the fault varnishes at 0.37 s, the levels of voltage and current on fault phases return to the steady state levels after stabilisation.



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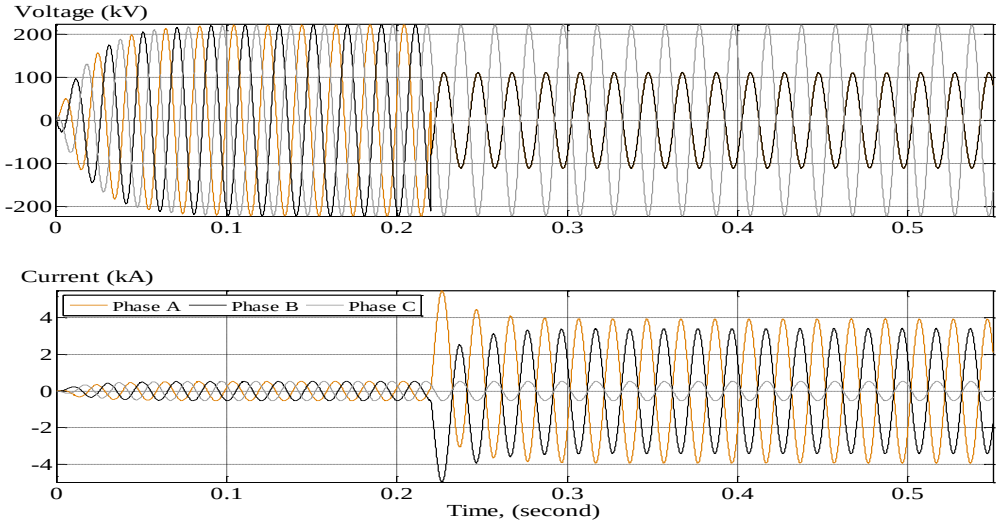

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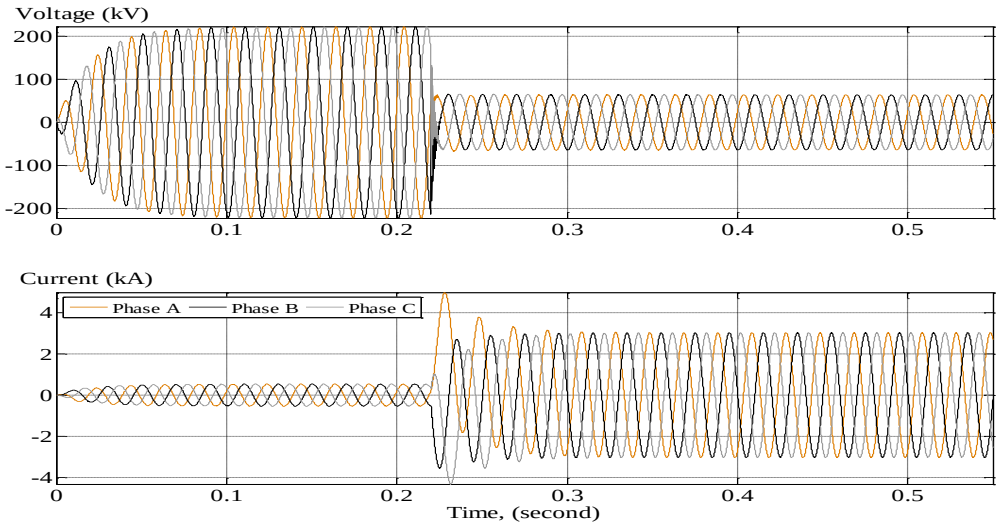
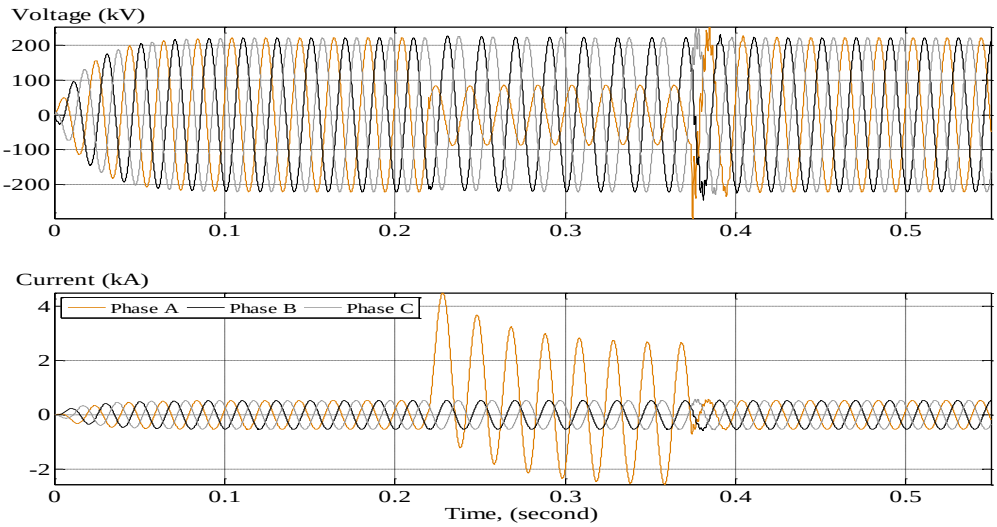


(c)

Figure 2 Voltages and currents under permanent faults (a) AG at K1, (b) AB at K2, (c) ABCG at K1



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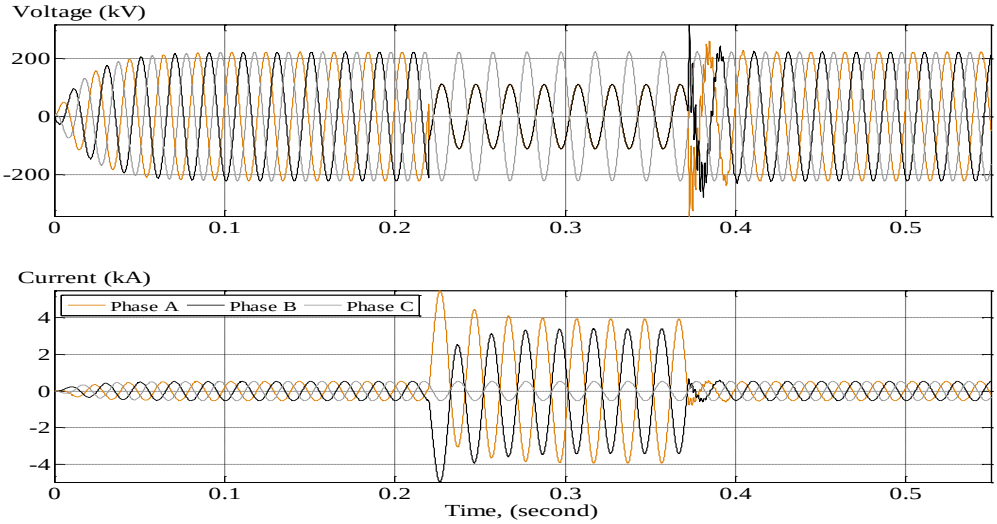

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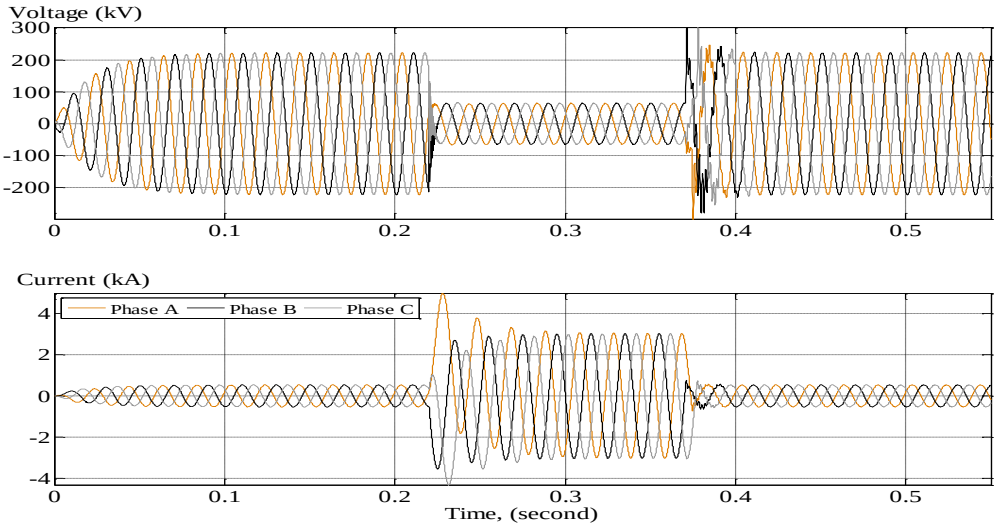


(c)

Figure 3 Voltages and currents under transient faults (a) AG at K1, (b) AB at K2, (c) ABCG at K1

Power System Protection

An accumulation of faults can lead to catastrophic failure and hence cause outages with serious health and safety, environmental and economic consequences. Therefore, the protection of electrical power systems will be essential. This can be realised by setting breaker clearing time and reclose time to reflect the on / off state of the circuit breakers in each phase. Figure 4 shows the voltages and currents under breaker controls where the breakers are controlled to trip off at 0.33 s and reclose at 0.38 s. In this case, circuit breakers trip off after the fault lasts for 0.11 s since initiated; the fault is cleared when circuit breakers reclose at 0.38 s. Breaker clearing time and reclose time can be adjusted in the simulations if needed.

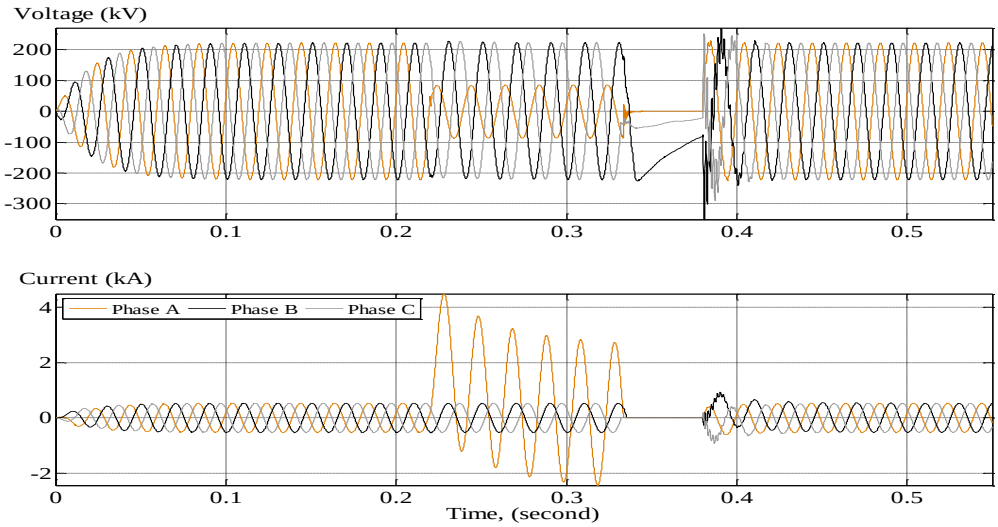
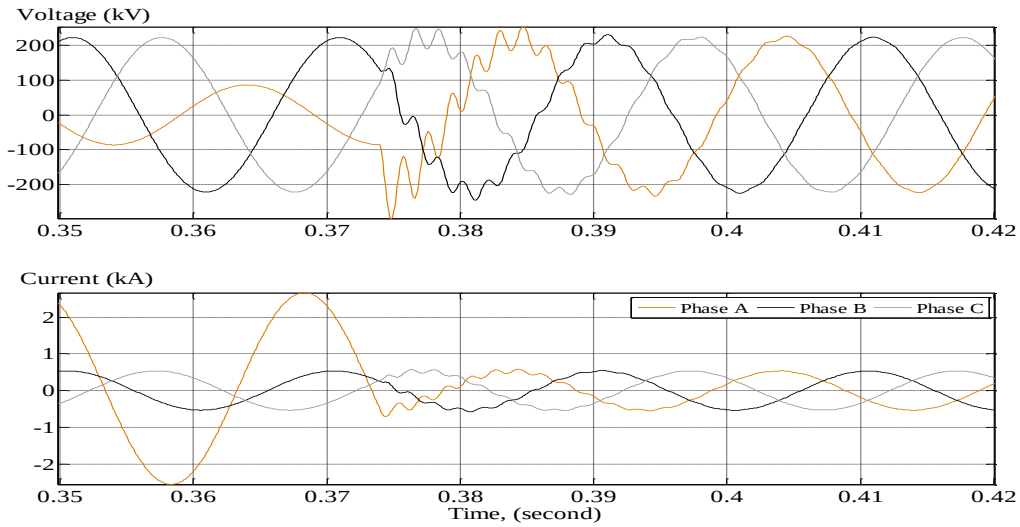


Figure 4 Voltages and currents under breaker controls under AG at K3

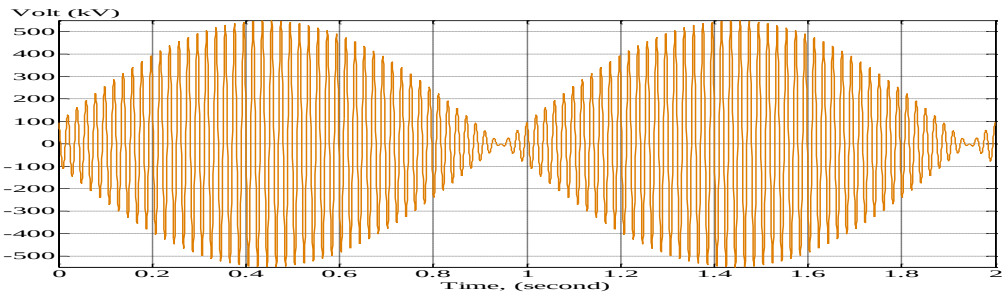
Power System Oscillation

A fault on a transmission line may excite oscillations due to the external disturbances it causes [7]. The voltages at the fault are small indicating active power transformed on the line is decreased. In reality, this will cause the generators that are unable to deliver power to speed up and, therefore, swing against the rest of the system. The oscillations are mitigated in the simulations because the dynamics of generators are simplified with ideal AC power sources. However, fault controls and the operation of circuit breakers still can interact with the system giving rise to voltage and current oscillations, which can be seen from the transient behaviours in Figure 3 and Figure 4. Figure 5(a) illustrates an enlarged section of Figure 3(a) after the AG fault is cleared showing the oscillation frequency is approximately 2.5 Hz before stability reaches.

If the power source at M side is set purposely to swing against the N side, for example at 1.0 Hz, the system yields unstable oscillations leading to an out-of-step event. This can be illustrated in Figure 5(b), where the oscillations behave like AC signals but are modulated by the swing frequency in the magnitude. Unstable oscillations may lead to rapid system collapse if proper measures are not taken.



(a)



(b)

Figure 5 Power system oscillations (a) stable oscillations, (b) unstable oscillations

TEACHING IMPACT

Skill Sets

The simulator can be used by a wide range of students, including: (i) students seeking ways in which to better understand difficult classroom concepts in power engineering; (ii) students trying to learn and enhance their skills in a more interesting context; (iii) students looking for ways to improve their numerical analysis skills in solving real-world differential equations that are dealt with in calculation; and (iv) students wishing to apply computer programming skills to the GUI design of the simulator.

The multidisciplinary approaches involved in the simulator require that students should have fundamental skills relating to objectives and schedules, analysing problems, understanding the structure and performance of the simulator, gathering and processing useful information from simulation data. These skill sets can be achieved by taking university courses such as computers and control, elementary calculus dealing with differential equations, and the fundamentals of power energy systems. The simulator is essentially designed to aid classroom teaching and learning of major courses in electrical power engineering. It can be a platform for the students to continuously develop their skill sets from the use of the simulator during their course of learning.

Transferable Knowledge

The simulator provides the students with an illustrative tool to help them bridge the gap between theory and the practical operation of a power system. Students can effectively interact with the electrical power system modelled by the simulator. It is difficult for students to operate a real power system to understand the system's response characteristics. Therefore, it is important to analyse a system's behaviour in order to understand the system's capability and limits using simulation.

As with most toolboxes developed for use in MatLab, the simulation programs are open to learning from the students. For example, a toolbox is designed in the simulator which allows students to configure the system including fault type, location, duration and development, and to understand how the system responds to the settings, with various combinations of the actions from circuit breakers. Mathematical solutions to the differential equations of the modelled system can be offered with different numerical methods in addition to the RK method. Students can be challenged by selecting different methods for in-depth analysis of the system in terms of minimising round-off errors and the length of time needed to complete all calculations. By taking advantage of modular basis design, more functionality can be added in the simulator to meet changing teaching and learning requirements. The simulator can be interfaced with large power simulation tools such as PSCAD/EMTDC by which students gain the knowledge about the dynamics of a more complex power system if needed. Students are also encouraged to return information regarding the use of the simulator to the tutor, so that the simulation programs can be improved, particularly with regard to their ease of use and flexibility.

Career Developments

One of the possible careers available to engineering students is a power system analysis engineer. In this regard, the simulator is an ideal demonstration and learning tool to show simulation techniques, power system dynamics and operation. By being trained on the simulator with a number of case studies, the students gain insight into the system operation in an interactive learning environment where they are an active part of the simulation.

Another relevant career would be protective relay engineers. As described above, power system protection is simply modelled by setting the on/off state of the circuit breakers on the transmission line. In reality, on/off state of circuit breakers is controlled by a protective relay installed at either end of the line and connected to CTs and PTs at its side. Figure 6 shows a schematic arrangement of protective relay connected to the simulated system. Briefly, the simulated bus voltages and phase currents are sent to the relay. The relay operates if the fault location is within the protection zone and relay signals are fed back to affect the simulation by opening and reclosing breakers. The main components of relay equipment can be simulated and integrated into the simulator, including signal processing to extract fundamental magnitude and phases, and typical protection schemes such as distance protection and over-current protection. The use of this approach would enable students climb the career ladder as potential protective relay engineers if they wish.

The knowledge and expertise gained from this simulation program may also help the students into another career ladder as system simulation engineers. The simulator can be easily developed into a real-time one if it performs on a high-speed computer. True close-loop simulation can be achieved if the simulator is equipped with a suitable hardware I/O interface. This would be beneficial for those students who want to develop their careers beyond power engineering such as industrial process applications and even in the creative game industries.

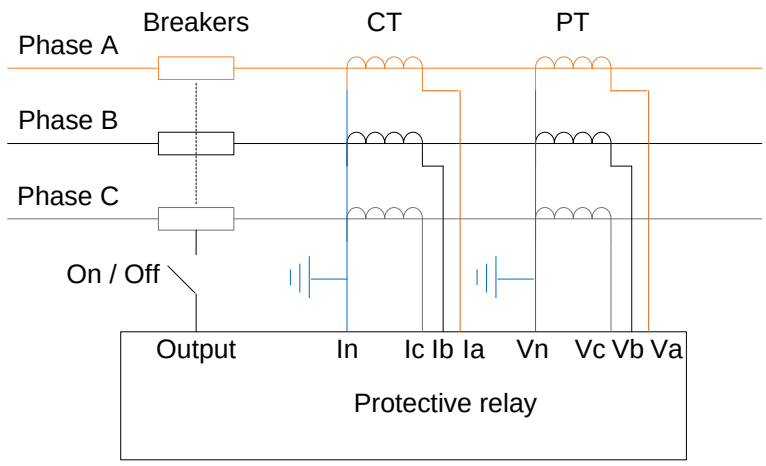


Figure 6 Schematic arrangement of protective relay

CONCLUSIONS

This paper has presented a modular simulation software framework, which is intended for educational use in power engineering. The study has shown that difficult concepts in power engineering can be effectively addressed in an interactive way, thus sustaining and increasing the students' learning interests. The simulation programs have been designed to accommodate representative types of unhealthy conditions of electrical power systems, including various types of fault situation and system oscillations. The proposed simulator can be effectively used to support power engineering education, coursework or projects.

The desire for cost-effective teaching is balanced by the ideal of giving students the opportunity to solve real design problems. Since its inception, the teaching goals of the Engineering Department at Lancaster University have focused on a multidisciplinary approach to real world applications. To this end, the Department puts great effort into the development of stimulating research and industry-based projects applicable to all parts of the degree scheme. However, these projects are supported by the use of innovative simulations tools such as the package described in the paper, which allow for rapid simulation-based experimentation, and facilitates student learning in a safe and cost-effective environment or where practical student experience is not feasible.

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APPLICATION OF CDIO PRINCIPLES IN AN INTEGRATED PROCESS AND PRODUCT DESIGN COURSE

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ABSTRACT

All B.Eng. courses offered at the Technical University of Denmark now follow CDIO standards. Recently (Spring 2008) a new course – 28156 Process and Product Design - was introduced in the Department of Chemical and Biochemical Engineering. The course has typically about 30-40 students. An integrated course combining the two disciplines of Product Design and Process Design has several challenges, not least because the subjects do not necessarily have much in common except a similar-sounding name. However, such a course gives tremendous opportunities, since it enables a student to follow the supply chain from raw material to finished product – at a time when a shift of the employment of chemical engineers from traditional bulk chemical positions to companies producing advanced products is observed.

From a CDIO perspective, it provides an excellent opportunity for a comprehensive implementation of CDIO principles in a single course. Already the traditional chemical engineering "capstone" design course has for decades embodied many of the essential features of CDIO (for example the focus on group work, development of interpersonal skills, the open-ended nature of design problems).

Another aspect of CDIO that is implemented in the course is standard 3 – Integrated Curriculum - meaning that the course projects draw on competences provided in other subjects the students are taking in parallel with Process and Product Design. This in turn has the benefit of requiring increased, broader teacher competence and forces teachers in different disciplines to communicate - which ties in with Standard 9 – Enhancement of Faculty CDIO skills.

KEYWORDS

Process and Product Design, Teamwork, Integrated Curriculum, Integrated Learning Experience.

INTRODUCTION AND BACKGROUND

The Technical University of Denmark (DTU) educates engineers in two separate streams of education, one stream being the Bachelor of Engineering (B.Eng.) which is a 3½ year program that qualifies the student to go directly into industry [1]. DTU's management decided to introduce CDIO as the engineering context for all its B.Eng. studies, and implementation started in 2008 with first year courses. In 2011 the process will be complete.

In the Department of Chemical and Biochemical Engineering, the 3½ years (7 semesters) are arranged such that the 5th semester is where the students undergo practical engineering

training in a company, and the 7th semester is devoted to the final research project. Large design/build projects are undertaken in the 1st and 4th semester [1].

Process and Product Design is given in the 6th semester, sandwiched between practical training and the final project. It is a large (10 ECTS points) course and is given simultaneously with Process Control and Reaction Kinetics (each 5 ECTS points). These courses thus offer the last opportunity for instructional education before the students begin working (some students choose to continue their education with an M.Sc. in Engineering, which they may do after undertaking certain "bridging" courses). Furthermore, the course Process and Product Design is designated as the "project course" for the semester, which means that the final course evaluation is based mainly on project work which must also include elements from the courses Process Control and Reaction Kinetics.

Product design as a discipline has been promoted very strongly in the department recently, with the result that (in addition to Process and Product Design) three courses are offered:

28110 Chemical and biochemical product analysis (5 ECTS points)
28410 Design and test your own product ideas (5 ECTS points)
28310 Chemical and Biochemical Product Design (10 ECTS points)

This last course is offered to M.Sc. students and is quite intensive, at 10 ECTS points, where a typical one-semester course is 5 ECTS points. In addition two DTU faculty members (Kiil and Vigild) are co-authors of a recently published textbook on the subject [2]. This book is also used as a textbook for 28156 Process and Product Design.

Process design as a subject on its own is taught to M.Sc. students:

28350 Process Design: Principles and Methods (10 ECTS points)

Again, this 10 ECTS point course is quite intensive. Process design was previously offered alone as a 7.5 ECTS points course to B.Eng. students in the 4th semester. The decision was then made from the Spring semester 2008 to move it to the 6th semester and combine it with product design to create the 10 ECTS point course 28156 Process and Product Design. In terms of weighting, the course is about 60% process and 40% product design. Two teachers are used on the course, one for product and one for process. Presently, product design is given first.

Both teachers on the initial course had taught their respective discipline (product or process design) as a full semester course. This gave challenges, since it was not possible to give each component of the course as given before – both sections needed to be cut down substantially (yet judiciously) in order to give meaningful coverage of the topics in much less time. It also meant that finding the connection between the disciplines was going to be tricky. Table 1 lists some of the characteristic differences between the two disciplines.

Table 1
Characteristics and differences between product and process design

Product Design	**Process Design**
Students typically choose a product to design	Students are told what process to design
Open-ended problem – wide choice of product and design method	Well-defined problem, limited scope for deviation from a defined solution
Best carried out with an interdisciplinary approach	Based mostly on chemical engineering fundamentals

The essential difference between the two is that process design is a "typical" chemical engineering subject, based on the fundamental disciplines students have learned (or are

taking simultaneously). Product design, on the other hand, is much more open-ended – for example students are usually allowed to choose their own product to design. This makes a relevant process design much more challenging to find, especially since in process design students are usually given a single (usually bulk) chemical for which they must design a process.

In subsequent sections we discuss the structure and content of the course as it is now, and then discuss what we have learnt in the three semesters that it has been offered – what went well, what went less well, how can we improve the course and (not least) what additional demands such a course places on the teachers involved.

STRUCTURE AND CONTENT OF THE COURSE

The course is run over 13 weeks. Since it is a 10 ECTS point course, 2 modules are assigned to the course per week. In practice this means that the course runs from 9 am to 5 pm every Wednesday, with an hour's lunch break. Teachers have freedom as to how they utilize this time, but it is usually divided between short lectures, in-class problem-solving sessions, group exercises and project work. Especially in the process design part, extensive use is made of the "Databar" – a classroom where the teacher and each student have a computer in front of them. Problems and projects which require use of software are carried out here. The students can be guided through an exercise since the teacher's actions are projected onto a screen. There have been 30-40 students in the course over the three semesters it has been offered.

The first 5 weeks are devoted to product design and the last 8 weeks to process design. Two group projects (P1 and P2, with 4-5 members per group) are performed in product design and three projects are performed for process design. In process design, the first and third projects (P3 and P5) are performed in groups of 4-5 and the second project (P4) is performed individually. Project P2 follows on from P1. Similarly project P4 follows on from P3 and P5 from P3 and P4. For example, in process design, the students have had to design a plant that produces 100 000 tons per year of cumene. In project P3 the overall process flowsheet is defined and the students identify that the key unit operations are a reactor, several heating and cooling units, and 2 distillation columns for separation of the various products and reactants. Based on this (approved) flowsheet the students divide the individual units among themselves and then do a detailed design of these units individually. Project P5 then brings the whole process together again and the students perform an economic analysis of the process in the groups.

Projects P1 and P2 account for 40% of the final grade, Projects P3-P5 account for 50% of the final grade and an individual oral examinations accounts for the remaining 10%.

Product design follows the text by Wesselingh et al. [2] and divides topics into various categories, each illustrated with an example – table 2 shows the major topics.

Table 2
Steps in product design with an illustrative example

Steps in product design	Illustrative example
Analyse the situation	The design of an improved detergent requires an analysis of the process of washing clothes
Find needs	The design of double-glazed windows for sloping roofs needs improvement – interviewing customers is an important step. It turns out that "fogging" due to condensation of water between the glass

	layers is a major problem which occurs after years of use.
Specify the product	Toothpaste requires quantitative specification in terms of aroma, viscosity (can it be squeezed out of the tube), yield stress (does it stay on the brush), price, storage temperature, abrasiveness, etc.
Create concepts	Marine organisms stick to large ships and cause an increase in fuel consumption due to increased drag. Considering the solution to this involves many alternatives – should we add a biocide? Or use a pipeline instead of a ship?
Select a concept	Considering the various options available to diabetes sufferers led to the Novopen™ – a pen-shaped injector with a fixed dose of insulin.
Formulate the product	The correct formulation of a powder coating for refrigerators gives the right balance between “flow” and “reaction”
Flowsheet the process	Scale-up and optimization of production of herbicide capsules is aided by a flowsheet where track can be kept of materials, energy inputs etc.

In the initial stages of the course, students were free to select (almost) any project they liked. This is very time-consuming and subsequently product ideas were proposed, and the number was limited to 33 (only!). The aim of the projects was to understand (and possibly improve on) how many everyday items worked. Examples include tissues, towels, batteries, paintbrushes, centrifuges, dishwashers, rainproof fabrics, dough-rollers. The emphasis on product design in our context is thus on the application of chemical engineering skills and disciplines (mass and heat transfer, chemical reaction, thermodynamics, surface chemistry). While this turned out to be a big challenge for the students, it fits in exactly with the aims of CDIO.

Process design follows the text by Duncan and Reimer [3]. The students are introduced to the design process by way of examples from very different types of processes. These include processes for the production of ammonia, the purification of heptane, production of electronics grade silicon, generation of electricity from fuel cells, desulfurization of natural gas, desalination of seawater, refrigeration. The emphasis is on the features common to these processes. Detailed design of certain common unit operations is covered (distillation columns, heat exchangers). Reactor design is covered in the course on reaction kinetics which runs concurrently. Economic and environmental aspects of process design are also covered.

For the projects, the students have (up until now) been given a specific bulk chemical (cumene) and told that they need to design a process to make 100 000 tons of it per year. There are three projects in process design – the first and third are solved in groups and the second individually. However each project depends on the one before it, so collaboration (or at least communication) is required even in the individual design. During the course extensive use is made of the commercial design program PRO/II [4].

EXPERIENCES, LESSONS LEARNED AND THE WAY AHEAD

The course has had a mixed reception so far. Below is a selection of things that went well or less well based on the course evaluations.

What students liked

The interactive way the course is taught;
The use of real-life software tools;
The teaching method of lectures broken with problem-solving sessions;
Working in groups;
Focus on project work;

What students liked less

Some students felt that the day became too long – especially in process design;
Some felt that the product design was too open-ended;
The connection between the two disciplines was lacking;
Applying chemical engineering tools to products from daily life was a challenge for many students.

In future, more emphasis will be placed on showing the connection between product and process design. Some suggestions for this are discussed below.

Connections between product and process design

Flowsheeting in product and process design

One of the latter stages in product design (as discussed above) is to outline a process for actually making your product (possibly on a scale larger than laboratory). This usually takes the form of a block diagram with each block representing a conceptual step which needs to be performed. This may or may not be an actual physical step (unit operation) in the process. Figure 1 illustrates a flowsheet for the production of polymer capsules containing a liquid herbicide [5].

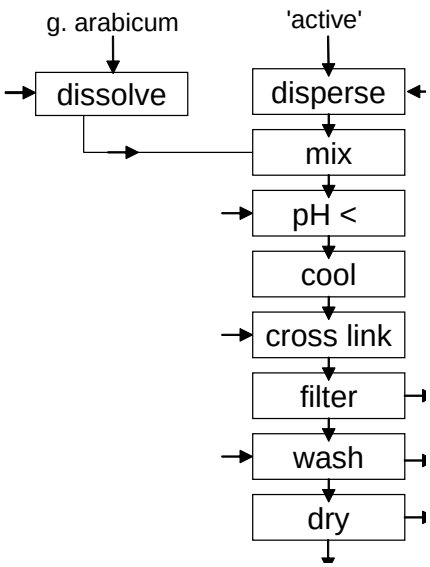

Figure 1. Flowsheet for production of polymer capsules containing a liquid herbicide

A process design flowsheet for the same product would contain actual unit operations for performing the desired transformations (a mixer for creating a dispersion of herbicide

droplets in water, a reactor for pH adjustment, a heat exchanger for cooling, an extraction column for washing, a filter and a dryer, for example). Such a process flowsheet would like something like figure 2 [6].

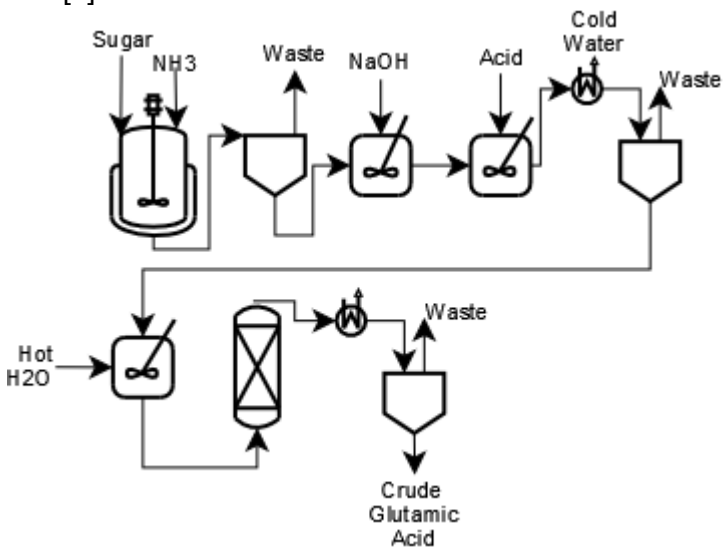

Figure 2. Process flowsheet for the production of glutamic acid.

The product is different here, but many of the unit operations are the same (reaction, mixing, cooling, reaction, decolorifying, cooling and crystallization. The key here is that each of these units represents actual physical process plant. It would be helpful in the course to make and emphasize the connection between the product and process flowsheets.

Relating the product to the process

Examples in Wesselingh et al. [2] and Ng et al. [7] discuss catalysts for the production of methanol and sulphuric acid. In catalysis, it is not only the chemical formula of the catalyst that plays a role, but also the shape of the catalyst. For example, a hollow cylinder has a higher surface to volume ratio than a solid sphere, while also reducing pressure drop on the reactor. Applying chemical engineering principles should enable the engineer to relate the overall conversion (and pressure drop) in a given reactor to catalyst size and shape. In designing a complete process for the manufacture of methanol, this will have a significant effect on all the other units in the plant – for example if the conversion is low in the reactor, more unreacted reactants will need to be separated and recycled, resulting in larger separation columns.

Another example of this connection could be the design of a pharmaceutical plant. The plant produces not only an active pharmaceutical ingredient at the right purity (process design) but also a finished product which must have the correct profile with respect to delivery (e.g. a slow-release capsule – product design).

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Assessment of CDIO skills in the context of the Civil Engineering course in the School of Architecture and the Built Environment at Singapore Polytechnic

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ABSTRACT

The division of Civil Engineering in School of Architecture and the Built Environment (ABE) at Singapore Polytechnic started to adopt the CDIO initiative in May 2007. A CDIO design team was formed in July 2007 to study, design and integrate this initiative into two diploma programmes – Diploma in Civil Engineering & Management (DCEM) and Diploma in Environmental Management & Water Technology (DEWT). From literature reviews of past CDIO conference papers and articles, the team affirms that many of these engineering skills are already emphasized in the course. It is timely to recognise the gaps, document them in CDIO terminology and integrate them into the curriculum. One gap is that assessments of these skills are not clearly linked to learning outcomes and documented. The CDIO syllabus has thus provided an overall framework for developing an integrated curriculum and a guide to address our needs for the training of civil and environmental engineering technologists.

This paper describes the process of outcome assessment using rubrics to assess CDIO skills (engineering skills) of DCEM and DEWT students at Singapore Polytechnic. The resultant assessment template aims to:

a) Assess students engineering skills using rubrics linking to a learning outcome
b) Help lecturers assess students CDIO skills within their respective modules

KEYWORDS

Civil Engineering, CDIO, assessment, rubrics, CDIO skills, learning outcomes.

INTRODUCTION

The CDIO (Conceive-Design-Implement-Operation) initiative was brought into Civil Engineering division, School of Architecture and the Built Environment, two years ago. A design team was formed and found that many of the CDIO skills in the CDIO syllabus were already implemented in the course but were not clearly documented in the module syllabus [1, p257]. CDIO skills related to disciplinary or technical knowledge are not covered in this paper as these are well covered in the existing syllabuses. The other CDIO skills are personal and interpersonal skills (section 2 and 3 of CDIO syllabus), and product, process, and system building skills (section 4 of CDIO syllabus). The CDIO initiative has provided a

good framework to develop and manage the integration of these skills into the existing diploma courses.

Staff and industry surveys were carried out to determine the expected proficiency level for each CDIO skill for fresh diploma graduates. Then a survey of the two diploma courses were carried out among staff to identify where we introduce, teach and use (ITU table) each of these skills. With this ITU table, an overall picture of CDIO skills for each course can be seen. Where there are gaps and overlaps, there are more apparent. From this exercise, it was discovered that assessments of CDIO skills are not linked to the module learning outcomes of the existing syllabuses. The challenge is to develop an outcome assessment to assess these skills and to reflect the integration of CDIO skills into the existing module syllabus.

INTEGRATING CDIO SKILLS INTO THE SYLLABUS

The CDIO initiative has provided a good student learning assessment process for the development and continuous improvement to teaching and learning [1, p155]. This process has guided us in deriving a model (Figure 1) which provides an approach to outcome assessment based on the CDIO syllabus and stakeholders (industries and lecturers) feedback.

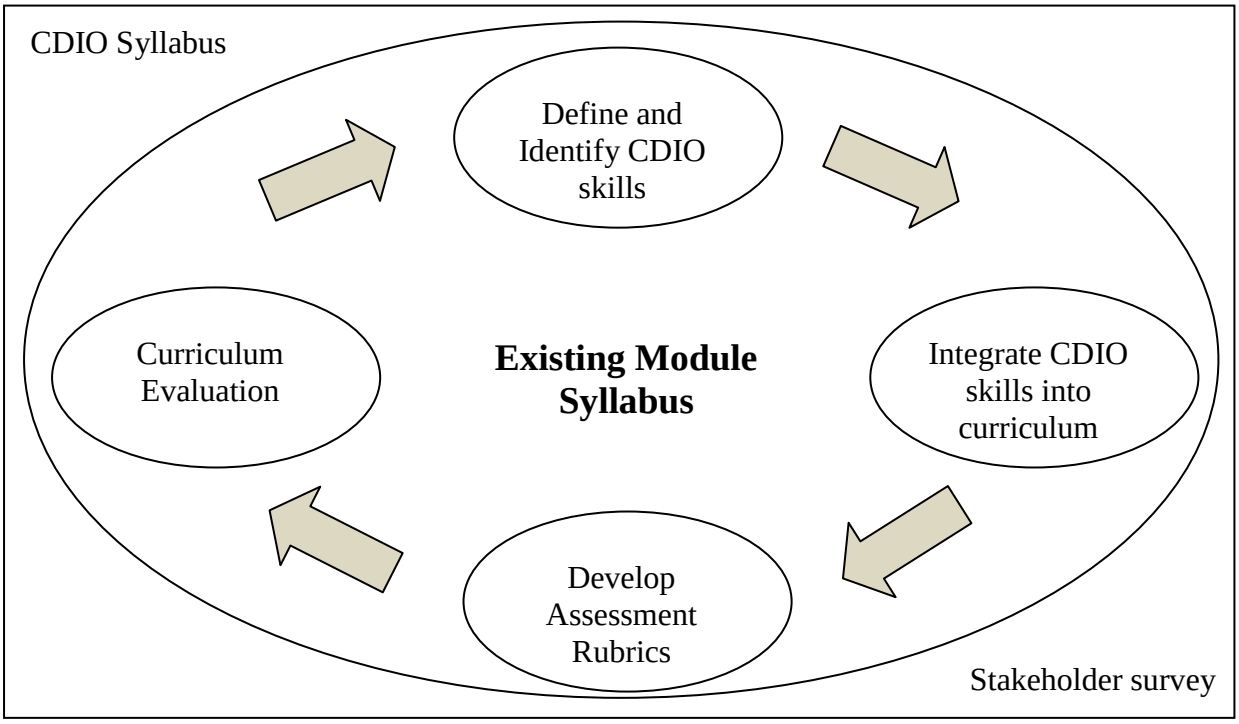


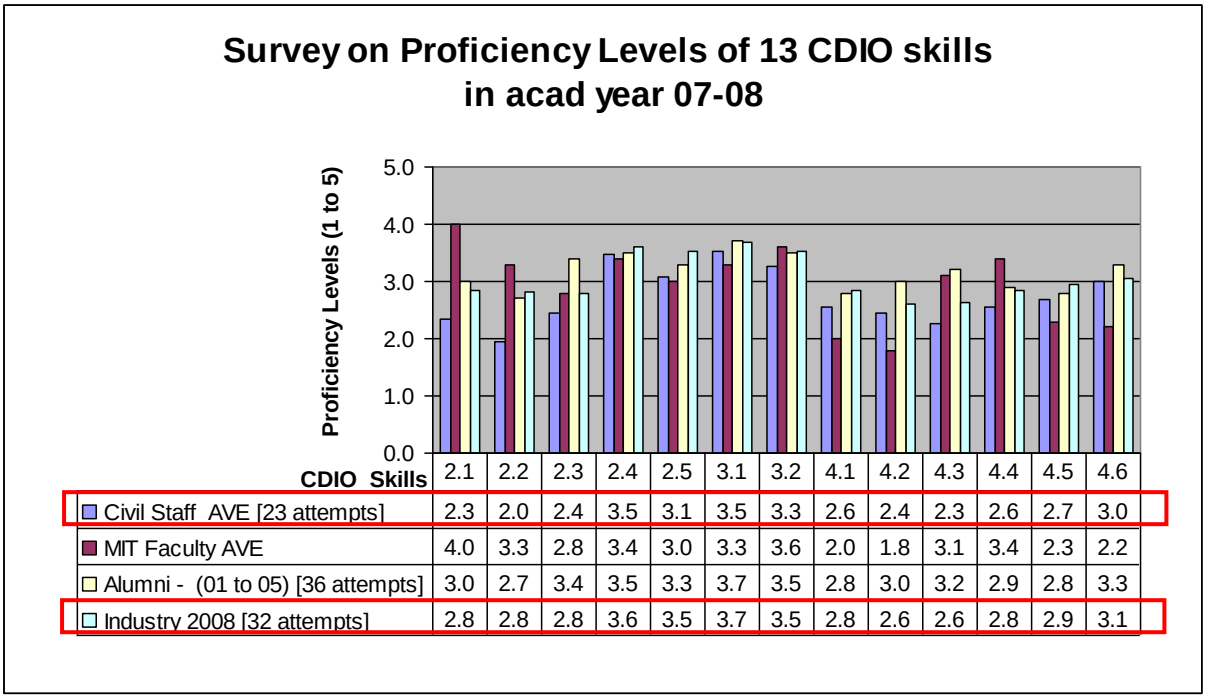
Figure 1 CDIO Skills – Outcome Assessment Model

The model in figure 1 also shows the process of integrating CDIO syllabus into our module syllabus to curriculum evaluation in four stages.

Stage 1 – Define and Identify CDIO skills

The process starts with defining and identifying CDIO skills for technologists. The CDIO design team distinguished between CDIO skills of civil engineers and civil engineering technologists. In the Singapore context, the technologists are middle-level managers in organisations. They work as technical officers, administrative officers, supervisors, assistant project managers, draftspersons, assistant engineers and sales executives upon graduation. A higher expectation of CDIO skills is in implementation and operation rather that concept and design.

Figure 2 shows the proficiency levels of 13 CDIO skills expected from Civil Engineering staff, alumni and industry in the first stakeholder survey conducted between 2007 and 2008. The results are compared with proficiency levels expected of MIT degree graduates by MIT faculty [2].



CDIO Skills	2.1	2.2	2.3	2.4	2.5	3.1	3.2	4.1	4.2	4.3	4.4	4.5	4.6
Civil Staff AVE [23 attempts]	2.3	2.0	2.4	3.5	3.1	3.5	3.3	2.6	2.4	2.3	2.6	2.7	3.0
MIT Faculty AVE	4.0	3.3	2.8	3.4	3.0	3.3	3.6	2.0	1.8	3.1	3.4	2.3	2.2
Alumni - (01 to 05) [36 attempts]	3.0	2.7	3.4	3.5	3.3	3.7	3.5	2.8	3.0	3.2	2.9	2.8	3.3
Industry 2008 [32 attempts]	2.8	2.8	2.8	3.6	3.5	3.7	3.5	2.8	2.6	2.6	2.8	2.9	3.1

Figure 2 Expected Proficiency Levels from Stakeholder Survey

The results show that the proficiency levels expected of civil engineering technologists match what are expected for them as compared to proficiency levels expected of engineers from universities, such as MIT. The plan is to conduct the industry survey annually to fine tune the expected proficiency levels.

Having defined the proficiency levels expected of civil engineering technologists, the expected skills that are covered or need to be covered are entered in the ITU table. The design team recognizes that capstone projects provide the context for development of many of the CDIO skills. Table 1 is, an ITU table showing some modules and capstone projects for year 1 of the DCEM course

Table 1
ITU Table for DCEM course

Technical Knowledge			CDIO Skill Sets												
1			2					3		4					
s/n	Module Code	Module Name	Personal and Professional Skills and Attributes					Interpersonal Skills: Teamwork & Communication		Conceiving, Designing, Implementing and Operating Systems in the Enterprise and Societal Context					
	Year 1 - Year-long modules		2.1	2.2	2.3	2.4	2.5	3.1	3.2	4.1	4.2	4.3	4.4	4.5	4.6
1	BE 750Y	CAD Studio	I			IU		U	U						
2	BE 751Y	Building Technology & Materials			T	U	I	U	U	T		I	I	U	I
3	BE 752Y	Structural Mechanics	T	U		U				Intro: Marina Barrage; Capstone Prj: Trellis, Bungalow,					
	Year 1 - Semester 1 modules														
4	MS 3440	Foundation Physics													
5	SP 0101	Character Development					T	U							
	Year 1 - Semester 2 modules														
6	BE 7500	Internet Technology	I		T	U									
7	SP0102	Innovation, Design & Enterprise in Action (IDEA)	IT					U	U						
8		GEM 1													

The module team identifies and discusses the key skills that are to be included in the module. Only skills which are indicated as "T" will be taught and assessed while "I" means skills will be introduced but not assessed and "U" means skills taught in other module but may or may not be assessed [1,p87].

Stage 2 – Integrate CDIO Skills into Curriculum

Once the CDIO skills are identified, they are integrated into the curriculum by breaking down into the knowledge, skill and attitude (KSA table) component with an intended weightage distributed to each existing means of assessment as shown in Table 2. In the existing syllabus, various means of assessment are defined, such as "CA" for Class assignment;"LAB" for Lab work"; "TST" for class test or "Exam".

Table 2
KSA Table

Breakdown of Knowledge, Skill and Attitudes Weightage						
	Weightage					
	CA1	CA2	LAB1	TST1	TST2	TST3
CDIO Skills from ITU table	15%	25%	15%	15%	20%	10%
1.0 Technical skills	5%	10%	5%	15%	20%	10%
2.1 Engineering Reasoning & Problem Solving	Introduce but not assess					
2.4 Personal skills & attitudes	5%	5%	5%			
3.1 Teamwork		5%				
3.2 Communication - oral		5%				
Communication - graphical	5%		5%			

The weightages in the KSA table are limited to 5% minimum in order to be considered significant for assessment. These weightages are then transferred to the table of specification (Table 3a) where first level of disciplinary knowledge learning outcomes are defined and categorised into knowledge (K), comprehension (C), application (A) and higher than application levels (HA) of Bloom's Taxonomy in the cognitive domain. After ~~much~~ literature review on Bloom's taxonomy [2] and comparison with CDIO syllabus, the team developed a correspondence between the CDIO syllabus (technical knowledge + CDIO skills) and the Bloom's Taxonomy as shown in Table 3b.

Table 3a
Existing Table of Assessment

Topics		Abilities (%)			Total (%)
		K	C	A/HA	
A	Introduction to environmental management and water technology	6	1	0	7
B	Organizational structure and management processes	4	2	0	6
C	Piping and valves in water conveyance	8	4	2	14
D	reading and understanding P&ID	10	8	2	20
E	Water treatment process	15	10	8	33
F	Engineering Calculation, Material and Energy Balance	10	6	4	20
	Total	53	31	16	100
Infusion of SP Core Values: Students take charge of their learning though coaching by the module lecturer. Self-discipline, Personal Integrity, Care & Concern, Openness, Responsibility and Excellence are highlighted during the lectures, tutorials and laboratory works. Marks are given for good housekeeping practices during the laboratory sessions.					

Table 3b
New Table of Assessment

Bloom CDIO skill 2 to 4

	Abilities(%)									Total
CDIO framework	1.0		2.1-2.3	*2.4	*2.5	3.1	3.2	4.5	4.6	
Bloom's Taxonomy	Cognitive Domain			Affective Domain		-	-	(only for module with capstone		
Topics	K	C	A/HA							
1. Introduction to environmental management and water technology	0	0	0		5	5				10
2. Organizational structure and management processes	0	0	0							
3. Piping and valves in water conveyance	5	0	0	10			10	10	5	80
4. Reading and understanding P&ID	10	5	0							
5. Water treatment process	15	10	0							
6. Engineering Calculation, Material and Energy Balance	5	5	0							10
Total	35	20	0	10	5	5	10	10	5	100

Stage 3 – Develop Assessment Rubrics

Rubrics and rating scales are used to assess learning outcome by observing student's performance in a task [1, p158]. At this stage, a list of rubrics is developed for each intended CDIO skills corresponding to the expected proficiency level from the stakeholder survey. Table 4 below shows an example of technical content and its assessment criteria and the rubrics for Personal skills & attitudes derived with the module team. These rubrics were used in the various assessment methods in table 5 to determine student performance.

The weightage column reflects the marks based on the percentage contribution indicated in the KSA table. For example, in table 3, the technical content contributes 10% to the total percentage of 25% for CA2 will be converted to 40 marks (100/25% x 10%) out of 100 marks for this mini-project task.

Table 4
Assessment Rubrics

Assessment Rubric for Mini Project - CA2 (25%)		
	Criteria	Weightage 100
	1.0 Technical Content	40
	- Model has appropriate structure components and sizes	
	- shows sufficient development with material assignment	
	- Demonstrated application of knowledge acquired in class	
	2.4 Personal skills & attitudes	20
1	Initiative and willing to take risks	
2	Worked and learned independently	
3	Choose logical solutions	
4	Creative thinking (execute the process of invention)	

Table 5
Assessment Methods

	Assessment Methods for CDIO skills				
	1	2	3	4	5
	Written or computer practical questions (e.g. tests , exams)	Performance ratings (e.g. tutorial, lab)	Product reviews (e.g. reports, presentation)	Journals and portfolios	self-report instruments (e.g reflection)
2.1 Engineering Reasoning and Problem Solving			√	√	
2.4 Personal Skills and Attitudes			√	√	√
3.2 Graphical Communication	√	√	√		

Table 6 shows the template created to help lecturer in administering each student assessment records. Under each skill, students are given a rating based on a scale of 1 to 5 which matches the proficiency level rating scale [1,65] used in stakeholder survey, to reflect the student performance.

Table 6
Assessment Template at Work

			1-Poor 2-Fair 3-Good 4-Very Good 5-Excellent						
			CA1 (20%)						
			CDIO project model (IO), final						
			skill	mark	skill	mark	skill	mark	Total
s/n	Adm No.	Name	2.4	25	4.5	50	4.6	25	100
1			1	5	3	30	5	25	60
2				0		0		0	0
3				0		0		0	0

Rating explanation:
1- Poor : to have experienced or been exposed to
2- Fair : to be able to participate in and contribute to
3- Good : to be able to understand and explain
4- Very Good : to be skilled in the practice or implementation of
5- Excellent : to be able to lead or innovate in

Stage 4 – Curriculum Evaluation

This stage, which is also the most important in the process, is the use of assessment results to improve teaching and learning and the curriculum as a whole [1,162]. As not all of our modules have implemented stage 3 in their assessment, ratings of CDIO skill for the course cannot be obtained. However, at module level, we have obtained the average rating of 2 groups (47 students) for skill 2.4, 3.1 and 3.2 to compare with the proficiency level rating we obtained from our stakeholder survey as an example.

Table 7
Module Evaluation

CDIO skills	Average rating of 47 students	Average Expected Proficiency Level from Stakeholders
2.4	3.46	3.55
3.1	3.24	3.6
3.2	3.71	3.4

Table 7 shows the average rating of student performance in a mini-project activity of a module comparing with the expected rating from stakeholder survey. The comparison result shows a close convergence indicating how well the intended learning outcomes (i.e. rubrics) of that skill are being achieved. However, this is not conclusive until more data are collected from the other 4 groups doing this same module before we can make use of it to adjust the module curriculum where needed. Similarly, for course curriculum adjustment more data has to be collected from other modules in the course.

CONCLUSION

CDIO framework has helped to develop and manage curriculum integration with CDIO skills of two diploma courses. The approach and guidelines outlined in CDIO standard 11 is a good reference to develop the process of outcome assessment using rubrics. Staff are shown through in-house training how to adopt the assessment approach presented in this paper. The rubric will be used for the final year students in the third year of implementation.

At the stage 3 – Develop Assessment Rubric, we recognize that it would not be realistic to set the learning outcomes of a year 1 module to correspond to the expected proficiency level obtained from the stakeholder survey. It would be more realistic to achieve the expected proficiency level progressively over the three years of study in the diploma course. We have started to work on defining the three levels of expected proficiency levels for each year of study in both diploma courses. We hope to pitch the different years of learning outcomes and expectations of CDIO skills to the right level.

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Business development and entrepreneurship: Combining engineering with the social sciences

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ABSTRACT

Demand in the business sector for highly skilled and multitalented new graduates is ever increasing. Engineers are more and more expected to not only to be familiar with the technical aspects of their work but also with financial, marketing and legal aspects as well as being skilled in leadership and communication. In this paper we describe the bachelors program, *Business development and entrepreneurship in the building sector (the AE programme).* The program aims at providing the housing- and construction sector with graduates who possess a broad view of the issues and tasks that face the sector. The programme is highly adapted to the needs of the business sector and is planned and carried out in close collaboration with the industry. The program combines studies in engineering with cross disciplinary mix of among others economics and finance, marketing, business development, project management, leadership and the behavioural sciences. The program is also open to students without a traditional educational background in the natural sciences or engineering so as broadening the recruitment base with the purpose of attracting more diverse talent into the area of engineering and business development.

KEYWORDS

Engineering education, social sciences, business development, cross disciplinary education

INTRODUCTION

Traditionally, engineering skills and skills in social sciences have been homed at separately. Engineering being taught at technical universities while social sciences such as economics an management being taught at business schools. While it's not uncommon that engineering graduates also pursue a degree in management or economics, combining engineering and social science skills to such extent that is done in a bachelors program such as the AE-program is to our knowledge relatively novel. There is however a need, both within the academic sphere as well as in the business sector, of combining these skills. For instance, technical solutions, say to environmental problems, will not be successful if individuals/customers do not see or understand the value with implementing them [1] [2]. This stresses the importance of understanding the marketing and behavioural aspects of successful adaptation and implementation of new technology. In research regarding the

abatement of environmental problems there is an increasing emphasis on multi-disciplinary research, with input from engineering, psychology, law, sociology, political science etc. An understanding of the multi faceted nature of today's problems and issues that will confront engineers is therefore vital [3].

Understanding what constitutes effective leadership and project management is yet another skill that is becoming increasingly important. In the management literature there has long been an emphasis on the "soft skills" relating to management. These include for instance leadership skills, motivation, and decision making skills. Leadership for one is an area that is attracting an ever increasing attention within construction management research [4]. It has furthermore been claimed that an understanding of social sciences gives engineers to go beyond the pure technical aspects of a project and thus tap into the decision making processes within projects [5]. Thus, having a combination of strong management and engineering skills provides students with the possibility to take on roles both in engineering as well as in management and act as links between the two areas within industrial organizations.

Being exposed to social sciences studies also gives students a better appreciation and understanding of how engineering fits into a larger societal context [6]. An understanding that is crucial especially with respect to the sustainability issues touched upon above.

Another important issue concerns making engineering education more attractive to prospective students. In Sweden there has over a period of time been a decline in the attractiveness of engineering and science studies. By increasing the amount of social sciences content, students who would have otherwise chose to pursue a business or economics education may be inclined to purse an engineering exam [7].

In the next sections we will outline the AE-program describing its background and history, the students, the market for the program, and where the students go after graduation.

BACKGROUND

The bachelor programme in building and civil engineering at Chalmers was a very traditional engineering programme with almost 90% engineering and mathematics and with small elements of for instance economy. This was the normal structure for bachelor programmes in engineering at Chalmers and at other Swedish universities.

After graduating, the new engineers started a career that after rather short time gave them a position as managers. In the construction industry, a new engineer starts as an assistant manager and after some time he/she can be responsible for a site with a project worth several millions SEK. Those who went to different consultants started as members in a project group, but often became responsible for the group after a few years. All of them have had good knowledge in engineering and have been well prepared for the technical part of the work. Similar for all of them was that they lacked experience of leadership and related issues. Leadership was often seen as something that was better learned when in the working situation.

Some different things happening at the same time started the thoughts of doing something new. There had for a long time been discussions about giving leadership courses or not, but the meanings differed. The main meaning had been that this was more efficient taught when in the management situation, but at that time the demand was growing. There was also a change in the construction industry. Some of the companies had started with a more total approach, developing projects themselves. They looked for older buildings ore some land, and worked with the possibilities to develop it, to give it a higher value, then build, rent out

and sell to some real estate company that is better at the property management. In this way they could take advantage of the increasing value from the total process.

There were also discussions about the future lack of students with a background from natural science in secondary school. Some smaller universities had already big problems recruiting students, and the number of students with natural science studies was decreasing because of reduced interest for studies in that area. The engineering programmes also had to compete with medicine and other popular programmes.

The decision was to try to do something new, which could be an alternative to the traditional programme, and which could meet the changing demands of construction industry as well as attracting students not traditionally inclined to pursue an engineering education. A mix of students with different backgrounds could give new values to the group, as they join the group with different experiences. But the ambitions were to keep the traditional programme parallel to the new one, and give the students a choice.

THE AE PROGRAMME

The BSC programme Business development and entrepreneurship for the construction industry was created. The new ideas in the construction industry were taken as a starting point. There was a need for persons that could act as “a spider in the net” and be able to discuss with all involved experts. They should be able to manage the project and get it to a successful completion. Without being able to do the detailed structural design themselves, they should get the right language and an understanding and be able to discuss the solutions with the experts.

Comparing to the traditional programme, the amount of mathematics and structural design was reduced. The engineering parts were also concentrated on buildings instead of covering the whole construction area. This gave free space for the softer parts of the programme, but the concentration gave still enough deep in the engineering parts that were studied. This was the important change that made it possible to recruit students without the background from natural science, as mentioned before.

There is a strand of social sciences through the three years. It starts already the first semester with Behavioural science. This is a basic course that gives the ground for the following studies. It is an important background (but uncommon) also for some of the engineering studies, such as building and urban planning and for the decisions when designing an apartment or a city area. It is followed by project management studies in the second year and leadership and management studies in the third year.

Economy is also as a strand from the first semester, with more commercial and financial aspects during the second and third year. They are accompanied by Business law, Construction contracts and Marketing. Then the necessary knowledge for an entrepreneur is formed, and the different parts are integrated in the course Business development in the last year, where the students have to work with a business idea of their own, and an idea for which they already have researched the market in the marketing course.

The forth semester starts with Project and commercial management, where the students for the first time have to combine the knowledge from almost all earlier studies in a feasibility project. They have to propose a solution of a building demand and decide what to do, how to do it, how to finance it, calculate the risks and present the results. This has to be conducted in rather large groups, so they have to practise what they have learnt about working in groups. One example of a project is to give a solution for a new office building, which could be the new entrance to the university from the east side.

As important as the different courses that form the programme is the way of working. The students work in project groups in many of the courses. There is always at least one project running in every period trough the three years. The projects are more and more complex as the students become more experienced. The students found it frustrating in the beginning of the first project, to realise that the necessary information wasn't available within university. They had to find industry contacts to be able to solve the problem. This has then been the normal of working and it shows that they work with questions that are actual and relevant for their future career.

The programme emphasise the communication abilities in both Swedish and English, and to support this there are two courses in language and communication through the three years, with their own credits to make them visible in the certificate. But the different lecturers cooperate, so that the assessment in the engineering course is at the same time an assessment in the parallel communication course. The lecturer in the engineering subject and the lecturer in language and communication often meet the students together, present the projects together and tutor the students together as well as assess them together.

THE STUDENTS

The programme is attractive, and high grades are necessary in order to gain admission. There is a good mix of students with different background and different experiences. Many of them have worked a few years or done other things for one or two years, experiences that are good to relate to in the project work. Discussions with the students have shown that most of them applied for the programme because of the mix of engineering and social sciences and the comprehensive view. It was rather clear that many of them shouldn't have applied for a traditional engineering programme. As a group, they are open-minded, communicative and supportive. The percentage of female student is also rather uncommon for an engineering programme. It has been steadily growing and in 2008 female students were in a majority.

THE MARKET

When the ides were outlined, some key companies were visited. These were contractors, consultants and real estate companies. The planned program was presented for high ranking executives within the companies. Almost all of them were positive to the plan. One big company was against, but have since come aboard when seeing the qualifications of the graduates, and now they also employ a larger number of AE students.

Only the student representatives were against, when the proposal for a new programme was discussed in the board at the university. The reason for the opposition is not altogether clear. However, one can suspect that students in the traditional civil engineering programs thought the AE programme to be somewhat alien to Chalmers As a result the students in the programme had problems with their membership in the student union during the first two years.

WORK AFTER GRADUATING

For the first years, the students had problems with finding a job. The main reason for that was that the programme was too unknown. This has changed now, and the graduates are rather attractive. It is interesting that they have become attractive as site managers, this was not anticipated. The skills they get are seen as important for that role. It is obvious that the reduction of engineering skills is well balanced by the social sciences approach. The interest in the management role is increasing during the three years of study, and being a site manager is a complex role. It is like being responsible for a rather big manufacturing company, when you compare to budget, number of employees etc. But you can also find them as project managers in business development roles in real estate companies or

construction companies. Another interesting observation is that the smaller or medium sized companies were faster in adopting the new type of engineers. This is probably a result of the smaller companies need for people with an overall knowledge, and the helicopter view, while the bigger companies work with more specialised staff.

CONCLUSIONS

In this paper we have outlined the rationale behind and the content of the AE-programme. The concept being combining behavioural science, economics, marketing, management and as such providing the students with a solid as well as diverse education thus enabling them to face a changing and developing construction industry. By seeking input from the construction and housing sector from the outset of the programme, as well as maintaining a close cooperation with the sector the programme manages to keep up with changing demands. The programme, with its strong emphasis on the social sciences, also attract substantial numbers of engineering students from other programs who wishes to enrol its social science courses,

The value of an education based on a truly cross-disciplinary basis is extensive. Not only does it provide students with a diverse array of knowledge giving them the tools to work in cross disciplinary business environments, but also provides them with an understanding of the multi-facetted nature of the issues facing today's society, one being the challenge of creating sustainable environments. This being an area in where the construction industry will meet major challenges in the near future.

Finally, we also strongly believe in the value of an early exposure of the social sciences within engineering educations in that it enables them to better integrate this knowledge. As noted above, the students in the AE-programme enrol in a behavioural science class in their first semester of study. Doing so, we believe the programme provides the students with a better possibility to integrating knowledge from the social sciences with traditional engineering subjects as well foster a proficiency in communication skills.

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CDIO APPROACH FOR REAL−TIME EXPERIENTIAL LEARNING OF LARGE STRUCTURES

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ABSTRACT

The traditional approach of teaching structural analysis and design modules has several shortcomings. This paper describes and illustrates how real world structural engineering can be brought into campus. A large structure was conceived, designed, and implemented in the existing workshop space. Strain gauges are installed to show how the parts of the large structure behave under different loading conditions. In the context of Conceiving, Designing, Implementing, and Operating (CDIO) framework, a capstone project was designed for students to do active and real time experiential learning of large structures. In addition, other student-centred real-time prototype experimental activities have been developed and planned for implementation in the "Structural Learning Space." The space now allows not only for normal use by students to optimize the utilization of the workshop space but also for staff to conduct lectures, tutorials, and experiments of structural engineering modules in an integrated manner.

KEYWORDS

Conceiving, Designing, Implementing and Operating, real time prototype experiments

INTRODUCTION

Structural analysis and design are the core modules of Diploma in Civil and Structural Engineering (DCSE) from the School of Architecture and the Built Environment, Singapore Polytechnic. However, these modules are perceived by DCSE students as "abstract", "dry" and "hard to visualise". Students traditionally have difficulties in grasping the concepts of structural behaviour. They tend to adopt learning by concentrating on manipulation of equations and memorizing particular solutions which obscures the underlying important concepts and principles. The reasons are mainly because structural engineering modules require students' good understanding of abstract concepts in structural behaviour and an ability to use them qualitatively.

On the other hand, the approach at present to teach these modules by lecturers usually includes a series of lectures on physical laws, mathematical tools and methods for structural analysis and design by using a methodology which consecutively subdivides a real world structure into extremely small sub-components, focusing on a particular element, detaching it

from all other connected structural members and then reducing it to a notation system of structural symbols, mathematical equations and annotations. Structural modules delivered in this way will only get students too much involved into calculation tedium and almost never attempts to connect detailed analysis back to broader building design and construction principles, which result in not seeing the wood from trees and thus lacking of fundamental conceptual understanding of structural system behaviour for the analysis, design and construction of building structures [1].

Although the traditional lectures on structural engineering modules are usually supplemented by laboratory experiments by using of scaled-down models to verify laws and to let students observe structural behaviours, however student feedback has shown that the traditional approach of lecturing and lab experiments have the following shortcomings:

1) Inaccuracy is always introduced when one transfers test results of scaled-down models to the large structures in the real world. The degree of inaccuracy is very much dependent on the similarities of geometries, materials and applied loads. When a scaled-down structural model is tested, dimensional analysis is always used to express the structural system with a few independent variables and as many dimensionless parameters as possible. However, due to its complexity, dimensional analysis can only be taught at the level of undergraduate or post-graduate studies. Hence there will always be a big question mark in our students' minds, "Can structural analysis methods verified by scaled-down model tests be truly applicable to large structures in the real world?"

2) Lectures and laboratory experiments are conducted in different sessions at different places. Students usually study concepts and methods for structural analysis and design modules during lecture sessions and then conduct laboratory experiments on other days. The time gaps between lecture and laboratory sessions will cause the following disadvantages in teaching and students' learning.

    - Lecturers are not able to verify the concepts and methods for structural analysis and design immediately during lecture sessions. The students' understanding is superficial and not rooted deeply into their minds.
    - When students come to the laboratories, they may have difficulties in relating the experiments with the concepts and methods that they learnt during their lecture sessions a few days ago. Some of them may even have forgotten what they have learnt during lecture sessions.

3) It is harder for lecturers to convince students that concepts and methods for structural analysis and design verified by scaled-down model tests can also be applicable to large structures in the real world without doing prototype real-time experiments in front of students.

As an ancient saying goes:

"Tell me, and I will forget. Show me, and I may remember. Involve me, and I will understand." – Confucius (551-489 B.C.E)

AN INNOVATIVE SOLUTION FOR REAL-TIME EXPERIENTIAL LEARNING OF LARGE STRUCTURES

To address the problems existing in the staff teaching and students' learning of structural engineering modules, the authors spoke to lecturers who are teaching structural modules, and carried out brain-storming sessions. A two-prong approach was adopted to overcome these problems and to give students integrated hands-on learning experience. The idea is to upgrade an existing laboratory space and design-build-operate a real size structural system [2].

The purposes of having such a real size structural system in the existing laboratory space are: a) motivating students in understanding of structural concepts and behaviours, b) integrating discrete and disconnected experiments across different structural engineering modules, c) providing a conducive learning environment within existing laboratory that was used for concreting and building technology work, and d) providing a platform for implementing principles and standards of CDIO in the context of civil engineering education.

Conceive-Design-Build the "Structural Learning Space"

During the stage of conceiving the "Structural Learning Space", the authors applied systems thinking to the problems at hand, and consulted significant staff members who involved in the overall course design, laboratory management, teaching of structural engineering modules and staff supervising concreting and building technology activities in the existing laboratory space. Then there was the consideration to prepare part of the laboratory space for design-build experiences required for the future implementation of CDIO as the context for civil engineering education.

The solution was to have a "Structural Learning Space" designed, built and operated at the rear of an existing laboratory that was used for concreting and building technology practice. The "Structural Learning Space" provides real-time experiential learning of the behaviours of a large structural system for civil engineering students across different structural engineering modules. It can also support the CDIO Education Framework which "provides civil engineering students with an education that stresses the engineering fundamentals in the context of real-world systems and products [3]."

During the stage of designing the "Structural Learning Space", the authors, by adopting the CDIO methodology, played various roles of 'owner' and 'design engineer'. Based on initial concept designs and requirements, engineering design specifications were written and the design of structural members and connections were carried out. Together with an external consultant, design drawings of the "Structural Learning Space" were issued to an external contractor for construction.

During the nine month construction stage of the "Structural Learning Space", working closely with the external consultant and contractor, the authors played the roles of 'site supervising engineer' and 'product system operator'. At the end of 2006, the "Structural Learning Space" was completed and ready for use. It is now located in a space within the workshop in W515. It is a single storey steel framed structure. Its columns are all UC 254×254×8, and the truss members are made out of hot rolled Rectangular Hollow Sections (RHS) with two different sizes of 160×80×8 RHS and 150×90×10 RHS respectively. Figures 1 and 2 show the external and internal appearances of the "Structural Learning Space".

Figure 1 External appearance of the "Structural Learning Space"

Figure 2 Internal appearance of the "Structural Learning Space"

The "Structural Learning Space" has the following unique features [4]:

1) All main structural members are not covered by ceiling boards so that students could see different parts of the steel members. This enables them to appreciate the actual size of various structural members. Students' learning of structural engineering modules will become more vivid.

2) All typical connection details between truss members, trusses to columns and columns to foundations are painted with different colours to highlight the main structural members with different types of connections. In this way, students could see and understand how one member is connected to another in a truss system and how these trusses in turn are braced and supported by columns. This promotes students' system thinking with regards to load transferring paths, structural system modelling and structural system design.

Install Structural Measurement System

In order to let students witness and experience the real-time response of large structures when loads are applied, state-of-the art structural measurement system was installed after the completion of the "Structural Learning Space".

The structural measurement system comprises of testing equipment, sixty high resolution strain gauges, and two 30-channel digital data loggers which are connected to two desktop computers respectively.

The strain gauges are installed at critical locations of the steel structural members. They measure the strains of critical points of a structural member. Strain gauges are then connected to the two data loggers which convert the analogue signals from each strain gauge into digital strain data.

Software programmes are installed into two PCs which process the acquired data and display the results according to users' requirements.

The installation of the equipment, strain gauges, wiring, data loggers and computers in the "Structural Learning Space" was completed at the end of March, 2007. Testing of the whole system was conducted at the end of April, 2007.

The schematic view of the monitoring system is shown in Figure 3.

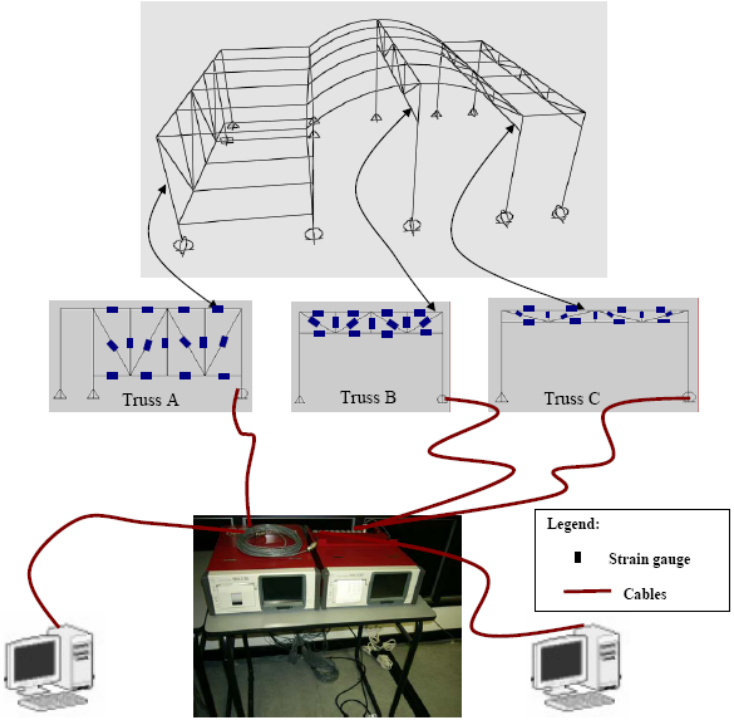

Figure 3 Schematic view of the structural monitoring system

CDIO APPROACH FOR REAL-TIME EXPERIENTIAL LEARNING OF LARGE STRUCTURES

The CDIO model is a model for engineering education that stresses the product lifecycle of Conceive-Design-Implement-Operate (CDIO). It should form the context for engineering education. The process of designing a CDIO programme is guided by CDIO standards.

The CDIO standards serve as guidelines for educational programme reform and evaluation, create benchmarks and goals, provide a framework for continuous improvement. The CDIO standards address programme philosophy, curriculum development, design-build experiences and workspaces, new method of teaching and learning, faculty development, plus assessment and evaluation [5].

With the help of the “Structural Learning Space” and its measurement system, staff can now apply the CDIO standards such as ‘CDIO Work Spaces’, ‘Integrated Learning Experiences’, ‘Active Learning’ and ‘CDIO Skills Assessment’ for staff teaching and students’ learning of structural engineering modules.

Based on the above-mentioned four CDIO standards, an integrated capstone project has been designed and implemented in module “Structural Steel Design & CADD” (A final year core module in DCSE course). A few student-centred experimental activities have also been developed for modules “Structural Analysis and Simulation” (A 2nd year core module in DCSE course) and “Structural Steel Design & CADD” to verify concepts and methods and to improve students’ understanding of structural behaviours. As the structure is full scale and the results obtained through experimental activities are “real-time”, students can be instantly convinced of structural theory and behaviour when subjected to different types of loads.

An Integrated Capstone Project on the "Structural Learning Space"

This integrated capstone project is designed by applying the above-mentioned four CDIO standards for module "Structural Steel Design & CADD" in final year of DCSE course. Students are to work in fours. They have to finish the whole project and submit a group report by the end of term 4 of each academic year.

Project objectives

The objectives of this integrated capstone project are to provide opportunities for students to: a) integrate all aspects of knowledge acquired and comprehended from other modules of the course in particular, in the areas of structural analysis, design and detailing using CADD, b) cultivate team spirit and team work through working with team members, c) practise technical skills, quality consciousness and time management, d) develop initiative, creative thinking and innovative ideas, and e) plan, organize and write a group project report.

Main tasks of the project

By applying the above-mentioned four CDIO standards (i.e. 'CDIO Work Spaces', 'Integrated Learning Experiences', 'Active Learning' and 'CDIO Skills Assessment'), the main tasks of this capstone project were set by the module team in such a way that by doing this project, students could learn how to design and construct real world buildings. The main tasks that our students need to complete within seven weeks in term 4 are as follows.

1) Scheming of structural floor plans based on architectural drawings

   Students are required to scheme and sketch structural floor plans which show the overall grid system, location of supports and floor support configuration from architectural drawings.

2) Load determination, calculation and transferring

   Students are required to determine loads based on the loading requirements for different types of buildings specified in Code of Practice for Design Loadings for Buildings and how the loads are transferred in the building.

3) Sizing, analyzing and designing of structural members

   Students are required to: a) try sizes for different structural members such as columns, beams and truss members, b) analyze the structural system using an integrated structural analysis and design software, either SAP2000 or Stadd.Pro 2007, to find internal forces of structural members, c) manually design structural members by following the design code: BS5950-Structural Steel Use of Steel Works in Buildings. This is a trial and error process which will continue until all the sizes of structural members meet the limit state design criteria (i.e. the Ultimate Limit State and the Service Ability Limit State) under the applied loads.

4) 3D modelling and virtual construction of the "Structural Learning Space"

   Students are required to: a) propose the construction sequence of the steel structural members, b) use a 3-Dimensional CAD software called Bentley Structural XM to draw 3D modelling of the "Structural Learning Space", c) animate the construction of the structural system according to their proposed erection sequence.

5) Report of the capstone project.

Each student group is required to submit a hardcopy of report which includes the details of tasks 1) to 4) and a softcopy of the 3D modelling and animation of the construction sequence of the "Structural Learning Space" which must be written into a CD and attached to the report.

Project schedule

The schedule of the capstone project is arranged as shown in the following table.

Table 1
Schedule of the Capstone Project

Week in Term 4	Tasks
Week 1	Project briefing and getting started on project
Week 2	Scheming of structural floor plans
Week 3	Load calculations & analysis using STAAD.Pro 2007/SAP2000
Week 4	Design calculations
Week 5	Design calculations and CAD 3D modelling using Bentley Structural XM
Week 6	CAD 3D Modelling and Animation of erection sequence using Bentley Structural XM
Week 7	Writing and Compilation of Report
Before 5:00pm, Friday of Week 7	Submission of the project report.

Project assessment

From CDIO point of view, assessment is regarded as learning-centred, that is, an integral part of the teaching process, promoting better learning in a culture where students and staff learn together [6].

Assessment is learning-centred in that it is aligned with learning outcomes [6]. With this statement and CDIO syllabus in minds, the module team came out the learning outcomes of the project, prudently chose suitable CDIO skills for assessment, and carefully allocated weightages to different learning outcomes as shown in table 2.

Table 2
Assessment Scheme of the Capstone Project

Item	Learning Outcomes	CDIO Syllabus [6]	Weightage
1	Reasonableness of assumptions of live loads, member sizes and modelling for structural analysis.	1.2 and 2.1.2	15%
2	Correctness of load calculation, load transferring, structural analysis and design calculations.	2.1.4, 2.4.3, 4.4.1 and 4.4.3	35%
3	Correctness of 3D CAD modelling and animation of construction sequence.	3.2.5	15%
4	Teamwork and communication	3.1 and 3.2.6	15%
5	Presentation of the report	3.2.3 and 3.3.1	20%

Student-centred experimental activities for real-time experiential learning on large structures

With the "Structural Learning Space" and its state-of-the-art monitoring system at place, many fun-filled experimental activities can be arranged to promote students' active and real-time experiential learning on large structures under different types of load conditions.

Many fun-filled experimental activities such as "verification of the stress-strain formula", "verification of superposition theorem", and "behaviours of the structural system due to the dynamic load caused by a mass of students jumping up and down on the floor, etc. have been planned. And the "verification of stress-strain formula" is one of the most favoured activities that have been arranged in structural analysis and design modules in the past two year. The details of the activity are as follows.

The stress-strain relationship is a very important formula in structural analysis and structural design. Based on the stress-strain formula, the internal stress and deformations of structural members can be calculated. The stress-strain relationship is given by:

$$\varepsilon = \frac{\sigma}{E}$$

Where ε and σ denote internal strain and stress of a structural member respectively, and E denotes elastic modulus of the material.

To verify the above formula, students are required to do structural analysis based on above stress-strain formula using an integrated structural analysis software program. At present the Structural Analysis Software, either SAP-2000 or STAAD.Pro 2007, is recommend to be used. Students carry out the analysis of a steel truss as shown in Figure 4. Under a point load P which is generated by a hydraulic jack, the strains in the truss members are measured by the measurement system. If the strain calculated by the software approximately equals to what the measurement system has given out. The formula is verified immediately.

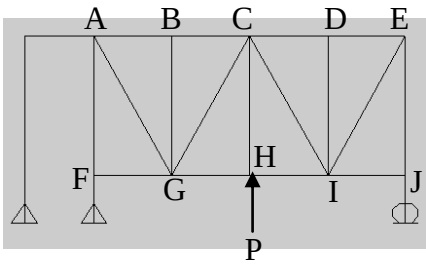

Figure 4 Experimental set-up for the verification of stress-strain formula

Table 3 shows a sample results obtained through the above activity by a group of students who took module "Structural Steel Design & CADD" in year 2008.

Table 3
Numerical Analysis and Experimental Results of Member BC

Applied Load (kN)	Numerical Results (ε_1)	Experimental Results (ε_2)	Difference ($\lvert\varepsilon_1 - \varepsilon_2\rvert / \varepsilon_1$)
14	4.3×10^{-6}	4.1×10^{-6}	4.6%
16	4.9×10^{-6}	4.7×10^{-6}	4.1%
18	5.5×10^{-6}	5.3×10^{-6}	3.6%

From the table 3 above one can see that the differences between theoretical analysis and experimental results are in a small range of about 5%, thus we can say that the stress-strain relationship is verified.

CONCLUSIONS

The “Structural Learning Space” is a two-prong approach to address problems faced by staff and students in the traditional mode of teaching and learning of structural engineering modules. After applying system thinking the authors came out with an innovative solution of designing and building a real size structure equipped with a state-of-the-art measurement system within the existing laboratory space for integrated learning. The entire system provides students opportunities to carry out integrated learning of structural engineering concepts, structural analysis, design and monitoring of structural behaviors under different load conditions.

By applying CDIO standards, an integrated capstone project was conceived, designed and has been implemented in module “Structural Steel Design & CADD” for the past two years. Many student-centered real-time experimental learning activities were developed and have also been implemented in Modules “Structural Analysis & Simulation” and “Structural Steel Design & CADD” for students to do active and experiential learning.

The “Structural Learning Space” is now intensively used by staff to conduct “on-site” lectures in a conducive learning environment and leverage students’ experiential learning by integrating discrete and disconnected experiments across different modules. Student feedback shows that by operating on the “Structural Learning Space”, learning of structural analysis and design modules is no longer boring but one that provides a pleasant experience.

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CDIO DESIGN BUILD PROJECT: IMPLEMENTATION IN THE SINGAPORE POLYTECHNIC

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ABSTRACT

Projects are frequently used to promote integration of knowledge and skills. However, designing effective project based activities is a challenge as it entails many variables. From our experience, we realized that there are several important considerations that have to be addressed in order to develop an engaging project experience. Having a clear objective of introducing the project is critical as it translates to the knowledge, types of thinking and other process skills that will be incorporated. In addition, the design of task activities, assessment criteria, resources to be made available and also readiness of staff and students have to be carefully considered to ensure project success.

KEYWORDS

Design-Build Project, Active Learning, Integration, CDIO Skills

INTRODUCTION AND CONTEXT

A significant focus of the CDIO pedagogic approach is on integrated capstone and design-build projects. A particular challenge for designing pedagogically effective projects is identifying and managing the activities to enable students to find their learning both challenging and achievable.

Most engineering students in the Singapore Polytechnic are required to carry out a project yearly to practise their hands-on skills and to be exposed to some project skills. Students used to build a technical artifact that fulfilled some pre-determined objectives as defined by their lecturers in Year 1 and Year 2 projects. Very often, students needed to apply technical knowledge gleaned from their lessons and some thinking skills to solve these given problems. As the projects were usually specific in the requirements, many of the students ended up with similar answers at the end of the process. Activities carried out by the project students were focused on how to build the project work as shown in Figure 1.

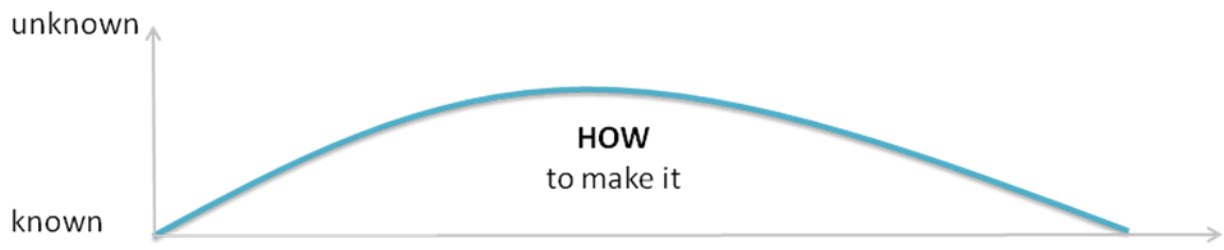


Figure 1 Project Focus

In 2007, we revamped all these projects in the School of Electrical and Electronic Engineering to include elements of conceive and design. As we do that, we introduced the dimension of "what to build" into the projects as shown in Figure 2. This new dimension brings about new activities and learning in the classroom which translates to new task activities, assessment criteria and resources development for the classroom. The remaining paper provides the details of how to design and implement a pedagogically effective project that promotes students' learning.

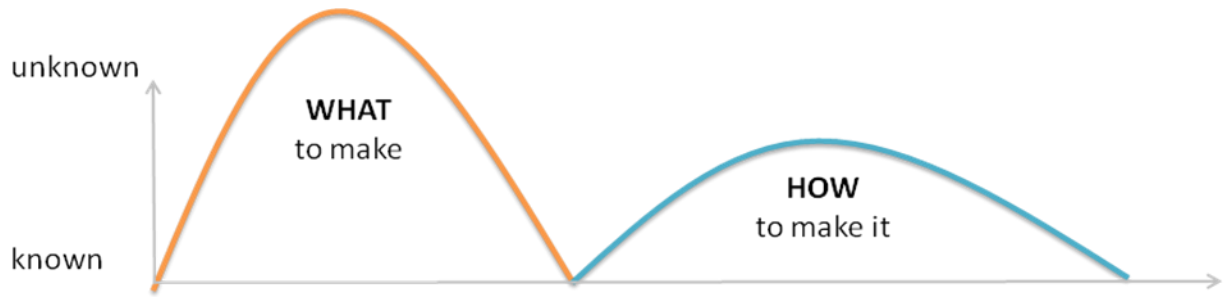


Figure 2 CDIO Project Focus

IMPLEMENTATION OF PROJECTS

To design projects that are fully calibrated to the course and module objectives, the four steps illustrated in Figure 3 have proved useful based on the experiences that our staff have gathered from the various projects that we had introduced in the Singapore Polytechnic.

This remaining section will first discuss the four steps and conclude with a case study of how these steps are applied to a project.

Figure 3 Steps in designing CDIO projects

Step 1*: *Identify the knowledge, types of thinking and other process skills

It is necessary to first identify the topic areas in the curriculum that will be utilised in the project. For example, what are the central concepts, principles and models that may be applied in the project. Besides the necessary knowledge, it is also important to identify the types of thinking which are important for promoting student's understanding and subsequent competence in this project eg. analysis, comparison, inference, evaluation, etc. In addition, other process skills that are required for promoting learning in the identified areas must also be identified. These may include skills in communication, searching for and organizing information, etc. A module such as 'Design and Innovation Project' in Year 2 may entail the knowledge and skills given in Table 1.

Table 1
Project Components of Design and Innovation Project

PROJECT COMPONENTS		
Subject Knowledge	Types of Thinking	Other Process Skills
- Microcontroller - Sensors and Instrumentation - Analog Systems - Biomedical Instrumentation	- Generating possibilities of project design - Analysis - part-whole relationships of a prototype design - Compare and contrast - previous solutions and new options generated - Making inferences and interpretations from data relating to market trends and prototype design - Evaluation of interesting options in relation to criteria	- Oral and written communication - Teamwork - Specific IT applications - Conceive-Design-Implement Product Cycle

Once the project is defined, we may then proceed to prepare the syllabus which should include the necessary activities and skill sets. For CDIO projects, there should be at least 3 components present in the syllabus; namely,

a) Technical knowledge and reasoning
b) Personal, interpersonal and professional skills and attributes
c) Conceive, design, implement and operate systems

After the project content is finalised, the supporting modules may need to be realigned to facilitate the smooth implementation of project which allow students to be exposed to the knowledge before using them in the project.

Step 2: Scope project

Project specifications may be very specific and constrained or it may be kept intentionally vague without a clearly described end deliverable as shown in Figure 4. Constrained problems are useful for early learning for students without any project experience. The other advantage is that projects may be designed closely to meet the curriculum requirements. In terms of administrative demands, this type of projects is likely to be less tedious as the all necessary logistics and preparation can be made ready before the project commences.

However, students working on such problems may not have the opportunity to find and frame problems which is an important skill set. Besides, students may not have the interest to work on assigned project that is given by the lecturer.

The Year 1 project at the School of Electrical and Electronic Engineering falls on this end of the spectrum where the task is specific and constrained. However, there is some flexibility that allows students to use their creativity to develop variations of the final project deliverable.

Figure 4 Continuum of projects

On the other hand, a different set of challenges arise if students do not have any constraints in their choices of projects. Students may decide to work on projects of interest that are out of the knowledge domain. Also, the scope of projects may be too wide that they have difficulty completing. This nature of projects inherently provides students the chance to frame and find interesting problems.

Instead of letting students work on either fully constrained projects or one without any constraint, the Year 2 Design and Innovation Project requires lecturers to supervise and guide students in finding problems. For this type of problems, the constraints could be broadly framed using project themes or they may be bounded by certain knowledge domains taught in the class. Lecturer who is setting the project has to carefully find a spot along the continuum shown in Figure 4 to find a level that is appropriate for students' learning at different stages of their learning. Guided problem finding satisfies the need for students to find personally relevant problems and at the same time allows students to work within the specified knowledge domains.

Some staff may opt for a totally "open" project instead of guided problem framing as they might feel that projects should not have constraints to promote students in pursuing their interests as much as possible. This is a valid argument that can only be answered by the readiness of staff and students in project work. In actual fact, there is unlikely a correct answer as it depends very much on staff and students working on the projects. However, even in the guided problem framing project, students are not working in a straight forward problem solving situation as there are many options and possibilities that students have to manage as they navigate in the problem and solution spaces as shown in Figure 5 which clearly depicts that students have to confront many possible and potential problems and possible solutions.

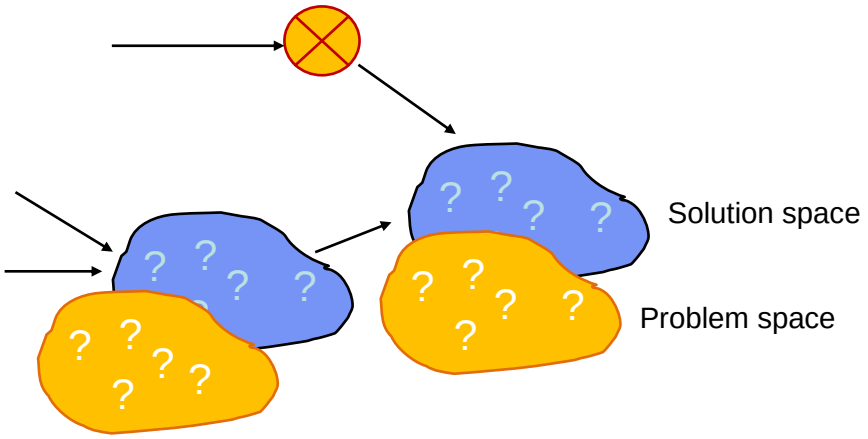


Figure 5 Problem and solution space

To ease the burden of supervising students, some lecturers may choose to assign students with very simple and easy projects. However, this will lead to undesirable students' responses such as boredom and relaxation. On the other hand, some lecturers may set very challenging projects to stretch their students. Again, we may not be able to achieve good project results as students may become unnecessarily stressed and worried all the time. Therefore, matching the right project to students' skill level is an important task that lecturers need to be good in. As can be seen in Figure 6, the lecturer has to align students' skills level to the right level of challenge so that students may operate in the flow region as suggested by Csikszentmihalyi [1].

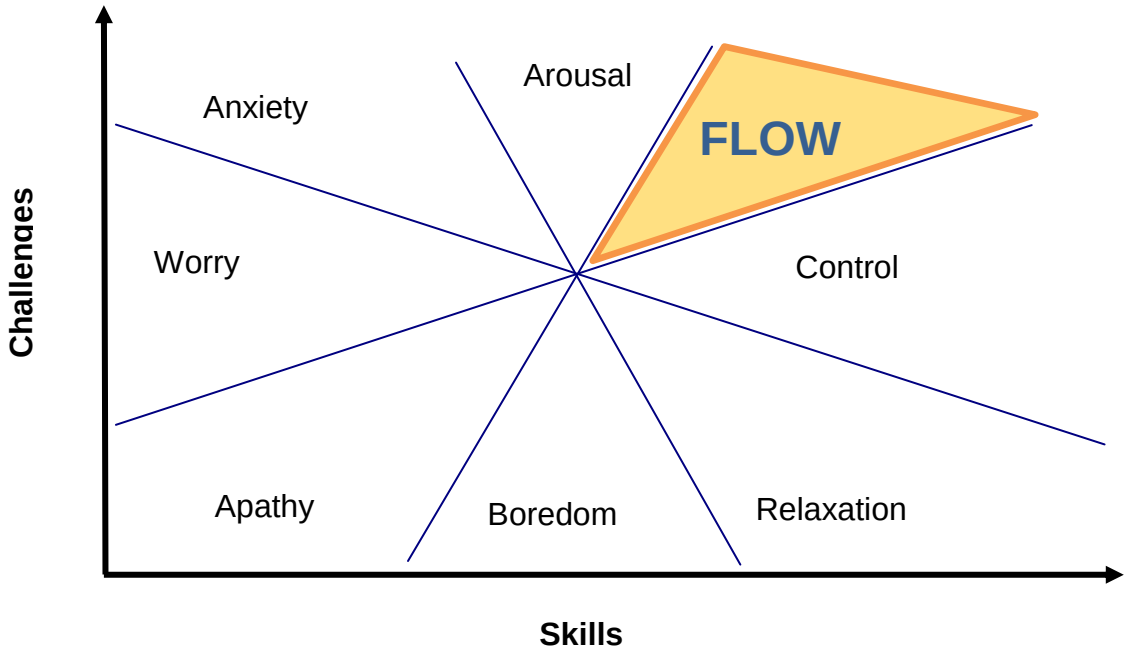


Figure 6 Csikszentmihalyi Flow

Step 3: Structure the project task activity

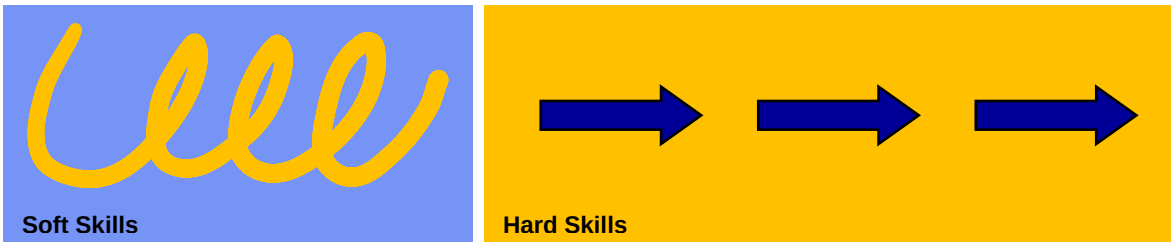
This stage involves constructing the project tasks. It is essential to ensure that the task incorporates the application of knowledge, skills and processes specified in Step 1. Also, it is important that the activities mirror, as far as possible, real world applications and it is sufficiently challenging, but realistically achievable in terms of student's prior competence, access to resources, and time frames allocated.

As far as possible, the project should be designed in such a way that successful completion involves more than one *correct answer* or there is more than one *correct way* of achieving the correct answer. This provides space for students to exercise their creativity.

Administratively, it is useful to provide clear notes which describe the products of the project task and specific formats of presentation that are acceptable in terms of written report, oral presentation and portfolio. It is also necessary to specify the parameters and scope of the activity e.g., time, length, areas to incorporate, individual/collaborative, choice is permitted, resource access, support provided, etc. While interacting with students, it is useful to cue their types of thinking and other desired process skills. As much as possible, all aspects of the assessment process and criteria should be spelled out at the start of the project.

As students work through the conceive – design – implement – operate stages, they will initially experience generative and problem structuring activities while the later stages are for problem solving activities. Thus, in relation to the skill sets, students start with soft skills such

as thinking, problem framing and progress to hard skills such as CADD and other predominantly engineering related skills. Therefore, as students progress through their projects, the support and tools have to correspond accordingly.



Problem Structuring Problem Solving

Figure 7 Stages in problem structuring

Step 4: Assessment

As projects provide good opportunities to assess types of thinking and the application of knowledge and skills, they are similarly the focus in the final assessment. Project assessment starts with the clarification of the exact performance areas that have to be assessed. These performance areas are essentially the knowledge and skills identified in Step 1.

Afterwhich, the criteria has to be established. These *performance criteria* define the key elements that underpin the performance - whether types of thinking, specific skills or knowledge applications. Performance criteria can then be organized into a marking scheme for the project. There are two formats frequently used as a marking scheme or scoring system; the checklist and the scoring-rubric.

a) Checklist

A checklist can vary in format, but essentially provides a breakdown of important procedures or operations in the activity being assessed. For each component of the checklist, there will be a statement or example of competent performance and, if marks are allocated, a weighting for that component is assigned.

Checklist are particularly well suited for assessing activities that can be divided into a series of clearly defined specific actions, e.g. conducting an experiment, math solutions, technical processes, etc.

b) Scoring rubric

A scoring rubric is a prepared scoring system for assessing student performance in activities where judgement is involved in the assessment decision. This is particularly the case with thinking and most skills, where assessment of a performance does not lend itself to a yes/no or competent/not competent type of judgement.

Each performance area can be assessed by way of a rating scale that defines the essential elements of performance (performance criteria) in that area. Such scales typically range from

very competent (5 marks) to *not at all competent* (1 mark). Rubrics are used in the projects implemented in the School of Electrical and Electronic Engineering.

Irrespective of the format chosen, the marking scheme must ensure that the most important performance criteria which underpin competence in each performance area are identified. In addition, the marks allocated should reflect the cognitive activities and skills which the assessment activity requires the learner to demonstrate. As much as possible, adequate provision has to be made for acceptable alternative answers. Finally, it may be necessary for the marking scheme to be sufficiently broken down and organized to allow the marking to be as objective as possible.

c) Allocation of individual marks

Besides awarding marks to the group for completing the assigned project, it is often necessary to have an individual mark component so as to allow lecturers to reward good students while at the same time be able to give lower marks to students who are free-riders. In view of this requirement, the individual mark weightage should be substantial enough to reflect the individual contribution towards the project.

CASE STUDY: INTRODUCTION TO ENGINEERING

In this section, we will use a case study of how we developed the project module "Introduction to Engineering" using the steps given above. "Introduction to Engineering" is offered to Year 1 students from the School of Electrical and Electronic Engineering and it aims to equip students with relevant practical skills such as electronic components identification, correct wiring methods, prototyping, soldering and use of DC power supply and multi-meter. Students are expected to work in teams on exercises where they make use of sensors and electronic circuits to control simple operation. This module is designed to reinforce and integrate knowledge gleaned from other first year modules. Also, students will have opportunities to develop their thinking skills, problem solving skills and interpersonal skills such as teamwork and communications.

Step 1: *Identify the knowledge, types of thinking and other process skills*

Before the project is designed, the development team first identified the knowledge, types of thinking and other process skills as shown in Table 2. The subject knowledge is derived from the modules covered in the same period as when the project is taken. Step 2 further illustrates how the subject knowledge is applied in a project. The types of thinking and other skills are derived after consulting the CDIO syllabus developed by Crawley, E.F. et al [2] and also taking into consideration the students' competency.

Table 2
Project Components of Introduction to Engineering

Subject Knowledge	Types of Thinking	Other Skills
- Principles of Electrical & Electronic Engineering - Digital Electronics - IDEA (Innovation, Design and Enterprise in Action)	- Creative and Critical thinking	- Teamwork and Communication Skills - Electronic Prototyping skills - Focus on Design and Implementation skills. Some coverage of conceive skills.

Step 2: Scope project

As this is the first project that freshmen encounter in the polytechnic, it is designed to be constrained with clear deliverables. This project comprises two mini exercises; the first exercise is a 7 segment display which responds to different input settings while the second exercise is model car that maneuvers based on the conditions it encounters.

The underlying concept for both exercises is similar, students are required to complete a task that has somewhat similar outcome but at the same time is flexible enough to accommodate minor variations in the final solutions. We will use the model car exercise to elaborate how this is done.

For this exercise, students are required to build a model car that moves to a predetermined station before returning to the starting point. Groups are assigned different return points which provide for variations in the final answers. Figure 8 shows the circuits that students have to build and the blocks in white are standard functions that are similar for all groups. The gray block is different as it pertains to the return station and students have to make use of their thinking skills to design it. As mentioned in the previous step, the project requires an integration of different domain knowledge and they are indicated in the boxes in brackets.

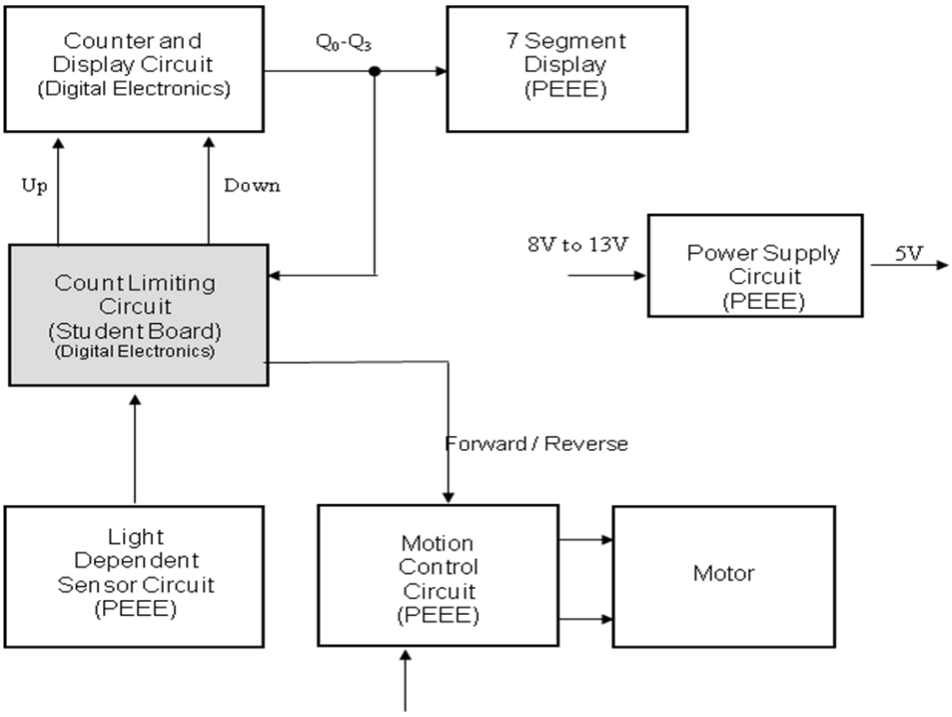


Figure 8 Schematic diagram of project

Step 3: Structure the project task activity

This project focuses on the hard skills such as electronic prototyping and simulation. Thus, students spend most of their time building and testing their circuits. Students will first discuss amongst themselves how they plan to construct the circuits. Afterwhich, they will simulate the circuits using Multisim software. Once they have designed the circuits correctly, some may proceed to using the breadboard to test the circuits while others may start to fabricate their stripboards.

As this project also allows some flexibility in the final solution, students will also make use of their creativity to generate interesting solutions. Thus, even though the stages appear to be in a linear fashion in Figure 9, the actual implementation tends to be a spiral that moves between hard and soft skills.

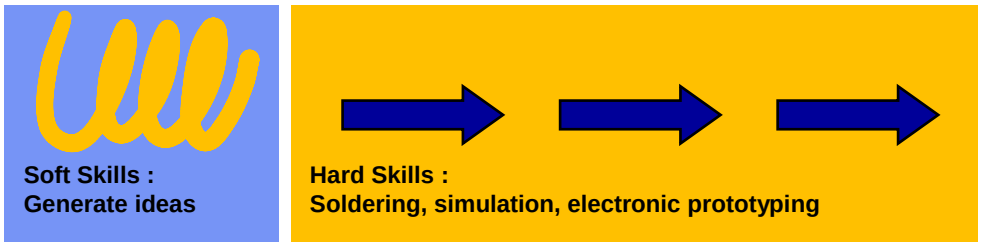
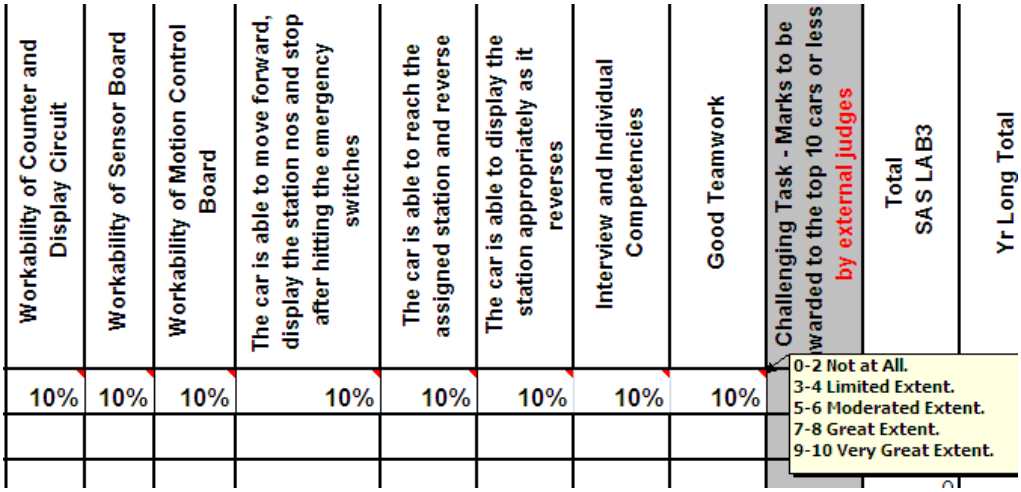


Figure 9 Project stages

Step 4: Assessment

A rubric as shown in figure 10 is used for marking this project. For every item, there is a range of marks that may be awarded based on the performance. Besides simplifying the marking process, this rubric also ensures that marks are more consistent among the different groups of students.



Workability of Counter and Display Circuit	Workability of Sensor Board	Workability of Motion Control Board	The car is able to move forward, display the station nos and stop after hitting the emergency switches	The car is able to reach the assigned station and reverse	The car is able to display the station appropriately as it reverses	Interview and Individual Competencies	Good Teamwork	Challenging Task - Marks to be warded to the top 10 cars or less by external judges	Total SAS LAB3	Yr Long Total
10%	10%	10%	10%	10%	10%	10%	10%	0-2 Not at All. 3-4 Limited Extent. 5-6 Moderated Extent. 7-8 Great Extent. 9-10 Very Great Extent.		

Figure 10 Marking rubric

CONCLUSION

This paper has provided a systematic approach to develop design build projects based on experiences gleaned from staff at the Singapore Polytechnic. It also highlighted several important considerations such as effective assessment and design of task activities.

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Biographical Information

Pee Suat Hoon is a Senior Lecturer in the School of Electrical and Electronics Engineering. Her current research focuses on innovations in education with specific interest in exploring embedded systems for use in projects.

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CHALLENGE BASED LEARNING IN ENGINEERING EDUCATION

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ABSTRACT

In this paper the implementation of Challenge Based Learning in Embedded Engineering as a part of CDIO Syllabus in Helsinki Metropolia University of Applied Sciences is studied and described. The Challenge Based Learning (CBL) method and its implementation is based on a study of project based learning in engineering education started in former EVTEK University of Applied Sciences during academic year 2004. [1] The project studied and described in this paper is the 6th challenge based learning project and will take place during the spring semester of academic year 2008 - 2009.

The paper focuses on introducing the implementation of the on-going project during the academic year 2008 - 2009, the study of learning outcomes and most important the amount of resources required from the lecturers and the amount of time students have used in the project. A discussion of the experiences of tutoring lecturers is also included as well as some recommendations for arranging a similar learning event.

KEYWORDS

Challenge Based Learning, Student Project, Teaching Resources

INTRODUCTION

The role of problem and project based learning is becoming more and more important in engineering education. Traditional teaching methods, e.g. lectures and exams, are often not adequate to serve the needs of modern day engineering education. Project based learning supports the development of skills such as life long learning ability and cross-cultural communication skills, which are required from modern engineer in addition to strong theoretical knowledge.

Various initiatives and projects have been started and studied in order to develop engineering education. CDIO Initiative [2] is one of the most successfully implemented and widely studied methods for modern engineering education and it has also been utilized in Helsinki Metropolia University of Applied Sciences.

The project based learning method in Information Technology Degree Programme of Helsinki Metropolia University of Applied Sciences is based on challenge based learning where the goal of the project is to respond to a product development challenge and test the results against other project teams. Challenge based learning has been studied in former EVTEK University of Applied Sciences for several years and some results have been presented in the 4th International CDIO Conference [3]. In the implementation of challenge based learning project, parts of three separate courses are combined in a form of multidisciplinary project

with the goal to design, implement and operate a product and test the performance and functionalities of the product against other project teams.

CHALLENGE BASED LEARNING PROJECT OUTLINES

Information Technology course sequence

The flow chart in figure 1 represents the structure of courses for 2nd year information technology students in embedded engineering module and the combined multidisciplinary project discussed in this paper. First year of studies, marked with dashed lines in the flow chart, consists mostly of basic courses, e.g. mathematics, physics, digital circuits, and circuit theory [4]. During the 2nd year more advanced topics are studied and the combined project discussed in this paper focuses on combining the topics of three courses together using challenge based learning method.

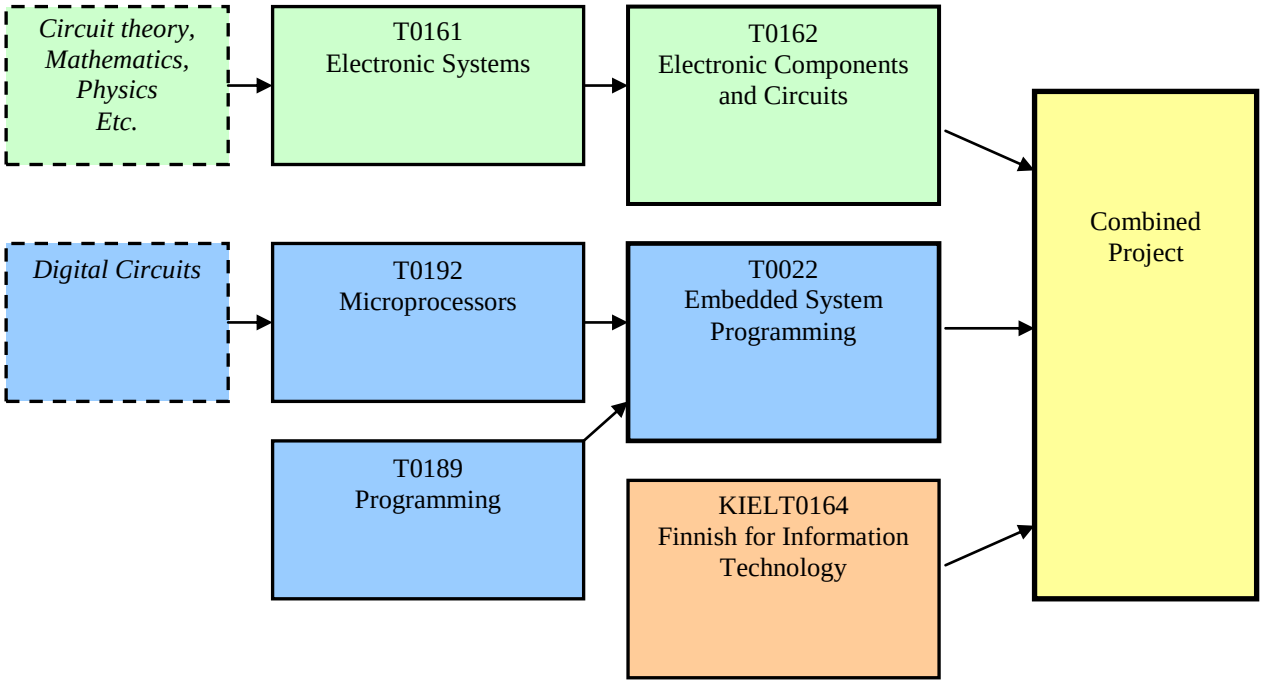

Figure 1. The structure of courses involved in the CBL project.

Electronics Courses

The primary goal of electronics education for information technology students is to provide students an adequate understanding of embedded systems hardware. Electronic Systems T0161 and Electronics Components and Circuits T0162 provide the foundation for understanding electronics [4]. The studies begin from understanding the principle of negative feedback on operational amplifier circuits, followed by most common operational amplifier applications, and concluding to active filters. After finishing the usage of operational amplifiers, the discrete active components are introduced with application examples. Practical application examples from the world of microcontrollers are constantly introduced throughout both of the electronics courses.

The combined project required some modifications to the syllabus. Some of the topics were emphasised in order to support the CBL project. Some additional laboratory sessions were also included in syllabus to provide guidance for the project groups.

Software Courses

The properties and usage of microprocessors are taught during the fall semester of second year on a course named Microprocessors T0192 [4]. Programming T0189 course includes the principles of C-language [4]. After those two courses, Embedded Systems Programming T0022 course [4] combines the previous topics and the new concept of embedded systems is introduced.

The Embedded Systems Programming course gives basic understanding on how to develop software for embedded processors. The course extends the knowledge acquired in the Programming course by introducing the usage of C-language in an embedded system. Laboratory work introduces students the debugging methods of an embedded system. Processor interrupts are an important focus point and the programming of interrupts is taught. However, much of learning in the embedded course is achieved by debugging different problems faced in the laboratories.

In Helsinki Metropolia University of Applied Sciences we have selected 8051-based microprocessors as our educational embedded systems platform. Students are using our own processor boards on the laboratories [5]. The boards are designed to simplify adding new hardware modules into microcontroller in order to evaluate different types of input and output devices. Even though an educational 8051 hardware platform is used during the theoretical part of the Embedded Systems Programming, the teams designed and build their own microprocessor boards as a part of the CBL project.

Language Studies

Finnish for Information Technology KIELT0164 is a compulsory course, which teaches group meeting practices, writing standard documents, and giving short professional presentations. The main purpose is to give students adequate communication skills required in their future position as an industrial engineer.

Project based learning requires that documentation is done in real time. Documentation should consist of not only the facts about what was done, but also how it was done and description of used methods. Self-reflection has an important part on problem based learning. Well made documentation will also support student in future learning and working careers.

Problem and Challenge Based Learning

The major ideas of problem based learning are that it uses a realistic problem as a basis of the studies and the students will learn by solving the problems [6]. The teacher's role varies from a lecturer to tutor, whose functions are more to do with controlling the learning process rather than giving the facts. Teacher's duty is still to plan the sessions by selecting the topic for the problems, organize the students into working groups, and keep the process rolling. Teacher does not anymore know everything about the problem, but the students will come up with their own valid approaches to solve the problem.

There are some reported problems in literature [6], which we should be aware of in our case. First, the teachers' role change is not straightforward, since the activity will change from the traditional lecturer-instructor into tutor-facilitator. This may cause some resistance among

some teachers, which means that the teachers must be open minded to adapt new pedagogical ideas. Second, the students' roles also change and the new learning method evidently causes some confusion in the beginning. Third, the teacher colleagues may exhibit some resistance just because the idea is new. Fourth, keeping the student teams together may be hard. For example, the team can break up easily if the personal values are different or if small argument just happens to escalate out of the proportion. Last, but not least, the teaching of the required process skills is difficult for most teachers. Therefore, without the direction and support the problem based learning will become almost impossible to handle.

Challenge based learning is a concept adopted by the authors of this paper to indicate the fact that the subject of this paper is not only an implementation of problem based learning in engineering education in a form of product development project. Instead the Suvi-project is a research and development project with a challenge and a possibility to test one's ideas and results against other project teams who start from the same level of knowledge with the same tools and means to accomplish their goal. Thus the name challenge based learning. Based on our five year experience organising the project and on the results of our previous studies of problem based learning in engineering education we have concluded that the challenge within the subject of the project increases the motivation and dedication remarkably. [1][3]

Project Guidelines

The CBL project has been organized five times since academic year 2004-2005. The project has evolved during these years and in the recent project in academic year 2008-2009 the project teams' goal was to design, implement, and test a remote controlled robot with some given basic electronic components and to attend to a competition with their robot at the end of spring semester. The subject was chosen based on results of the previous study where remote controlled robot was found to be a motivating and challenging subject. [3]

Students were divided into project teams by lecturers and each team had 3-4 members. When assigning members into team, each student's skills were considered. Additionally each student was asked to assess their personal interest in electronics, software development and documentation prior to the forming of project teams. In this way well balanced teams (considering hardware versus software) were constructed. After the teams were formed, each team named responsible persons for software, hardware, and documentation.

Project Implementation

Project was started with a kick-off meeting in January 2009 where the topic and the guidelines for the project were presented. The presence of each team member was mandatory. Two weeks after the kick-off meeting project teams attended a tutoring meeting where the teams had an opportunity to ask questions regarding the project plan and the fundamental designing problems were outlined.

Progress of student projects was monitored by several project meetings and written project minutes were submitted to a project portfolio which was inspected by teachers. After three weeks of project work, teams were required to make a customer presentation about their project. Teachers were in the role of customer. In the implementing phase of the project, when the basic prototypes were under construction, project teams were required to make another customer presentation. Real customers were invited to the presentations to provide feedback to the project teams. In addition, voluntary laboratory sessions were reserved to the

schedules every other week during the spring semester. During these sessions at least one teacher was present to guide the teams with building and testing their prototypes.

Documentation

The progress of the project work was documented and the final documentation consisted of:
- project plan
- customer presentation documents
- project meetings minutes
- technical documentation

Each team submitted their documentation to a project portfolio which will be submitted for evaluation at the end of the project. This time we decided to use a paper portfolio instead of a Web-based portal since the electronic services were under development when the project was started.

Evaluation

The project is treated as a compulsory part of the courses Electronics Components and Circuits T0162 and Embedded Systems Programming T0022 and it directly affects on the evaluation of both of the courses. Although the courses are individually graded, they both use the competition results as a part of the total grading.

The students' grades from the project have several parameters. The grades are ranging from 0 (=failed) to 5 (=excellent) and it is a sum of competition (from 0 to 2 points), group excellence in electronics and software (from 0 to 3 points), and achievements in documentation (from -1 to 1 points).

The competition points are combined from three different categories:

1. Speed: Three trials on 800 cm acceleration track. The competitors are sorted based on the times.

2. Robot Wrestling: The goal is to disable the opponent robot or push it outside the ring.

3. Tuning: The appearance of the cars is judged by other students. Three marked papers are given to each group, where they can give votes to any other group but their own. The competitors are sorted based on the votes.

Final competition results are then calculated by adding the sorting numbers of each group together and sorting that list of merits. This final list is then divided into three parts; two points are given to highest group, one point is given to middle group, and no points are given to the lowest part.

Teaching Resources

Designing and maintaining a problem based learning project requires always more resources than traditional classroom teaching. In our case, we used the teaching resources that were reserved for normal, self guided student projects. Unfortunately, the resources are quite minimal and without any additional hours spent on designing the project would not have been possible. We estimate that in our case each teacher spent about one extra hour per student more than in traditional “lectures and laboratories” type course. However, when the project

was implemented the first time, the planning and managing the project took at least twice the time.

One very important resource on the design part was that one of the authors, Mr. Anssi Ikonen, did his pedagogical research [1] as a part of vocational teacher education program, which is compulsory for a teaching tenure in a Finnish polytechnic.

Students Comments

Since this is a study of on-going project, the latest results will be available by the end of May 2009 and will be presented in the 5th International CDIO Conference.

Based on the student feedback from our previous study [1][3], we can say that a multidisciplinary project is a motivating method for learning. The teams evidently learned project and team working skills and gained knowledge and experiences on embedded systems design process. Some of the project teams faced problems beyond their engineering capabilities. One of the project teams made an excellent remark when they were asked to define the most important learning outcome during the project. Their response was that "we found out that designing embedded systems is 5% of planning and implementation and 95% of testing and debugging".

Teachers Observations

This was the 5th time the project was organized and the choice of topic and the over-all management of the project appear to be well in balance. Only a minority of project teams had difficulties in getting the project started and the progress of the project is very well in schedule. Project teams did work some extra hours due the challenging nature of the project. Most of the project teams were not satisfied with a basic designing solution, but additional features and ambitious solutions were developed.

Furthermore, ECTS system study unit is based on the estimate of students working time on the topic. We had allocated about 50 hours of students work on this project, but it seems that in average the students did more than that. However, the students majoring in Embedded Engineering will get acknowledged their good work in future courses, where they can continue developing their robots.

Discussion

Based on our short, five years experience in combined Problem Based Learning project in the area of the Embedded Engineering, we have noticed it to be an effective and activating method of teaching. Based on the feedback from the students we can conclude that a combined project consisting electronics, embedded systems programming, and documentation is far more motivating than having three separate project works. Additionally the challenging nature of the topic, a remote controlled robot and a competition against other project teams increase students' motivation and dedication to the project. The percentage of the projects finished before the deadline indicates also that the students found this way of working very motivating even though the subject for the project in academic year 2008-2009 was rather demanding for 2nd year engineering students.

Based on our experiences we give some recommendations for arranging a similar event:

Having enough of planning resources play a crucial role on getting the project started and completed successfully. The instructors of each course must spend considerable time

together outlining the main goals, synchronizing the course curricula, and agree on the evaluation of the project work. Also the information flow between the teachers has a major effect on the success the project. Project outlines must be planned carefully in advance and students should receive same information from each teacher regarding the project and there should be one source of information available.

One major factor affecting to successful project work and learning process was the guidance provided by teachers acting as tutors. Active involvement and guidance was required especially during the first weeks of the project. Most of the guidance took place during the first team sessions and in the laboratory sessions. There were noticeable differences between project teams. Some teams were more innovative and got started with the project very fast and they were able to decide the role of each team member easily when others required more support. It requires professional skills from the teachers to evaluate the team forming process and to see where and when additional guidance was required, but still remain as a tutor and do not affect on the problem solving process by providing solutions.

Get tools to help maintaining the project and test the usability before purchasing it. There are several learning environments commercially available, which fit or doesn't fit for problem based learning in competitive project setup. The system must support student groups and allow public and private areas. There also has to be a quick look area, which the teachers can use for evaluation.

Select the project topic carefully avoiding too general topics. It is not recommended to let the students to make up their own ideas, simply because these projects are less likely to be completed. This recommendation is based on our experiences organizing the first project. In the academic year 2004-2005 project teams were allowed to come up with their own topics. The result was high motivation and enthusiasm in the beginning of the project, but lower number of projects was completed before the project deadline. Major factors affecting the results were too complex and ambitious topics and the lack of competition and support between project teams. In academic year 2005-2006 project topic was selected by the customer, i.e. teachers, and the result was a higher percentage of successful projects.

Do not let the students to form their own project teams. Instead let the students to evaluate their own experience and interest on different categories of engineering skills like electronics design, programming and documentation. Use this information and your own knowledge to form the project teams. This presents a real life situation where project team must go through a team forming process in the beginning of the project. Additionally this ensures that all teams are more or less on the same level of engineering skills.

Eliminate extra variables to simplify project maintenance. Especially, do not allow any exemptions or special arrangements.

The Problem Based Learning requires extra time and effort from instructors. Do not think that dividing students to groups and giving them a common task means implementing PBL method for teaching. A successful learning process requires guidance and support. Also adequate amount of resources should be allocated for planning and managing the project. In addition, the teachers involved should be highly motivated and devoted to learn and try new pedagogical methods. This requires more resources compared to traditional class-room teaching and the allocation of the resources should be agreed in advance with the employer.

Conclusions

Introducing Embedded Engineering for second year Information technology students can be effectively done by applying Problem Based Learning principles in a combining student

project. It requires seamless cooperation between course instructors, some extra resources, and interesting topic. This means a lot of hard work for both students and teachers, but when the project is a success, it gives very gratifying moments for everyone.

In future, we are going to continue the series of Suvi-projects with some modifications. Due to merger of Helsinki University of Applied Sciences and EVTEK University of Applied Sciences, the academic syllabus of information technology students changed substantially. The students will be selecting their majoring option half year earlier as they did on EVTEK University of Applied Sciences. Practically, this means that there will be fewer students to attend the combined project. However, since they already have selected their majoring option, they are most likely well motivated to learn Embedded Engineering project skills.

Good practices learned from the Suvi-projects are going to be used in other CDIO learning projects in Helsinki Metropolia University of Applied Sciences. Some parts of it were adopted in the first year students' Introductory Project during academic year. We also have plans to expand the general idea of our concept to International Summer School on Embedded Digital Signal Processing, which will be organized together with three other European Universities of Applied Sciences.

Acknowledgments

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CHALLENGES IN IMPLEMENTING CDIO IN ALL ENGINEERING EDUCATION PROGRAMMES

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ABSTRACT

The paper discusses the first steps in introducing the CDIO approach in Bachelor level Engineering Education at Helsinki Metropolia University of Applied Sciences. All engineering programmes of the university are committed in implementing new curricula that are based on the CDIO principles including introductory and capstone projects and integration of courses in the form of a 10-weeks-long study modules. The motivation of adapting the CDIO pedagogy is raised from the needs of the engineering students but also from the chances of the working life. An evaluation of the current situation at the institution was carried out in the spring 2009. The evaluation was based on framework of the twelve standards of CDIO. Further development activities will be justified on the results of the self-evaluation.

KEYWORDS

self-evaluation, implementation, CDIO, commitment of the management

INTRODUCTION

This paper describes how we are aiming to employ the CDIO approach itself to facilitate the changes to all engineering education programmes of the institution. We describe how the implementation process was started and which strategies were adopted to overcome resistance within the institution.

In a conference on CDIO, there should be no need to convince the audience about current concerns over engineering education. However, there are many issues associated with the introduction of necessary changes to the practices of engineering education and in such a way that these might be solved through the implementation of the CDIO scheme. The CDIO approach can be used to facilitate the changes to all engineering education programmes of the institution.

Helsinki Metropolia University of Applied Sciences is a recently created institution (August 2008), a result of a merger between two former polytechnics in the Helsinki Metropolitan area. This merger is forcing us to re-think the whole organization from the perspective of our educational programmes and their management. Also, the merger gives us a unique opportunity to reflect-on and to adapt much deeper changes. These could raise major challenges. Nevertheless, we consider the ultimate benefits to be worth of the necessary efforts.

Helsinki Metropolia University of Applied Sciences entitles seven schools; three of them concerning engineering education: School of Information and Communication Technology, School of Industrial Engineering, and School of Civil Engineering and Building Services. 7000 engineering students are enrolled into 20 degree programmes. 700 of them are studying and working full-time in industry.

The CDIO implementation process was started year ago (spring 2008) when new curricula were created for all engineering programmes. Also, it was discussed, which strategies should be adopted to overcome a potential resistance within the institution. In doing this we also recognise that the issues being faced by us are far from unique and in fact have a much wider relevance.

The main objectives that will be addressed in the implementation project are:

- Start the process with a self-evaluation of all our engineering programmes to identify from the present situation (a) the greatest success factors that already exist and might be used in the future, as well as (b) the largest development needs in comparison with the CDIO criteria;
- Establish and develop, with the visible support of top management, a “change agent” network inside the organization to support the necessary changes;
- Begin to collect information systemically and analyze the outcomes of the process as it progresses;
- Plan how to continue with these important and necessary changes.

We all recognize that there are many issues to be addressed in order to improve engineering education. However, recognizing an inevitable change in the issues is one thing, but to achieve such a change is a different story. By introducing and sharing these themes we place our hopes on generating discussion and getting feedback at the conference.

The initial steps into the CDIO collaboration were taken in a SEFI conference some years ago where a presentation of CDIO approach was given. After that two principal lecturers, who were studying engineering education pedagogy, were asked to write their “thesis work” about the implementation of best practices of engineering education, including CDIO approach, and how to introduce them in Helsinki Metropolia UAS.

The thesis work resulted in a Finnish guidebook, an easy introduction, which can be easily handed out to all faculty and staff and even to students. The guidebook was widely distributed in the occasion of the first internal CDIO workshop held in June 2008. In that workshop more experienced CDIO users from Gothenburg, Stockholm and Turku were presenting their ideas and thus contributed to our internal discussions.

It was highly salient in that stage that we decided to create “our own way”, called “engineering education of great spirit”. All the experience and good practices will be gathered together under the umbrella of “Metropolia engineering education” and the criteria of CDIO will be used as a tool to execute the work. The already used PBL (Project Based Learning) Learning) and TPL (Total Project Learning) are actually promoting perfectly the objectives of the same framework – and the combination will be suitable for us.

As a next step we have decided to gather the already existing experience by a self-evaluation using the criteria of CDIO. That work started with a one day internal seminar, additionally highlighting the importance of making decisions for our next development actions. The self-evaluation helped us to find out criteria by criteria if is it relevant for us and where do we stand on the general level of the CDIO norms. Defining the target status and the gap to the target gives us tools to prioritize the coming actions.

CURRENT CONCERNS OVER ENGINEERING EDUCATION

Attractiveness of engineering studies

In many OECD countries, many post-secondary students not only find the profession of an engineer attractive, but also are not inspired by its challenges. Although the degree requires hard work to be accomplished, it is not seen as leading to senior positions, significant financial remuneration, not to mention a secure stable employment. Furthermore, engineering has more of a reputation for creating rather than solving problems. That is somewhat better in Finland, as engineering education continues to be well appreciated, and engineers are hired to many new areas of work, as they are expected to have the systematic capability to analyze, dissect information and identify solutions to problems even outside their area of specialties’. The number of engineers (per capita or per university degrees) in Finland is roughly double as much as in many other OECD countries, only South-Korea has higher density of engineers. [6]

Changes of the working life has influence to the requirements of education [1]

Concurrent Engineering (CE) and Collaborative Planning (CP) [2] were both introduced as operational models and as a best practice when they appeared in 1990’s to improve the competitiveness of companies in these respects. The goal of these approaches is the same although CE focused on internal collaboration with adapting the customer into the processes. The goal of CP was to collaborative planning of the logistic chains to the profits of all parties.

Similar approaches should be deployed in educational processes, as well as take into account a holistic and comprehensive planning and delivery operation from supplier (i.e. teacher) to customer (i.e. students). In an opposite case the personnel will lose sight of customer (student). Thus they are able to develop their own operation but will do it at the expense of the integrity.

Working in a real working environment means a continuous development process and therefore the change management is an important part of teaching. The ability of effective acquisition of information is an essential part of this. Students must learn to flow in the refining process upwards and downwards during his/her student years by migrating his/her qualifications and skills.

The Finnish industry has moved towards the customer and amended their products significantly. The companies try to dominate their own role in supply chains, the customer relationship has been tightened and the customer service has become consulting service taking over the traditional customer oriented duties, such as product design and manufacture.

The products are renewed frequently and more often based on the initiative of a customer. The amount of product variations has increased in pursuance of non-standard individualized and customized products.

This development cannot be ignored and bypassed while the competence requirements are set. In these situations, change management and understanding the comprehensive operations should be highlighted.

The changes in the economic life and generally in the society have been radical and sweeping: the work is globally distributed, not to forget the new emerging nations. The industry is worried about the availability of work force and it is anticipated that only half of the industry will be able to recruit sufficiently qualified staff in the coming years. The focus and challenging interests of the industry in Finland have changed substantially from 1993 to 2003. In 1993 the customer service and quality were ranked to be the most important objectives while in 2003 the production costs were raised to be the most important objective in development (Figure 1 and Figure 2).

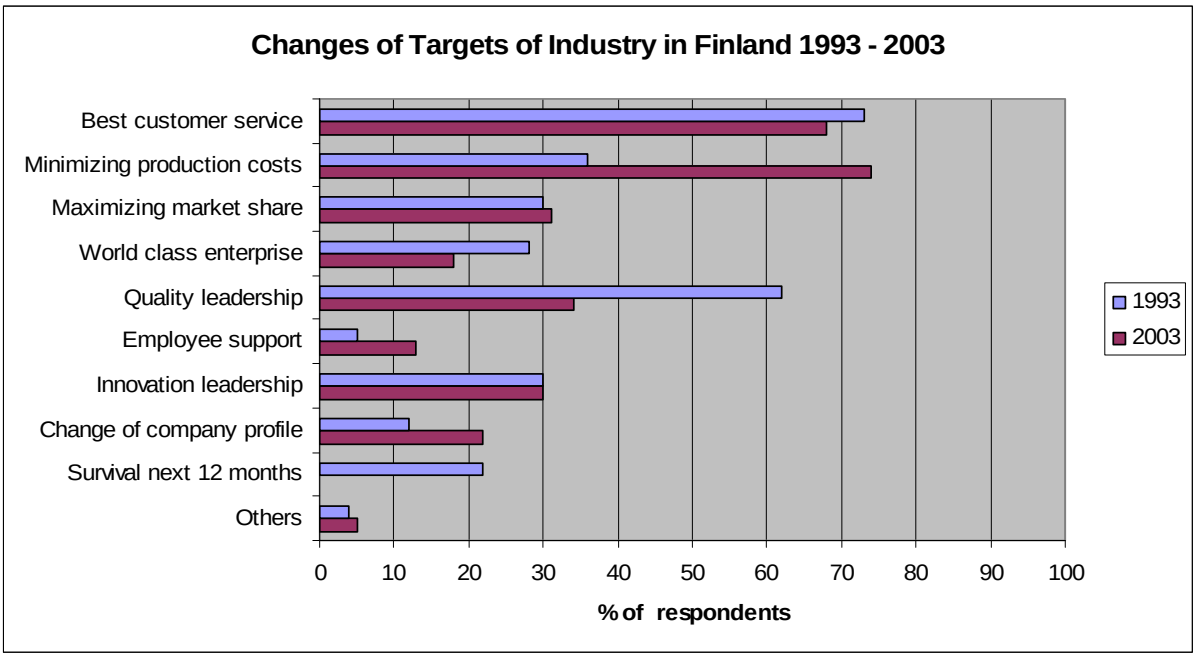

Figure 1. Changes of Targets of Industry in Finland 1993 – 2003. [3]

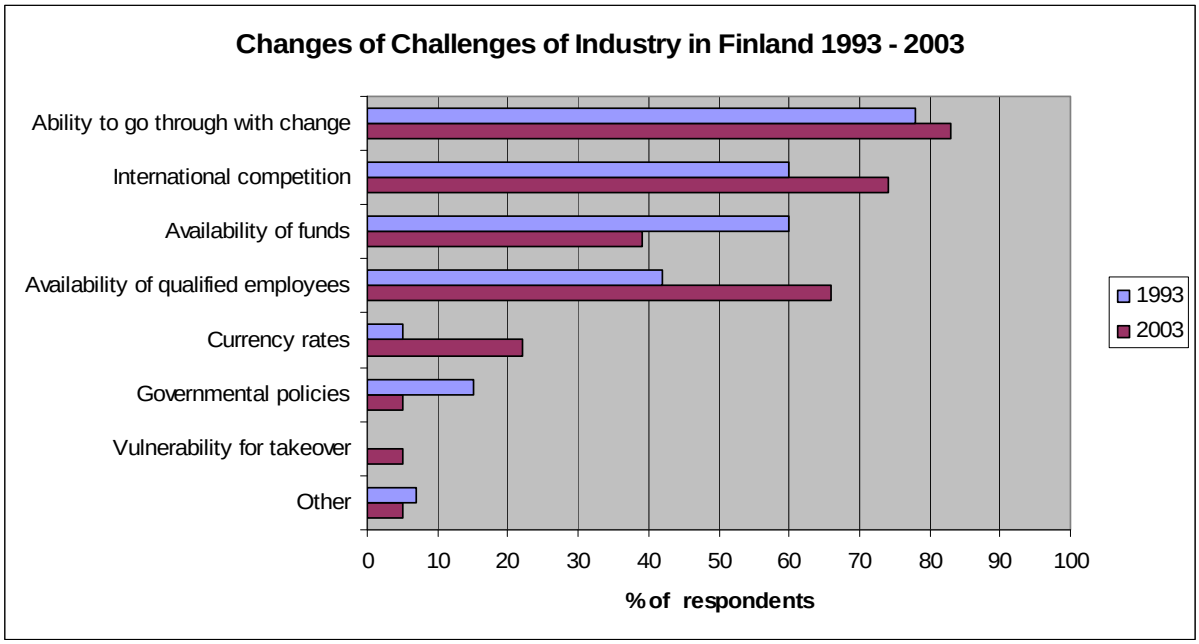

Figure 2. Changes of Challenges of Industry in Finland 1993 – 2003. [3]

Changes of the working life due to outsourcing and changes of business models enforce the engineering education to be changed respectively (Figure 3). There is a need to educate people who are able to transfer easily from a position to another and from a profession to another during their lifetime. The changes of surrounding society and business life must be reflected and have an effect on engineering education.

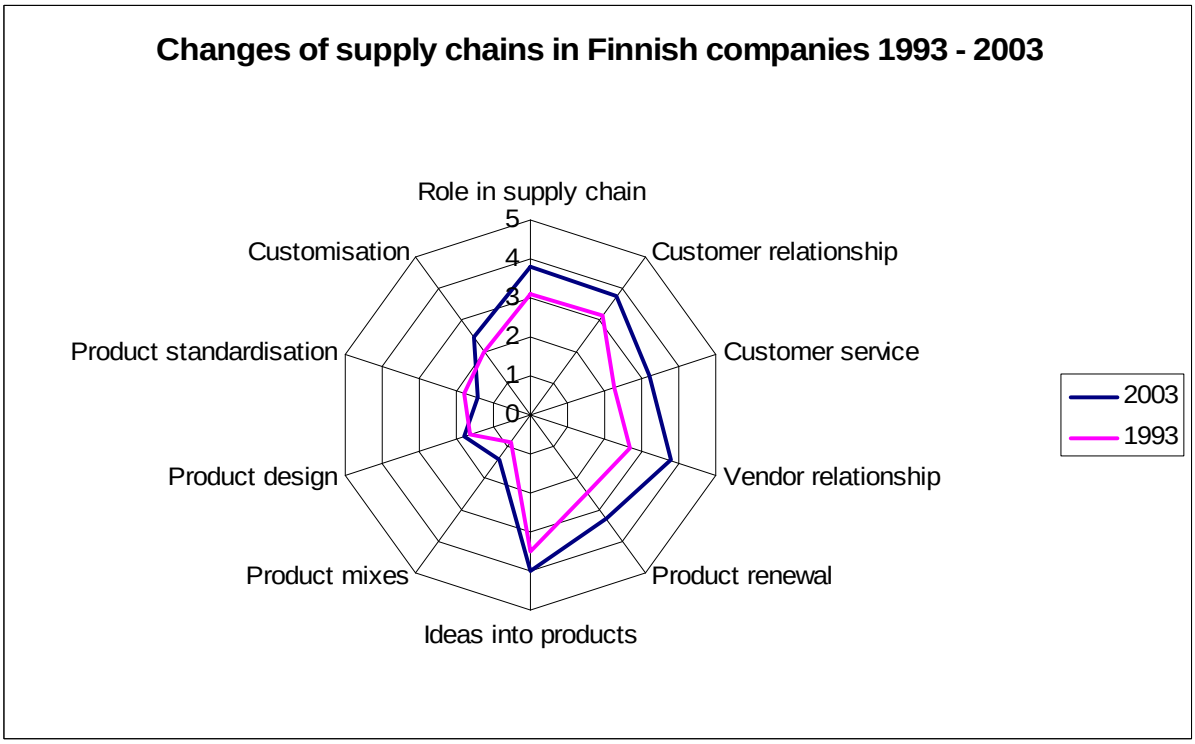

Figure 3. Changes of supply chains in Finnish companies 1993 – 2003. [3]

SELF-EVALUATION

The aim of the self-evaluation is to find out development areas to focus the efforts and resource allocation in future. It is seen that this evaluation is a part of the overall continuous development process of the university of applied sciences. Thus our development work has a relationship to the national evaluation of higher education institutions (HEIs) which will be carried out in three years time – the self-evaluation is executed and will be documented so that there will be measurable evidence of the improvements when the new self-evaluation with the site visits of the national evaluation board will take place. In this way the development work done in practical level meets the needs of the top management [4]

CDIO framework and its 12 standards [5] are to be used to give a consistent structure for the evaluation. The evaluators were given a summary of CDIO standards translated into national language, i.e. into Finnish. Each evaluation was carried out in 20 different degree programmes having a curriculum of their own.

The implementation process is organized by creating an advisory board that consists of the directors of the engineering schools, some pedagogical experts, the communication manager and a few students. A working group of four authors of this paper is coordinating the real implementation work, and all the interested staff is called to join the everyday work.

One significant challenge is to find a balance between the issues students have to learn during the time of the studies – which ones they need only to know how to retrieve the necessary information later on – or even just to know how to find someone to help – which things can be left to be learned when they are faced in working life, and which ones are so fundamental that you cannot even understand the task without mastering them.

The self-evaluation of the CDIO implementation at Helsinki Metropolia UAS was carried out during the spring semester 2009.

The five evaluation questions of the self-evaluation were as follows

1. How important the standard is seen in your degree programme (range 0 – 4)
2. What is the current situation in your degree programme regarding the respective standard? (range 0 – 4)
3. The current situation and its strengths
4. The current problems
5. The target situation and actions to be done within three years time

The Table 1 contains the preliminary results of the self-evaluation.

Table 1. Self-evaluation of the CDIO implementation at Helsinki Metropolia UAS

Standard	Importance	Current situation	Current situation and its strengths	Current problems	Target situation and actions and resources to be taken within three years time
1 — CDIO as Context	4	3	various projects and work-based learning activities; active teaching/learning, pedagogical studies, small teaching groups	further integration of core and professional subjects; team teaching; timing problems; collective labor agreement	better schedule management; team teaching deployment;
2 — CDIO Syllabus Outcomes	2	2	competence-based curriculum under construction; detailed outcomes missing; identification of soft skills missing; inconsistence	not too much willingness to reformulate the curriculum in details	competence-based curriculum by 2012
3 — Integrated Curriculum	3	1	missing integration of mutually supporting disciplinary subjects; existing projects (2 – 4 for each student) integrate to some extend	delivery of mutually supporting disciplinary subjects	module based curriculum and team teaching with a superior teacher of one period (i.e. 10 weeks) for each class
4 — Introduction to Engineering	3	1	implementation of a project on Introduction to Engineering has started 2008	how to integrate the subjects of Introduction to Engineering: not too difficult, not too easy; heterogeneous starting groups	proficiency in Introduction to Engineering among the faculty should be acquired
5 — Design-Build Experiences	4	4	Design-Build Experiences has been implemented many years ago in a form of projects with professional suitability, some of them are work-based and some on commission	learning aspect may have been undervalued compared to the quality of outcomes	better implementation of bigger projects with challenging results; R&D activities incorporated with potential financial incomes
6 — CDIO Workspaces	4	1	current situation is inadequate;	some projects do not require workspace and laboratories (like business and economics); ICT has a moderate requirements but most engineering disciplines require a significant space	new buildings with appropriate functionality are needed
7 — Integrated Learning Experiences	3	1	teaching and subjects are too much independent from each other and integration is left on the shoulders of students	holistic learning is not understood by the teachers	more qualified pedagogical methods should be implemented
8 — Active Learning	3	2	methods of active learning are deployed to some extend	too much lecture-based teaching	activating web-based teaching approached should be developed
9 — Enhancement of Faculty CDIO Skills	3	1	no actions have been taken so far; faculty has been enthusiastic about CDIO approach; a need for change has been admitted	ignorance of CDIO skills; ignorance of the real consequences of CDIO; shortage of human and financing resources	gradual progression
10 — Enhancement of Faculty Teaching Skills	3	1	generally teaching skill are good; faculty has been enthusiastic about CDIO approach; a need for change has been admitted	ignorance of the real consequences of CDIO; shortage of human and financing resources; pedagogy is not so much appreciated among faculty	gradual progression; pedagogical strategy should be developed
11 — CDIO Skills Assessment	3	1	so far is based on "common sense"	no systematic practices to carry out assessment of student learning in personal, interpersonal, and product and system building skills, as well as in disciplinary knowledge	a systematic practice must be created and adapted
12 — CDIO Program Evaluation	2	1	study programme evaluation has been carried out with other criteria	involvement of all stakeholders	system should be created; system should be approved by the national accreditation agency

As one can see in the self-evaluation (Table 1), the biggest challenges at Helsinki Metropolia UAS are related to concrete problems which concern workspace and laboratories. They become extremely important prerequisites when introductory and capstone project are carried out. Some of the study programmes are more flexible regarding the physical working environment, like business and production economics. The requirements of ICT related projects are moderate compared to the real massive requirements of construction, machine, mechanical, and process engineering.

Another great challenge concerns the type of project assignments. Are they based on working life assignments or educational assignments? How realistic the assignments should be? A real customer may require real outcomes in a realistic environment. A real customer may be interested in requiring results of good quality and they may be willing to award some kind of scholarship or financial support.

CONCLUSIONS

To avoid change resistance and get success-stories, pre-work should be well executed. This task is usually underestimated, and thus much unnecessary problems are faced during the implementation. Implementing CDIO should follow the guidelines of CDIO! In the light of all above considerations, this presentation should encourage the collaborators who are considering to start the implementation.

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Biographical Information

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COMPARISON AND CLASSIFICATION OF DESIGN BUILD PROJECTS IN DIFFERENT ENGINEERING BACHELOR PROGRAMS

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ABSTRACT

In order to find inspiration for creating novel design-build projects we have examined projects given at the B ENG program at DTU for civil, architectural, IT, electrical, chemical and mechanical engineering students. This resulted into a classification scheme which identified five different types of project work: *bucket-of-water* project, *minced-meat* project, *build-the-bridge* project, *make-it-fly* project, and *what's-up* project. At DTU it seems that the *build-the-bridge* type is predominant.

KEYWORDS

Design-build experience, bucket-of-water project, minced-meat project, build-the-bridge project, make-it-fly project, what's-up project.

INTRODUCTION AND BACKGROUND

The Technical University of Denmark educates engineers in two separate streams of education. One stream is the Bachelor of Engineering (B ENG) which is a 3½ year program that qualifies the student to go directly into industry to jobs in e.g. production units, project management or control and support functions. Another stream is The Master of Science in Engineering (MSC ENG) which is a 2 year program that follows the 3 year Bachelor of Science in Engineering Program (BSC ENG). The BSC ENG and the B ENG programs include different curriculum and are taught to different student bodies. The DTU management decided to introduce CDIO as the engineering context for all its B ENG studies, and implementation started in 2008 with the first year courses. In 2011 the process will be completed for the full B ENG program [1]. The full B ENG program include six degrees in engineering covering mechanical, chemical, civil, architectural, electrical, and IT engineering.

The introduction of CDIO philosophy to the B ENG programs at DTU serves the obvious purpose of improving the quality of the engineering education. More specifically we see the combination of CDIO and a faculty of research active professors, as a way to maintain what has always been the hallmark of B ENG studies at DTU: emphasis on applied engineering *and* an up-to-date and high level of professionalism.

The implementation process was headed by a committee lead by the Dean of Education, which included representatives from students, teachers, program coordinators and the study administration. The committee concluded its work in 2008 and set up guidelines on how DTU should adapt to CDIO and produced a detailed plan of action [1] that defined common goals and guidelines for the future CDIO-based study programs. Following this plan the program coordinators of the individual B ENG programs have implemented the necessary changes together with supporting working groups of teachers and students.

In order to support the implementation process an important step was to translate the CDIO syllabus into Danish. We translated the full syllabus, but quickly realized that a more condensed version was needed, where all skills were expressed in operational terms, and with more generic descriptions of competences (detached from mechanical engineering).

At DTU one semester equals a credit of 30 ETCS points and covers a 13 week teaching period with weekly classes, an examination period of a couple of weeks, and finally a three week period devoted to a single learning activity or course work. Traditionally, the study programs at DTU contain a very high degree of freedom for the students to compose study profiles and elective courses. Thus the emphasis on implementing CDIO into the education is focused on the first four semesters of the B ENG programs, which consist of compulsory courses and projects that provide the students with a broad basis in the specific branch of engineering. The last three semesters consist of a semester of industry internship, a number of elective and compulsory courses and the final project work, which is 20 ECTS points. The internship can be regarded as a design-build experience in itself, as it holds plentiful opportunities to design, implement and especially operate systems. However, the CDIO structure is mainly integrated in the compulsory elements of the B ENG programs during the first four semesters as indicated in Figure 1.

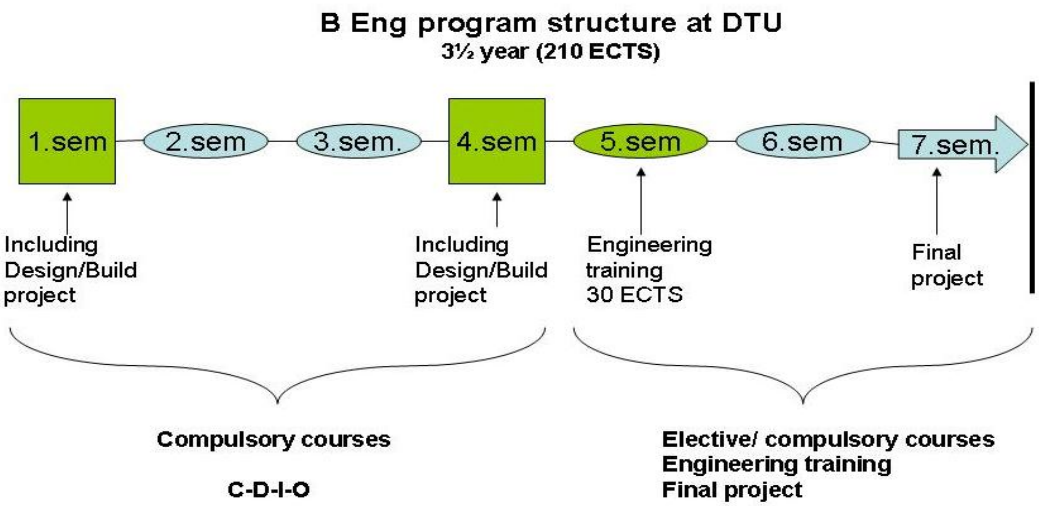

Figure 1. Outline of the study plan for the B ENG program at DTU.

Generally, we have adopted the structure of a basic level and an advanced level design-build project in the first and the fourth semesters of the study program following CDIO Standard 5. Our preliminary analysis of the structure and classification of these design-build projects are discussed in the following.

CLASSIFICATION OF DESIGN BUILD PROJECTS

During the work of developing design-build projects for the six different B ENG studies at DTU we have come across general features which distinguish different types of projects and characterise them in the CDIO context. The design-build experiences spread over the B ENG programs of mechanical, chemical, civil, architectural, electrical, and IT engineering. We would like to present the general trends in an attempt to classify project types, which hopefully will serve as inspiration to others who have to develop design-build projects. In Figure 2 we have identified – and named – different models for working processes in design-build projects which seem to work well in different walks of engineering. These are discussed below.

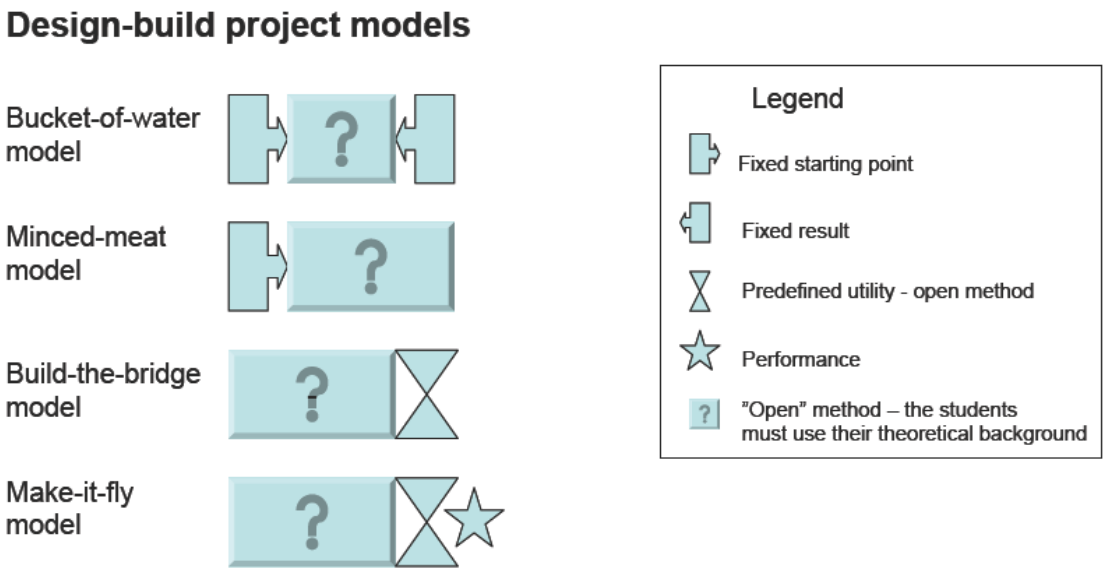

Figure 2. Four different models for design-build projects. See text for explanations.

Bucket-of-water model

In the *bucket-of-water* model we operate with a specific starting point. The students can then use their theoretical background to conceive, design and implement a solution that leads to a fixed result. The example of the *bucket-of-water* project is anecdotal. [3] A professor at a university in the Netherlands ran a course in the 80s which he kicked off by giving a bucket to the group of students with the instructions to go to the canal behind the building and fill it up. When the students returned to his office with the bucket of water, he informed them that their task was to design a method to purify the water so they would drink it themselves. In this kind of project the specified starting point (the dirty water) and a desired result (drinking water) are the only direct instructions given to the students.

Minced-meat model

In the *minced-meat* model we operate with a specific starting point which the students have to analyze. The methods and the solutions are open and depend on the choice of the students during the project work. The example of the *minced-meat* project originates from the preparatory work to design a novel B ENG education in food quality control [4]. Here the focus is often on analysis and control in the food industry. Basically, a packet of minced meat is randomly collected from the fridge in a grocery store and must be subjected to proper analysis, which is not specified. In this kind of project the specified starting point (the minced

meat) is all that is given to the students. The result solely depends on the theoretical and practical knowledge of the students and their desire to innovate.

Build-the-bridge model

The *build-the-bridge* model is a rather open project model. The end result is a predefined utility, which the students can aim at using their knowledge to design and implement. Predefined constrains can be introduced, but in the pure form the only instruction is the end utility. The example of *build-the-bridge* is very simple and has been a recurring problem of mankind for all times. Basically, you stand on one side of a river – and want to cross over to the other side. The task is simply to connect the two sides. In this kind of project the specified end result (the bridge) can easily be supplemented with more specific side criteria which can guide the students in their project work, but this project form holds great potential in training the students to identify and define the problem context at hand.

Make-it-fly model

The *make-it-fly* model is rather similar to the *build-the-bridge* model. The difference is that the *make-it-fly* project contains an element of performance or competition. The goal is e.g. to create the higher, longer or faster system. The competition element is important and motivating and can result in very intense student activity. At DTU a team of students have formed *DTU Roadrunners*, which organises coursework for mechanical engineering students that leads to the construction of energy effective vehicles and propulsion systems (i.e. cars). Each year the cars participate in the annual Shell Eco-marathon event in Nogaro, France. [5] Recently the DTU students won the competition setting a world record in driving the longest distance on one litre of fuel. The inspiration for the make-it-fly name originates from a course at the KTH Royal Institute of Technology, which includes designing a lightweight structure that can fly and carry a specific weight a specific distance. [6]

What's-up model

Finally, at the end of the list it is important to mention the *what's-up* model, which basically leaves everything to the student. Nothing is specified from the teacher – apart from the total study credits that the students will receive upon completion. This kind of project is a completely open model with no predefined starting point or end utility, and obviously it carries a lot of administrative and logistic problems. However, it aims at what we want to obtain with our education: Students who can do it all by themselves. DTU has no experience with this kind of projects.

DESIGN-BUILD PROJECTS IN CIVIL, ARCHITECTURAL, IT, ELECTRICAL, CHEMICAL AND MECHANICAL ENGINEERING AT DTU

At DTU design-build projects have been developed for all the different B ENG programs. In Table 1 the characteristic features of the different design-build projects are listed. As mentioned above the projects run in the first or the fourth semester, and only the first semester projects have been completed at this time. In Table 1 the theme of both projects are given in the second line. This text does not allow for a complete description of the details of each individual project, but the following rows of Table 1 describe the projects with respect to the size of the student projects teams, the amount of credits point given for the project, the most relevant aspects of the CDIO phases addressed by the project work, and finally the most descriptive model for the project adopted from the classification introduced above. An arrow pointing from the first to the fourth semester project indicates any progression of the addressed indicators.

Generally, all design-build projects are organised by assigning groups of four students to each project. Very often this organisation is left to the students to manage, and the teacher only assists if an individual cannot find a team. The practical aspects of working in teams are mainly addressed as learning by doing. In such a way the students do generate their own experience, but some assisted and specifically addressed teaching elements could be of help to support the students team working skills. A few programs have build in some progression into the required team working abilities of the students by increasing the size of the team drastically in the second (fourth semester) project. This necessitates a different approach to organizing the project work and sharing the work load.

Table 1
Overview of the different themes for design-build projects in civil, architectural, IT, electrical, chemical and mechanical engineering. Data is listed for the first and fourth semester projects.

Engineering Program	Civil Eng.	Architectural	IT	Electrical	Chemical & Biotech.	Mechanical
Design-Build Project theme 1.Semester 4.Semester ⇩	Heating of houses - energy consumption ⇩ Digital building modelling	Construction design ⇩ Indoor climate/ Energy design	Implement a text based version of the game Monopoly ⇩ Not finally described	Design of a digitally operated oven ⇩ Design of an energy converting system	Combustion ⇩ Enzyme production	Design/build of a sound muffler for a lawnmover ⇩ Design/build of an automation system in Lego
Design Build Project team size	Groups of 4 ⇩ Groups of 4-5	Groups of 4 ⇩ Groups of 4	Groups of 2-4 ⇩ Groups of 4-6 (or more if collaboration between groups)	Groups of 2 ⇩ Groups of up to 10	Groups of 4-5 ⇩ Groups of 4-5	Groups of 4 ⇩ Groups of 4
Credits (ECTS points)	5 ECTS (13 weeks) ⇩ 10 ECTS (13 weeks)	2,5 ECTS (7 weeks) ⇩ 7,5 ECTS (? weeks)	10 ECTS (part of 16 weeks course) ⇩ 10 ECTS (16 weeks)	10 ECTS (16 weeks) ⇩ 10 ECTS 16 weeks)	3 ECTS (14 weeks) ⇩ 7 ECTS (16 weeks)	10 ECTS (16 weeks) ⇩ 10 ECTS (13 weeks)
C-D-I-O Phases	C-D-I-(O) ⇩ C-D-I-(O)	C-D-(I) ⇩ C-D-(I)	D-I-(O) ⇩ C-D-I-O	D-I ⇩ C-D-I-O	C-D-(I) ⇩ C-D-I	C-D-I-O ⇩ C-D-I-O
Classification of projects	Build-the bridge ⇩ Probably bucket-of-water	Minced Meat + Build-the-bridge ⇩ Build-the-bridge	Build-the-bridge ⇩ Probably Build-the-bridge	Build-the-bridge ⇩ Build-the-bridge	Bucket-of-water ⇩ Minced-meat	Build-the-bridge ⇩ Build-the-bridge

Mostly the student credits for the project work is 10 ECTS points. The design-build projects can be incorporated in the time schedule in two ways:

- The project can be integrated as a ***framework*** with contribution from several courses in the semester. This means that the project does not exist in its own right but is an integrated part of several courses in the same semester.
- The project can be carried out as a practical project in a *separate* course, which is allocated its own time in the time schedule. This can e.g. be a four hour slot in the morning or afternoon once or twice a week during the 13 week semester, or a full-time allocation during the three week interval.

Sometimes these models are combined so that the project starts as a framework but ends up as a separate course with a concentrated period of a three week interval where the students mainly *implement* or *operate* in the work spaces.

With respect to the model types it is obvious that the *build-the-bridge* type is the mostly used. In many cases a range of limiting criteria and conditions are set up by the teachers. The other project types are used except the *what's-up* project model, which is not yet applied at DTU. In some of the study programs a combination of different project models have been

used. At the B ENG Program in Architectural Engineering a project model is used which combines the *minced-meat* and the *build-the-bridge* models. Here the students first have to analyze a concrete building in order to learn how buildings are constructed. After that they have to use the generated knowledge to design and build a bird-observation tower for themselves.

LESSONS LEARNED

The most frequently used project model at DTU at the moment is the *buid-the-bridge* model.

Today only a few B ENG programs at DTU provide teaching in team work and project management as a part of the design-build projects. The trend seems to be 'learning-by-doing'. However, in most programs the need for proper teaching in team work has recently been recognized. It is planned to develop a joint model for teaching the students team work and project management techniques.

The design-build projects need to become more complex during the semesters to ensure an appropriate progression in the programs. One way of increasing the complexity of the project work is by increasing the size of the work groups. In the B Eng program in Electrical and Electronic Engineering the group size is increased from 2 persons in the first semester to 10 persons in the fourth semester. Being 10 persons in a group force the students to split up in smaller groups and they experience the importance of proper project management, coordination, a realistic time schedule etc. when they work together towards the same overall target.

For several of the B ENG programs it has been a challenge to incorporate as many of the C-D-I-O phases as possible in the design-build projects - especially in the first semester projects where the students are just started at the university. The number of C-D-I-O phases incorporated in the fourth semester project is higher, which reflects the increased student capability. A quite general observation is that students have great difficulties in focussing on Conceiving (problem identification, clarification and limitation). Very often the teams will rush into a solution mode (Design), which is locked by (unexpressed) predefined assumptions.

Design-build projects seem to inspire the students but nevertheless they put a lot more time and energy in the project if it ends up with some kind of assessment. The students are not motivated sufficiently solely by knowing that putting a lot of effort in a project make them become better engineers. Assessment and grading is a necessary factor for motivation.

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Construction of EIP-CDIO Quality Assurance System Based on ISO

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ABSTRACT

School of Engineering, Shantou University has been working on EIP-CDIO (Ethics, Integrity, Professionalism, Conceive, Design, Implement, Operate) engineering education and training mode reform since 2005, whose main purpose is to cultivate student's personal ability including self-learning, creation, team work, systematic adaptation and control. In order to guarantee quality of EIP-CDIO education, as well as bring teaching quality control and management in line with international standards step by step, we apply ISO Standards in teaching, administration and student management in our school. Taking our actual situation into consideration, we prepared four manuals: Quality Manual, Administration Manual, Teaching Manual and Student Management Manual. As a result, we were granted ISO19001:2000 (quality management system) and ISO 14001:2004 (environmental management system) certifications by TÜV Rheinland in April 2008. This paper describes how to construct quality assurance system for EIP-CDIO training mode based on ISO. Eight principles of ISO are descried in detail in how they are applied in education reform.

KEYWORDS

EIP-CDIO, ISO9000, Quality Management, Practice and Exploration

1. Introduction

CDIO is a training mode for engineering education, originally proposed by several universities such as MIT. It stands for Conceive, Design, Implement and Operate, which covers whole life cycle of product from R&D to running. Carrying this in education, student can not only study in a more active and practical way, but also learn relationships between different courses. Moreover its Quality Syllabus is simple, feasible and applicable, which makes it usable by any program of engineering education.

The philosophy of CDIO was introduced to School of Engineering, Shantou University in 2005. Through yeas of practice we found that its syllabus details the characteristics of CDIO requirements, however as an ovulation for education and reform practice, it needs a normative framework for sustainable improvement. The family of ISO9000 standards provides such a good framework. The family of ISO9000 standards is a series of standards for quality management and quality assurance formulated by the International Organization for Standardization. It is widely recognized as quality assurance system by international certification accreditation bodies because of its strong guiding principles, high practicality and logic in nature. Introducing ISO standards to CDIO is helpful to standardize teaching management and administration, ensure gradual and sustainable improvement of teaching management of CDIO training mode.

2. Establishing ISO Management System

Since we establish ISO management system on purpose of guaranteeing education quality of CDIO training mode, the first thing is to make sure systematic character of quality management system, particular environment of department, our management policy and objective, responsibilities or duties of staffs in each level. Then we set up a verification system and improve programs for every education process, through which establish a seamlessly connected management system for continues improvement.

The establishment of our ISO management system mainly includes 9 stages: summary and investigation, training of standards, determination of objectives for quality management, determination of responsibilities and resource allocation, preparation of management documents, trial running, inner check, third-party certification, continuous improvement and perfection.

Fig. 1. Procedure of establishing ISO management system

In stage summary and investigation, we summarize experiences of education quality management and education administration in a systematic and scientific way, and then draw a picture of whether each education process is up to standard requirements through investigation. In standards training stage, we require administration team to carry out ISO 9000 standards training and every staff to learn ISO 9000 standards. In stage determination of objective for quality management, we set up quality policy in accordance with customer's requirement and education purpose, formulate long-term and annual quality objectives, and clarify internal structures and functions of positions within them. In stage determination of responsibilities and resource allocation, we set up a sound system of personal responsibility and allocate resources accordingly to guarantee effective functioning of the education system. Then we go to the preparation of management documents stage. In this stage we make sure the administration files have great influence on the realization of quality management objectives to overcome arbitrariness, randomness and formalism in education management. In trial running stage, we confirm all kinds of documents in the whole school, through which improve their effectiveness and reliability. In inner check stage, we require all procedures to be implemented in accordance with these documents, and provide corrective and preventive measures if anything improper are found. After all the above steps are done, we can seek for a third-party certification, and finally improve our quality management system constantly through continuous improvement and perfection stage.

To ensure successful implementation of EIP-CDIO, we establish a four-level document system as illustrated in Fig.2. Level 1 is programmatic guiding document, i.e. Quality Manual; level 2 are general specification documents including technology, management norms and procedures; level 3 are program documents including plan programs and measures; level 4 are record and evidence documents including identification and evaluation reports as well as records.

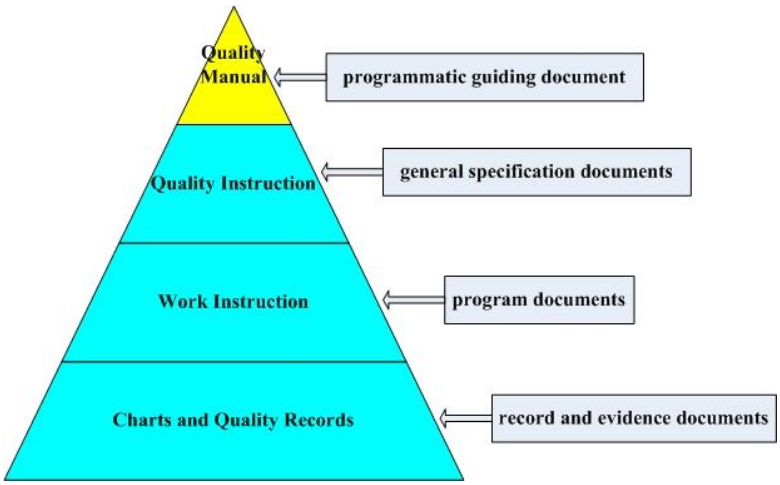

Fig.2 Teaching quality management document system

3. Eight principles in the process of CDIO education management

ISO 9000 standards have an Eight Principles: customer focus, leadership, involvement of people, process approach, system approach to management, continual improvement, factual approach to decision making, and mutually beneficial supplier relationship. For our CDIO training mode, these 8 principles are not only guiding spirits when setting up education policy, goals and quality documents, but also fundamental basis of planning CDIO education strategy and program.

According to the Eight Principles, CDIO training mode should be built upon involvement of all faculties in the school. ISO emphasizes fundamental effect of every faculty in each position because only through their fully involvement can the organization benefits from their abilities. In the very beginning of the EIP-CDIO education reform, we realized the importance of involving all faculties. First of all, all teachers are required to participate in formulating training plan to make it more reasonable and operable. Secondly, training plan is divided into teaching steps, through which teachers could learn their objectives and importance in it. As a consequence, these objectives can motivate staff to work hard and also can be references of evaluating faculty's performance.

Leadership in the Eight Principles is a key point. ISO 9000 puts great emphasis on devotion and responsibilities of top administrators. We set up "top-leader" responsibilities for education quality control in school and department levels. President of the school and chair of each department are the first ones in responsible in school and department levels, respectively. President and chairs should be planners, leaders and promoters of quality control. There is also a vice president who is responsible for the implementation of teaching procedures. According to ISO 9000 standards, leaders in each level should formulate policy, define objectives and allocate tasks for education quality control. They should play the role of leaders to drive other teachers to practice the principles and policies of EIP-CDIO education. Leaders should also establish a good teaching environment through effective resource allocation and incentives to advocate a common value and set an example for faculty. Great efforts should be paid to create a good working environment for faculty to reflect cares from the school and departments.

Customer focus and continual improvement are two basic points in implementing ISO. Students are direct customers of education management in university, employers and parents of students are indirect customer. In our CDIO training mode, students are the focus of teaching and training in project-oriented learning. We use discussions, inspirations, etc in class teaching, changing the old way in which teachers are players while students are audiences to the new one that students are players while teachers are directors. Through this way, enthusiasm and initiative of students are activated. In the project design, teachers

raise problems, students manage teams themselves to conceive, implement and accomplish the projects. All these activities are to be correspondent with “student focus” principle. We are continue to upgrade our education and teaching to provide better and better education services to students.

In ISO’s point of view, continual improvement is a permanent purpose of an organization. It includes improvements in objectives, objects and approaches. To make sure sustainable development of CDIO training mode, we must transform education quality control from static gate-keeper type to dynamic sustainable-development type, must keep the sustainable development and creativity throughout the whole procedure of education quality control. The processes of education quality control should be carried out in a Plan-Do-Check-Action (PDCA) fashion, sustain continuous and proceed systematically between PDCA cycles to establish a self-diagnosis, self-correctness and self-improvement system. In this way, our long term effectiveness of quality control is guaranteed, education quality is continuously improved. The procedure of PDCA in School of Engineering is shown in Fig.3.

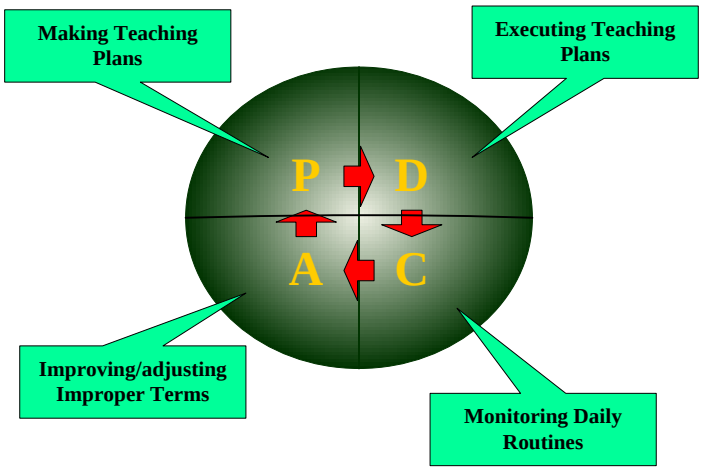

Fig. 3 PDCA cycle in teaching management of School of Engineering

4. Conclusion

The key point of introducing ISO quality control system is to introduce advanced management ideas. ISO 9000 standards emphasize process and putting process under control. We established a management system for education quality to put various teaching process under control, through which education quality is improved steadily and students, parents and employers are satisfied eventually. It is proved from our practice that the introduction of ISO quality management in CDIO teaching practice is effective in guaranteeing reasonable, effective inspection and supervision and normalizing CDIO teaching processes.

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CONTRIBUTIONS OF INDUSTRY EXPERTS TO FACULTY DEVELOPMENT: EXPERIENCES FROM THREE UNIVERSITIES IN NORTH AMERICA

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Abstract
Fifty years ago, university faculty were distinguished practitioners of engineering with rich experiences in the practice of engineering in industrial settings. Today, most engineering faculty are experts in research and development in very specific disciplines. There is a gap between need and reality. Involving industry experts in the faculty development process may be a way to narrow the gap. This paper provides a rationale for faculty development in engineering skills, and links it with CDIO Standard 9. Three universities that have adopted the CDIO approach to engineering education – Massachusetts Institute of Technology, the U. S. Naval Academy, and the University of Manitoba – provide examples of bringing industrial professionals to engineering faculty teams, and of inviting industry experts to be involved in engineering education programs.

Keywords: faculty development, industry involvement, CDIO Standard 9

Introduction
The history of faculty development in engineering education has deep roots in engineering practice. Fifty years ago, university faculty were distinguished practitioners of engineering with rich experiences in the practice of engineering in industrial settings. Today, most engineering faculty are experts in research and development in very specific disciplines. They are evaluated on the basis of their disciplinary knowledge and achievements in terms of the impact and quantity of their engineering scholarship, and the levels of research income they generate. [1] New Ph.D. graduates join university faculties with limited experience in the practice of engineering.

There is a gap between need and reality. Involving industry experts in the faculty development process may be a way to narrow the gap. For example, sending engineering faculty to industry or introducing industrial experts to faculty teams could benefit engineering education programs, overall. This paper provides a rationale for faculty development in engineering skills, and links it with CDIO Standard 9. Three universities who have adopted the CDIO approach to engineering education - Massachusetts Institute of Technology, the U. S. Naval Academy, and the University of Manitoba – provide examples of bringing industrial professionals to faculty teams, and of inviting industry experts to be involved in engineering education programs.

Background

Engineering programs that adopt a CDIO approach to engineering education set high standards for faculty. They are expected to demonstrate competence in the personal, interpersonal, and product, process, and system building skills, delineated in the *CDIO Syllabus*, and be able to educate students in these same engineering skills. [2] As part of the *CDIO Initiative*, (www.cdio.org), universities have been exploring ways to enhance faculty competence in engineering skills. They examining best practices in building bridges between engineering education in the university and engineering practice in industry.

Past experiences of CDIO collaborating universities have shown that industry's involvement in engineering education has contributed to the improvement of the quality of that education, by providing learning contexts and environments, as well as much-needed resources. Specifically, industry contributes to engineering education programs by

- Building the context of engineering education (CDIO Standard 1)
- Identifying specific learning outcomes of graduates who are ready to engineer (CDIO Standard 2)
- Providing projects to stimulate 1st-year students' interest in engineering (CDIO Standard 4)
- Providing design-implement projects so that students experience the C-D-I-O cycle of product, process and system (CDIO Standard 5)
- Providing opportunities to faculty members to gain industry working experiences and professional skills, or by directly sending engineers to the program as lecturers or advisors (CDIO Standard 9)

It is this last reference to CDIO Standard 9 that is the focus of this paper.

Enhancement of Faculty Competence in Engineering Skills

Engineering faculty are expected to be innovators in research and development, and in teaching and learning methods. They are asked to adapt their teaching styles to one that is more student-centered, and to teach the personal and interpersonal skills, and product, process, and system building skills specified in the *CDIO Syllabus*. There must be a process for supporting faculty as they enhance their competence in project-based learning approaches, and in the practice of engineering skills that are highlighted in project-based learning experiences.

Enhancement of faculty competence must be accomplished while protecting the academic careers of faculty. Professional development activities should enhance their opportunities for promotion and tenure without putting future academic promotions at risk. The recognition and incentives for faculty need to support faculty professional development.

Effective CDIO programs provide support for faculty to improve their individual competence in personal and interpersonal skills, and product, process, and system building skills as described in the *CDIO Syllabus*. The nature and scope of faculty development varies with the resources and intentions of each program and institution. Actions that enhance faculty competence in engineering skills may include:

- Professional leave to work in industry
- Partnerships with industry colleagues in research and education projects
- Inclusion of engineering practice as a criterion for hiring and promotion
- Appropriate professional development experiences at the university

Enhancement of faculty competence in engineering skills related to the *CDIO Syllabus* is the focus of CDIO Standard 9.

STANDARD 9 -- ENHANCEMENT OF FACULTY SKILLS COMPETENCE
Actions that enhance faculty competence in personal and interpersonal skills, and product, process, and system building skills

If faculty are expected to teach a curriculum of personal and interpersonal skills, and product, process, and system building skills integrated with disciplinary knowledge, they need to be competent in those skills themselves. Most engineering professors tend to be experts in the research and knowledge base of their respective disciplines, with only limited experience in the practice of engineering in business and industrial settings. Faculty need to enhance their engineering knowledge and skills so that they can provide relevant examples to students and also serve as role models of contemporary engineers. Faculty development and support may take forms similar to these three basic approaches.

- Hire new faculty who have industrial experience or give newly hired faculty a year in industry to gain the experience before they begin teaching.
- Provide educational programs, such as seminars, workshops, and short courses, for current faculty, or allow current faculty leave or sabbaticals to work in industry.
- Recruit senior faculty with significant industry experience to teach and mentor other faculty, or attract practicing engineers from industry to spend time teaching at the university. [2]

Each of these three approaches is described below.

Faculty Experience in Industry

In hiring new faculty, one would consider whether they have had any actual engineering experience. If so, this should be valued as a positive aspect of their background. If not, the department or program could offer released time to fill in this professional experience. As an example, some programs send newly hired faculty to work with industry for one year prior to the start of their formal teaching responsibilities. This program is aimed at professionals beginning their faculty careers immediately after their advanced degrees. The goal of the year with industry is to develop product, process, and system building skills, as well as to broaden their perspectives on engineering research. This time does not count toward the time required to gain promotion. As an added benefit, they return with a deeper understanding of the research needs of industry. Programs must have institutional support to resource this effort.

Education in Engineering Skills

Programs also face the challenge of encouraging existing faculty to teach personal and interpersonal skills, and product, process, and system building skills in their courses. A variety of approaches can lead to enhanced skills of existing faculty. One approach is to sponsor short courses or training programs within the university on personal and interpersonal skills, and product, process, and system building skills. Commercially available short courses can be used as well. Larger industrial enterprises often have extensive internal training programs and will allow local faculty to participate. Encouraging such programs also sends the message to faculty that program leaders consider these skills important and are willing to expend resources to help faculty acquire them.

Faculty leaves and sabbaticals that are often taken at other universities or in government agencies can be taken in industry. Again, program leaders must ensure this time is used to expand the faculty member's competence in teaching the engineering skills specified in the *CDIO Syllabus*. Otherwise, faculty might be inclined to pursue only their research interests.

Contributions of Practicing Engineers

Finally, programs can attract distinguished engineers with significant experience in product development and system building. Programs will need institutional support for this effort, as career engineers often do not satisfy traditional hiring criteria. An excellent example of a nationally sponsored effort of this type is the *Visiting Professors' Scheme*, sponsored by the Royal Academy of Engineering in the United Kingdom. [3] This program brings experienced engineering professionals back to the university to share their experiences with both students and faculty.

Faculty Development Practices at Three Universities

Three universities that have adopted the CDIO approach to engineering education describe ways in which their engineering programs involve industry experts in faculty development.

Massachusetts Institute of Technology

Since the Massachusetts Institute of Technology (MIT) was founded in 1861, its motto, *Mens et Manus*, has been at the core of its culture. What Founder William Barton Rogers called "the most earnest cooperation of intelligent culture with industrial pursuits" [4] shaped MIT in its dedication and respect for practical learning, and defined its purpose of "instituting and maintaining a society of arts, a museum of arts, and a school of industrial science, and aiding generally, by suitable means, the advancement, development and practical application of science in connection with arts, agriculture, manufactures, and commerce". [5] In such a cultural environment, MIT faculty have diverse academic and industrial backgrounds. They are dedicated to teaching and research, with relevance to the practical world as a guiding principle. The extensive collaboration between MIT and industry has an important effect on faculty development and the support of a practical learning culture.

Professors-of-the-Practice. The MIT School of Engineering has always had full-time and part-time appointments of practicing engineers. In the 1990s, the position of *Professor-of-the-Practice* was created to recruit and hire high-level expertise from the world of practice into the academy. Their main responsibilities were to teach and to conduct and supervise research. There are currently more than 20 *Professors-of-the-Practice* in the MIT School of Engineering. For example, the Department of Aeronautics and Astronautics has three *Professors-of-the-Practice*: Jeffrey Hoffman, Robert Liebeck, and Deborah J. Nightingale.

Dr. Jeffrey Hoffman, former NASA astronaut with extensive spaceflight experience, continues to participate in international space cooperation activities. He now combines his research projects related to the International Space Station with his teaching of space operations, design, and space policy. Robert Liebeck, member of the National Academy of Engineering, is a world-renowned authority in the fields of aerodynamics, hydrodynamics, and aircraft design. He now heads Boeing's blended-wing aircraft project, and works with students in experimental and capstone courses. Deborah J. Nightingale, member of the National Academy of Engineering, has a distinguished career in higher education, the private sector, and U.S. government agencies. With her experience in executive leadership positions in operations, engineering, and program

management, she contributes relevant and practical insights to students' studies in these areas.

Visiting Lecturers From Industry. MIT also has *Visiting Lecturer* and *Senior Lecturer* positions that attract senior practitioners from industry and government to teach and advise students. Senior Lecturers complement the faculty; their professional experience and distinguished teaching accomplishments are equivalent to those of the faculty. Visiting Lecturers come to MIT to present series of lectures. The flexibility in appointments to these positions enables MIT to have faculty teams who stand on the frontier of knowledge and practice. For example, Fredric F. Ehrich of General Electric, Colonel John Keesee of the U. S. Air Force, and the late Robert Seamans of the National Aeronautics and Space Administration, served as Senior Lecturers in MIT's Department of Aeronautics and Astronautics.

CDIO programs aim to provide a Conceiving — Designing — Implementing — Operating context for engineering education. One of the main responsibilities of industry professionals is to help students understand real engineering environments, and to develop personal, interpersonal, and product, process, and system building skills. At MIT, these practitioners not only bring their experiences into the classroom, but also provide guidance in student engineering projects.

United States Naval Academy

When considering the engineering faculty composition at the United States Naval Academy (USNA), it is important to recognize the career activities of its graduating seniors. First, the Navy hires all USNA graduates. Secondly, all graduates go into operational fields, for example, driving ships, submarines or airplanes, or commanding marines in the field. No USNA graduates go directly into engineering jobs. After an initial operational sea tour (4 to 6 years after graduation), some will elect to move to career opportunities in engineering, acquisition, program management, or test and evaluation. There they will work in concert with the Navy's civil service engineering manpower, with the engineering officers, progressing to roles in systems engineering and program leadership. In contrast to other U. S. services, all officers in engineering and acquisition start their careers as fleet operators. For those who ultimately land in engineering capacities, they will necessarily be thrust into systems engineering or management roles. As long as they're in uniform, they do not work as discipline-specific engineers.

Military Faculty. From its founding, the Naval Academy has had a unique civilian/military faculty structure, distinct from both traditional university faculties and the faculties of the other U. S. service academies. USNA attempts to keep the Engineering Division staffing at 50% active duty military, and 50% civilian, believing that each contributes distinctive strengths to the overall program. The civilians are largely tenure-track with Ph.D.'s in their respective fields. The uniformed officers have at least a Master's degree, with half having a Ph.D. as well. The uniformed faculty members provide the connection with fleet applications, helping to motivate students to the relevance of engineering studies to their operational careers. The younger officers serve three-year tours, returning afterward to their sea-duty careers. In most engineering departments, they teach either service courses, such as *Statics* and *Dynamics*, or core courses such as *Electrical Engineering*, which are required of all midshipmen regardless of major. These junior officers provide a youthful enthusiasm, and model the role of young officers of high technical competence, drawing the connection between operations and engineering for students.

The more senior officers come to the Naval Academy after significant career accomplishments either at sea or in engineering roles, and then complete a Ph.D. en route to joining the faculty for the last decade of their uniformed service (nominally, in their forties). For the aviators, most are graduates of the Test Pilot School and will have served in acquisition, test and evaluation, or engineering assignments. Officers from other warfare areas will have served as engineers at sea, shipyards, or acquisition. Regardless of their academic discipline, they unavoidably bring a systems and operations perspective to engineering, viewing disciplines such as thermodynamics or materials science from the perspective of the 'whole airplane' or 'whole ship.' While they do not have the disciplinary or publishing credentials of the civilian faculty members, they have better insight into both what engineering officers do in the field, and commonly will have spent years working with civilian engineers in both government and industry. Hence, many are very conversant with the skills required of a practicing engineer in the modern workplace.

Civilian Faculty. Civilian faculty members fall into four categories. *Adjuncts*, as elsewhere, are term appointments with a Master's degree, teaching exclusively lower-level service courses, such as *Statics*, or core courses in electrical engineering. All have industry credentials. *Tenure-track* civilian professors have career histories, credentials, and expectations similar to those at research institutions, with the research and teaching balance shifted more toward teaching. Due to the promotion and tenure requirements, their development has the same strengths and weaknesses as at other research institutions. They are nationally published scholars with deep disciplinary expertise, and are expected to be master teachers. Few have held jobs outside of higher education, and lean toward a reductionist or engineering science perspective on the skills of engineers.

The last two groups are similar, both which are designed to be analogs of MIT's *Professors-of-the-Practice*, though that term is not applied locally. These two groups are distinguished only by the source of their funding. Internally funded members must hold a Ph.D. by law, whereas externally funded members need only hold a Master's degree. The latter is important, allowing USNA to include individuals with stunning credentials as senior executives in government and industry. Their appointments are rolling multi-year terms, paid on a full-professor's scale, yet without tenure. Of five Aerospace Department members in this category, four are retirees from industry or government, and three hold Ph.D.'s.

Boeing's John McMasters wrote insightful articles on the subject of aerospace industry workforce skills. He whimsically describes the industry demand for both the deep disciplinary expert and the systems thinker as "splitters" and "lumpers." The former are reductionists and analysts, while the latter are synthesists and integrators. One wants to split problems to their constituent parts; the other is interested principally sweeping the whole together. The aerospace industry, he insists, needs both, while noting that the latter are more difficult to develop and tend to be both more rare and more valuable to modern industry. [6]

Educators, developed and rewarded in traditional engineering science domains, will not likely transform themselves into systems thinkers. The process of their growth has demanded that they become disciplinary experts in order to gain promotion and tenure. If students are to grow to be systems thinkers, to respond to customer needs, they must see both "splitters" and "lumpers" in the classroom. Hence, while USNA military faculty are expected to bring a systems perspective. USNA is very deliberate about targeting hires within each of these categories among the

civilians. The tenure-track system tends toward disciplinary expertise—the splitters, while senior military and *Professors-of-the-Practice* tend toward system-building perspectives—the lumpers.

University Of Manitoba

Manitoba is a province of approximately 1.1 million persons, about 800,000 of whom live in or near the capital city of Winnipeg. The economy is based on a mix of manufacturing, mineral exploitation, transportation, hydroelectric generation, medical research, financial services, agriculture and food processing. The University of Manitoba, located in Winnipeg, is home to the only Faculty of Engineering in the province. At any point in time, the student population averages about 1,200 undergraduate students and 400 graduate students. The university offers five different accredited engineering programs at the undergraduate level. Approximately 80% of the Professional Engineers in Manitoba hold at least one degree from the University of Manitoba, creating a close working relationship with industry.

Chair in Design Engineering. In July 2000, with the appointment of an Associate Dean for Design Education, responsibility for the further development of this relationship was established. This was further strengthened in January 2001 when the faculty was awarded a Natural Sciences and Engineering Research Council (NSERC) Chair in Design Engineering with the mandate to improve the quantity and quality of design within the curriculum, and improve the image of design, in general, throughout the province. As is the case in most engineering schools located in research-based universities, the majority of faculty members at Manitoba have based their careers on their research interests. Fewer than 10% of tenured staff have industry experience. Design classes, where they existed, tended to focus on the application of technical tools to constrained problems. In fact, there was, and continues to be, a great deal of debate over the definition of the term *design*.

The NSERC Chair provided resources to develop a home for design. It has provided a non-departmental base to appoint persons who support engineering skills, such as, communications and team building. It has become the Design Center to which students, staff and industry look for a broader perspective on design in particular, and engineering in general. Looking at the mandates of the NSERC Chair and the Associate Dean for Design Education positions, it was necessary to change the mix of professional resources available to students. The basic solution was to create positions defined as *Engineers-in-Residence* (E-i-R).

Engineers-in-Residence. Initially these were part-time (60%) positions filled by either retired engineers from industry, or principals in small consulting firms. They were provided with offices, communication connections and a mandate to establish relationships on campus, based on their industrial backgrounds. *Engineers-in-Residence* have exceeded initial expectations. It was anticipated that they would be a convenient source of industry-based input for both academic staff and students. They have become much more. There are now seven *Engineers-in-Residence* involved in a variety of ways. They are teaching, both singly and on teams, at both undergraduate and graduate levels. Within the capstone design courses, they serve as advisors, or, in civil engineering, as course coordinators. In these roles, they encourage their colleagues from industry to participate as advisors in the capstone courses. Design reviews have become a feature of capstone courses, with the review panels composed of engineers from industry. This broadens input well beyond the formal meetings, and improves communication between students and potential employers.

Supervision of student clubs, such as SAE, IEEE, and the Great Northern Concrete Toboggan Competition, is a time commitment that many academic staff find difficult to meet. Because these groups are focused on design, construction and competition, the backgrounds of the *Engineers-in-Residence* are very appropriate to teams' needs, and they have become very involved. One notable involvement is with the SAE student branch that has grown to be the 6th-largest student branch in the world. Competitive success has improved significantly and industry now provides financial, technical and in-kind support, thanks largely to connections developed by E-i-R faculty advisors.

Industry Collaboration. Because researchers are always looking for support from industry, the *Engineers-in-Residence* have become a source of information input. For the most part, their roles have been that of facilitators who appreciate the constraints experienced both on and off campus. This has led to a number of new research projects that have industry involvement beyond that of a funding source. Because of the pre-existing relationship that one of the *E-i-Rs* brought to the discussion, it has been possible to develop a formal working relationship with the Manitoba aerospace industry. Four industry partners -- three major companies and an aerospace human resources group -- have entered into a Memorandum of Understanding with the University that provides the resources needed to fund one of the *E-i-R* positions. Functionally, the Manitoba Aerospace Engineering Liaison Group meets quarterly for a working dinner at which the education needs of the companies and the functional academic constraints of the university are discussed in detail and at length. This has raised the level of understanding and involvement to a higher plain. Three other industry groups have approached the University with the intent of establishing similar arrangements.

An idea that sought to bring a limited number of individuals on campus to share their specific experiences with students and staff has grown well beyond the initial expectations. The University has benefited from the communication links that *Engineers-in-Residence* bring with them to access both human and physical resources from local and regional industries. Traditionally, the academic staff established connections by approaching industry. Today, industry is approaching the University to determine how to work together to improve the quality of engineering graduates and research results.

Summary

The involvement of industry in faculty development is growing with great benefit to engineering students and programs. The practices at the Massachusetts Institute of Technology, the U. S. Naval Academy, and the University of Manitoba are examples of introducing industrial professionals into the education program, and helping to increase the proficiency level of the entire faculty team.

MIT has created positions that attract practitioners from industry, including *Professor-of-the-Practic*e, *Senior Lecturer*, and *Visiting Lecturer*. These industry experts help faculty to incorporate personal and interpersonal skills, and product, process, and system building skills into the classroom and student projects.

The U. S. Naval Academy has a unique civilian/military faculty structure, with each group accounting for 50% of the faculty. The civilian faculties are largely tenure-track with Ph.D.'s in their respective fields, while the military group has rich working experiences and

achievements at sea or in engineering roles. The combination of the two provides both disciplinary expertise and systems perspectives to engineering education.

The University of Manitoba appointed an Associate Dean for Design Education, and an NSERC Chair in Design, and created a Design Center. The University created several positions for *Engineers-in-Residence* who serve as teachers, team directors, advisors, project reviewers, and research facilitators, and help to bring more human and physical resources into engineering education.

At all three universities, they have created positions for practicing engineers in the faculty structure, and established flexible management systems to attract industry experts. These professionals join in every aspect of the education process, including program design, teaching, project instruction, student assessment, thus, providing real contexts for product and system lifecycle development.

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CYBERLAB, REMOTE VIRTUAL EDUCATIONAL LABORATORY

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ABSTRACT

Online learning is in its infancy, but is developing rapidly on a global scale. The shift from the classroom to online can be described as a shift from “efficiency to quality”. [10] High quality online teaching is not just a matter of transferring class notes or a videotaped lecture to the internet; new paradigms of online learning which include both the process and content are needed.

In this paper, we discuss the design and development of interactive online learning materials that enables the virtual replication of the learning of both the process and content of electronic laboratory - CyberLAB, Remote Virtual Educational Laboratory. CyberLAB refers to a representation of the laboratory that is distributed on the network and provides access to and control of the real laboratory instrumentation and experiences. The CyberLAB not only provides interactive animation but adopted the high level simulation technique in designing the virtual instrument. The design refined to every details behavior of the instrument to achieve the real experiences and authentic learning environment. To avoid moving the experimental setup to the classroom or to overcome the difficulties of accessing laboratories facilities at any time, CyberLAB allows students to explore and conduct real-time experiments over the internet. This online facilities helps developed our students to be an independent learner, allowing them to take charge of their own learning. CyberLAB allows students to immerse themselves into the virtual laboratory experience allowing the chance to practice, reflect, and implement new approaches based on feedback and learned content.

KEYWORDS

Remote, virtual laboratory, simulation learning, online experiment

Introduction

Online learning is in its infancy, but is developing rapidly on a global scale. High quality online teaching is not just a matter of transferring class notes or a videotaped lecture to the internet; new paradigms of online learning which include both the process and content are needed and are being explored. Lecturers and students are now looking forward to new e-learning (online learning) experiences for different reasons [1]. While lecturers gain time for higher level teaching by moving the knowledge acquisition of basics into self learning activities, students like the flexibility for time planning reasons.

On the other hand, the traditional laboratory teaching programs are costly and the high-cost instruments could only be shared by a limited number of students at one time, at times limiting the effectiveness of the learning process. Thus, there is much potential and benefits in leveraging on technology to create an online virtual laboratory environment.

However, a key component of current online learning implementation is missing – online practical learning or laboratory experimentation. In engineering education, written exercises are necessary for a student to master mathematical tools while virtual experimentation done by simulation serves to reinforce the understanding of the subject. In engineering, real experiments are indispensable for developing skills to deal with instrumentation and physical processes, while, practical projects provide the framework for a group of students to learn to cope with real world problems. There is no doubt that nothing will replace synchronous learning through face-to-face interaction and physical hands-on experiences but it is not always feasible for students to attend conventional classes. Thus, the design of online learning materials is not meant to replace for face-to-face sessions but rather as a complement (and at times a supplement) to facilitate all related learning and teaching experiences.

Hence, the team's challenge was to ensure that what the students experience online is identical to the actual experiment. The online practical learning has to be designed such that it allows the students to immerse themselves into the virtual laboratory experience, allowing them the opportunity to practice, reflect and implement new approaches based on feedback and learned content.

System Planning and Design

The advances made by Information Technology has led to some learning processes being replicated to varying degrees in the form of courseware available through the Internet, thereby providing flexibility and convenience as well as overcoming some traditional barriers such as time and space. Leveraging on web-based learning systems, the team decided to integrate the concept of virtual instrumentation and the concept of an e-Learning community to address the challenge.

The team developed the CyberLAB system which is designed in an interactive web-based environment consisting of virtual instruments and guided experiments on basic circuits to create a virtual laboratory. The strategies used in designing the system were based on the essential characteristics of the change in the learning process as learning progresses [2]. It is important to match resources and support to the appropriate stage. Hence, the architecture of the CyberLAB system is designed in three stages, describing the transition from novice to expert performance – conceptualisation, construction and dialogue [2].

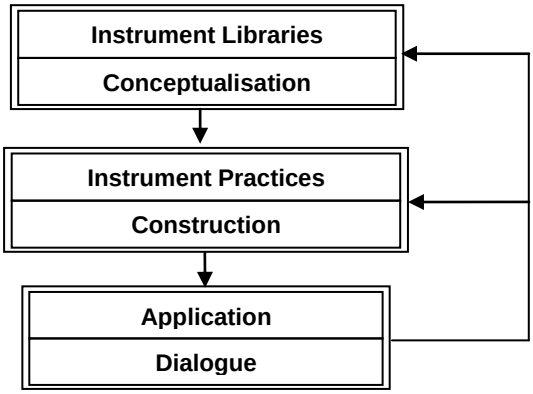

Figure 1. Learning cycle used in CyberLAB system

The first section of the CyberLAB system – **'**Instrument Libraries**',** consists of a series of simulated instruments that are commonly used in the laboratory. The purpose of this section is to present the instruments in interactive activities for students to explore and build concepts. This involves an interaction between the students' pre-existing framework of understanding and a new exposition.

Figure 2. User Interface Design for the 'Instrument Library'

To allow the process of building and combining concepts through the use in the performance of meaningful task, the second section of the CyberLAB system was developed into a series of 'Instrument Practices**'** that consist of the combination of more than one instrument. By designing a specific practice, the system allows the student to combine the concepts grasped in the earlier section of 'Instrument Library' and to reinforce their understanding of each instrument. The instructional design of this section follows closely on the cognitive scaffolding and experiential learning.

Figure 3. User Interface Design for 'Instrument Practices' - Function Generator & Oscilloscope

As a complete learning cycle, the conceptualisations built in the first section are tested and further developed in the last section of the CyberLAB system – **'**Application**'**. This section was designed as a situated learning or task-based learning activity through the online experimentation. The defining characteristic of this section is the 'combining' of the learning experiences and self reflection.

Figure 4. User interface design for the ‘Application’ - Experiment setup for Inverting Amplifier

The development of the instrument libraries and practices is based on the simulation technology. The process of development of each instrument involved: familiarisation of the instrument, studying every detailed function and behaviour of the instrument, modelling the instrument into mathematical models and graphical representations. The result is an integration of the simulated instrument into a learning framework.

Hardware Setup of Remote Online Experiment

The hardware setup of the system is illustrated in the block diagram shown in Figure 5. The experiment circuit was connected on the analogue and digital logic trainer. The input signal to the experiment was generated from the function generator and the output signal from the experiment was measured using the oscilloscope. Both instruments were connected to the GPIB (General Purpose Interface Bus) controller to allow the access and control thru the PC system. The relay/ DIO (Digital Input and Output) controller is used to control the circuit connection.

Compared with simulated experiment in virtual reality, remote manipulation on real processes is easier to implement and more versatile. In fact, adding another instruments hardware in the system does not involve the elaboration of complex mathematical models and graphical representations.

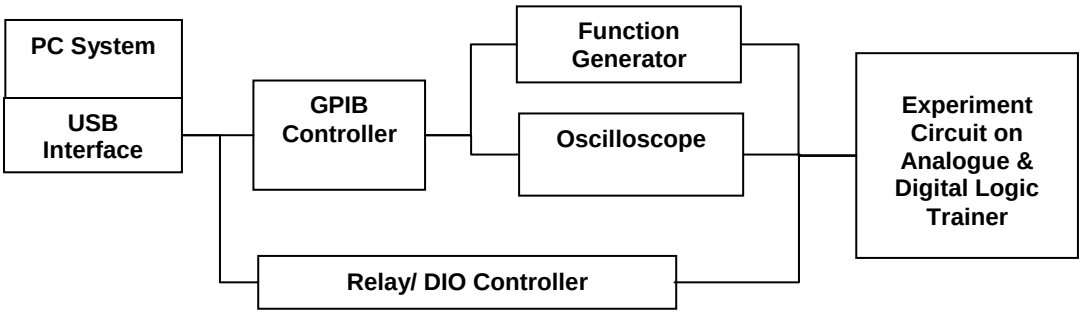

Figure 5. The block diagram of the system hardware setup

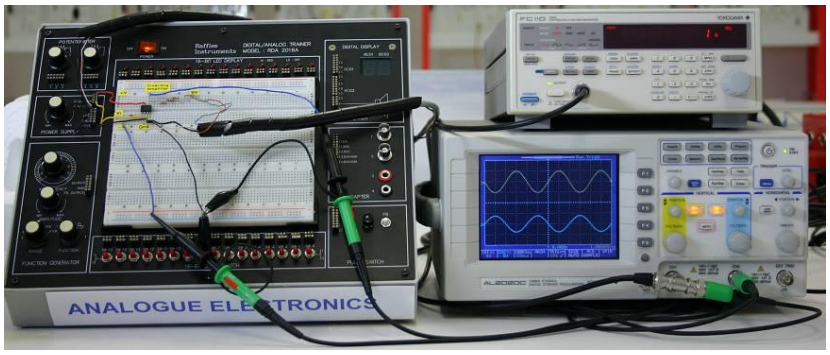

Figure 6. System Setup

Benefits of the System

The key benefit of the CyberLAB system is to leverage on simulation technology to increase students' engagement in practical learning. With the pedagogy in place, CyberLAB has enabled students to explore and conduct experiments over the internet and to have an advanced understanding on the concepts of experiments and how to operate the equipment even before the actual hands-on session [3].

CyberLAB has helped to shorten the learning time required in the laboratory. The students' advanced understanding on the concepts of experiments and the operation of the equipment has helped to reduce potential damage to lab equipment by new students as it would be easier for them to recognise the knobs and buttons on the front panel once they have used the virtual system. It has also facilitated revision for students to further reinforce the understanding of the experiment. It has provided an opportunity for on-demand experiments which enables the students, especially the slow learners, to repeat their experiments.

This online facility has helped developed our students to be independent learners to take charge of their own practical learning, thus cultivating a life-long learning habit. CyberLAB has indeed enabled students to immerse themselves into the virtual laboratory experience, allowing them the chance to explore and conduct experiments over the internet and to practice, reflect, and implement new approaches based on feedback and learned content.

Staff have also benefitted from the use of CyberLAB as it has enabled them to devote more time to the weaker students as well as provide more challenging experiments for the better ones. With the remote online feature of CyberLAB, staff could also access it and conduct live demonstrations in the classroom when necessary.

With CyberLAB, high-cost instruments are now being able to be 'shared' by many students which would substantially reduce the cost of training instruments and increase the utilisation rate of instruments.

Evaluation Results

The evaluation of the CyberLAB has been focused on the course design and course delivery workflows. [9] The evaluation process contains face-to-face sessions that are combined with CyberLAB online activities. Questionnaires have been developed to gather the opinion of 160 students who undertook the evaluation. In general, evaluation results were very positive in regard to the different issues dealt with. Staff felt that the students were able to set up the instrument with better understanding during the actual hands-on session after learning thru the CyberLAB. Students felt that this mode of experiment learning is interesting and useful where they can practice the practical experiment at home without having to access the

laboratory. A large majority of students responded positively to this mode of learning and enjoyed learning with this package.

Table 1
The responses obtained from 160 students during the evaluation

Evaluation element	Quality criteria	Question	Percentage of Satisfaction
Resources	Usability	The interface is user friendly.	95%
		The navigation is easy to follow.	92%
	Difficulty	It is easy for someone with minor computer skills to use the online course.	86%
	Clarity	The graphics/symbols clear to the user.	83%
		The layout (use of colours, fonts, icons) is appealing to you.	85%
Activities	Usefulness	The exercises are useful and meaningful.	88%
	Difficulty	The exercise is easy to complete.	85%
	Clarity	The exercise instructions are clear and precise.	88%
	Motivation	In general, the online course encourages independent learning.	93%
	Timing	You completed the 2 units of the online course in one hour or less.	87%
	Progress	In general, your level of technical skill improved after completing the online course.	87%

Conclusion

Unlike the theory-based online learning, CyberLAB provides an interactive web-based environment, consisting of virtual instruments and guided experiments on basic circuits to create a virtual laboratory for practical learning. “Good teaching practice is creative and provides energy, excitement, inspiration and enjoyment; ingredients that are essential for learning to happen.” [4]. The CyberLAB not only provides interactive animation but adopts the high level simulation technique in designing the virtual instrument. The design is refined to every detailed behavior of the instrument to achieve the real experiences and authentic learning environment.

With the remote online experiment feature, CyberLAB allows students to explore and conduct experiments over the Internet and to have an advanced understanding on the concepts of experiments and how to operate the equipment even before the actual hands-on session. With this advanced understanding on the operation of the equipment, CyberLAB has helped to reduce potential damage to equipment. Furthermore, the system facilitates revision. To avoid moving the experimental setup to the classroom or to overcome the difficulties of accessing laboratories facilities at any time, CyberLAB allows students to explore and conduct real-time experiments over the internet. CyberLAB has helped developed our students to be independent learners, allowing them to take charge of their own practical learning.

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Design and Realization of CDIO Elements in Civil Engineering Material Course

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Abstract: In order to cultivate creative civil engineering graduates with CDIO (Conceive-Design-Implement-Operate) competencies, a core engineering fundamental course, "Civil Engineering Materials", was redesigned and implemented since 2006. One of the main objectives of the course was changed into developing CDIO competencies through a teamwork redesign project. The curriculum synopsis, contents, teaching methods and the resource of course-books were re-designed to follow CDIO initiatives. The results of the teamwork redesign project and the students' assessment were discussed in this paper. It can be seen, comparing to reform before which performed by mainly using sitting, listening and testing fashion, that the ability, knowledge and personality of the students were effectively enhanced through such course reform.

Keywords: CDIO competencies, Civil Engineering Materials, Team design project, Teaching methods

INTRODUCTION

"Civil Engineering Materials" (CEM) is a core engineering fundamental course. The objectives of the course before reform was to enable students to understand, choose, mix and apply various materials correctly according to curriculum synopsis of china[1]. The main teaching and learning method were carried out by classroom teachings for 38 hours, and then demonstrated and validated experiments for 10 hours. The assessment was given based on a written examination and an experimental report at the end of the semester.

In 2006, Shantou University joined the CDIO Organization [2-3], and CEM was redesigned according to the competencies and standards of CDIO and implemented since then. The objectives of the course have been reform to: a) understand and apply materials correctly; b) understand and practice the process of designing and developing materials; and c) develop CDIO competencies through a teamwork redesign project. The curriculum synopsis, contents, teaching methods and the

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resource of course-books were re-designed to follow CDIO initiatives. The curriculum synopsis was set according to the "Ability Interrelated EIP-CDIO Mode" provided by the university. A web (http/www.matcv.stu.edu.cn/) was constructed to extend studying resources and to display students' projects.

CURRICULUM SYNOPSIS

The objectives of the course have been shifted from "enable students to understand, choose, mix and apply various materials correctly" to "develop new materials with a special attention on energy, resource, and environment problems" and to "cultivate CDIO competencies". In order to fulfill these objectives, the curriculum synopsis of CEM course was rebuilt with a reference to "I,T,U" method[4] as shown in Tab.1. Compared with reform before, the contents in CEM course were extended and increased as follow: 1.2 Production and application of civil engineering material considering social and resource problems; 1.3 Fundamentals on environmental friendly insulating materials; and 1.4 Teamwork redesign project with repeated C-D-I-O processes for developing a new material.

The levels of the related competencies to achieve after this reform are shown in Table 2. In order to discipline and cultivate the competencies of conceiving, designing, and implementing and operating systems in the enterprise and societal context, more attention was paid to 2.2 Experimentation and knowledge discovery, and 3.1Teamwork design project was also put forward and extremely emphasized as shown in Tab.2.

Table 1 Curriculum synopsis of CEM course after reform

	Detailed rules	Objectives			
		Knowledge	Comprehension	Application	Synthesis
TECHNICAL KNOWLEDGE AND REASONING	1.1 Basic civil engineering materials principles and knowledge	**B**	**B**	**B**	**B**
	1.2 Production and application of Civil Engineering Material considering social and resource problem.	**B**		**B**	**B**
	1.3 Fundamentals on environmental friendly insulating materials	**C**	**B**	**B**	**C**
	1.4 Teamwork design project	**B**	**C**	**A**	**A**

Table 2 Ability inter－related EIP-CDIO mode of CEM course after reform

		Instruction	Teaching	Utility
PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES	2.1 ENGINEERING EASONING AND PROBLEM SOLVING		B	B
	2.2 EXPERIMENTATION AND KNOWLEDGE DISCOVERY	A	B	A
	2.3 SYSTEM THINKING	B	B	C
	2.4 PERSONAL SKILLS AND ATTITUDES	C	B	B
	2.5 PROFESSIONAL SKILLS AND ATTITUDES		B	B
INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION	3.1 TEAMWORK	B	A	B
	3.2 COMMUNICATIONS		A	B
	3.3 COMMUNICATIONS IN FOREIGN LANGUAGES		C	
CONCEIVING, DESIGNING, IMPLEMENTING AND OPERATING SYSTEMS IN THE ENTERPRISE AND SOCIETAL CONTEXT	EXTERNAL AND SOCIETAL CONTEXT	D		
	ENTERPRISE AND BUSINESS CONTEXT	D		
	CONCEIVING AND ENGINEERING SYSTEMS		B	
	DESIGNING		B	A
	IMPLEMENTING		B	B
	OPERATING		C	

CONTENT AND METHOD

In order to reach at the objectives of “Ability Interrelated EIP-CDIO Mode” provided by the SHANTOU University and the curriculum synopsis as shown in Tab.1 and Tab.2, the contents of CEM course were redesigned; the significance differences of curriculum contents before and after reform were shown in Table 3.

From Table 3, it can be seen that the course contents after reform emphasize on self learning, teamwork spirits, system thinking, experimentation and knowledge discovery, and communication competencies. The course contents were composed of three parts. The first part containing basic civil engineering materials principles and knowledge was the same as reform before. This part was accomplished mainly through the classroom lecturing and self learning in 24 hours, a total duration of six weeks. The second part was an extension of what the students had to learnt and perceived, including the influence of material production and application on energy, resource, and environment.

Six hours in three weeks were allocated for the second part, and students needed to perform self learning, adopt system thinking and share through classroom discussions. The significance of this reform is the teamwork design project for developing new materials (such as a durable marine concrete, or an environmental friendly insulating concrete) in another 5 weeks. In order to fulfill the project's aim, students needed to perform self learning, adopt system thinking, engage experimentation and knowledge discovery and share through classroom discussions.

It also can be seen from Tab.3 that the assessment was also changed from "according to classroom examination and an experimental report at the end of the semester" to "the design report and the product display, as well as classroom examination." Then, the standard of grade was also changed. Before reform, writing examination and experimental report were made up 80% and 20% of the total grade respectively. And after reform, redesign process (including performance during design and final report) and writing examination were made up of 60% and 40% of the total grade respectively. The abilities of working independently and learning independently, as well as team spirit and communication skills were emphasized in this reform.

Table 3 Contents and methods of CEM course before reform and after reform

	Before reform	After reform
Contents	Master basic civil engineering materials principles and knowledge; Enable students to understand, choose, mix and apply various materials correctly;	Master basic civil engineering materials principles and knowledge; Enable students to understand, choose, mix and apply various materials correctly ; An extension of civil engineering materials principles and knowledge such as, production and application of civil engineering material considering social and resource problem; Knowledge about environmental friendly insulating materials; The teamwork redesigns project usual including repetitive discussion, design and practice process.
Assessment	1) Classroom examination 2) An experimental report at the end of the semester	1)Classroom examination, 2) Design report and display of products as well as routine performance

Grade standard	80% , writing examination 20% , experimental report	40% , writing examination 60%, t Design report and display of products as well as routine performance

TEAMWORK REDESIGN AND CDIO PROCESS

CDIO competencies were cultivated mainly through completing a team redesign project in this course. The students were divided in groups, and each group was made up of four or five students. The title of the projects were provided by teachers or students themselves, such as 1) high-performance concrete used for high-speed highway; 2) high-performance concrete used for seacoast; 3) heat preservation mortar; 4) water resisting mortar and so on. Throughout the design process, teachers guided students to go through an entire CDIO cycle; the students' experienced independent inquiry learning, worked in collaboration with their teammates, and competed among teams.

The project was carried in two stages. The first stage was the design stage and the second was the evaluation stage. In the first stage, each team accomplished references reading and comprehending, mixture planning, raw materials selecting, sample preparation, testing procedures, results and discussion analyses, and received conclusions for the selected item. In the second stage, each team displayed their products, and whole class would then evaluate the design and give their comments on the design. The team displaying the design needed to defense or debate or accept the comments. After the evaluation, each team needed to revise its design according to the comments, and put forward another discussion, design and practice process.

Figure 1 shows a team completing a teamwork design project including discussion, design and practice process. The team tried to development a new wall material by using shell-lime and fly ash. The project was put forward after considering social and resource problem, and the new wall material would be an environmental friendly insulating material. First they accomplished reference reading and comprehending, then they selected raw materials and mixture planning based on the principles of environmental protection, energy-saving and materials on the spot. They applied the first mixture and found that the w/c ratio was high, leading to lower strengths, as shown in Fig.1a.

The team, then modified their mixture design according a further reference reading and discussion as well as suggestions of teachers and the students of other groups, as shown in Fig.1b. The polymer was added to enhance the tensile strength, the w/c ratio was reduced, and a new curing method was put forward in the second mix design. After the test and analysis for the second designed mixture as shown in Fig.1c, the third designed mixture was proposed by the students as shown in Fig.1d. It can be seen, that the students' innovative ideology, analysis ability, teamwork spirits, system thinking, experimentation and knowledge discovery as well as knowledge of CEM were effectively enhanced through such three times of CDIO process. The teamwork redesign project also improve students' ability to communicate with others and capability of self-learning.

Microsoft Excel - 粉煤灰免烧砖第一阶段配比

	A	B	C	D	E	F	G	H	I	J	K	L
1						Mixture						
2		Mixture of the fist experiment		Fly ash	Cement	Lime	Shell ash	Gypsum	w/c			
3	Experiment	2008.5.23～2008.6.23	1	55%	10%	15%	16%	4%	50%			
4	Experiment	Five group specimens	2	55%	15%	15%	11%	4%	50%			
5	Experiment	Based on the experme	3	55%	20%	15%	11%	4%	50%			
6		1. W/C will be lower to 40%										
7	2	2. Adding reduce water agent										
8	3	3. Testing slump										
9	4	4. Adding 3% SBS										
10						Mixture						
11				Fly ash	Cement	Lime	Shell ash	Gypsum	SBS			
12			1	55	10	15	16	4	3%			
13			2	50	15	15	16	4	3%			
14			3	45	20	15	16	4	3%			
15			4	40	25	15	16	4	3%			
16			5	35	30	15	16	4	3%			
17										1cm3		
18						Data						
19				Fly ash (kg)	Cement(kg	Lime (kg)	Shell ash	Gypsum	SBScm3	Sand(kg)	Water(kg)	
20			1	1.31	0.2385	0.35	0.38	0.0954	0.0712	3.56085	0.9496	2.3739
21			2	1.26	0.34455	0.34455	0.3675	0.092	0.0723	3.6129	0.9634	2.4086
22			3	1.22	0.443	0.33225	0.3544	0.0886	0.0611	3.6574	0.9753	2.43825
23			4	1.18	0.53	0.32	0.34	0.08556	0.0737	3.6833	0.9822	2.45556
24			5	1.136	0.6201	0.31	0.33	0.08268	0.0744	3.7182	0.9915	2.47878

a) The first mix design

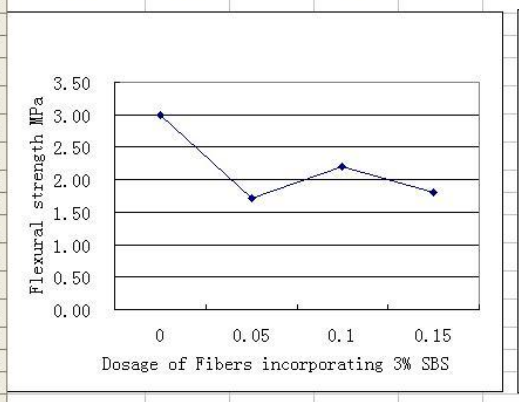
24	配合比	Fly ash	Cement	Lime	Shell ash	Gypsum	SBS	Sand/Ash	W/C	Fiber(%)	reduce
25	1	40	15	25	16	4	3%	0.5	0.3	0	
26	2	40	20	20	16	4	3%	0.5	0.3	0	
27	3	40	25	15	16	4	0%	0.5	0.3	0	
28	4	40	25	15	16	4	1%	0.5	0.3	0	
29	5	40	25	15	16	4	5%	0.5	0.3	0	
30	6	40	25	15	16	4	3%	0.5	0.3	0.05	
31	7	40	25	15	16	4	3%	0.5	0.3	0.1	
32	8	40	25	15	16	4	3%	0.5	0.3	0.15	
33	9	40	25	15	16	4	0%	0.5	0.3	0.05	
34	10	40	25	15	16	4	0%	0.5	0.3	0.1	
35	11	40	25	15	16	4	0%	0.5	0.3	0.15	
36	12	40	25	15	16	4	3%	0.5	0.3	0	
37	13	56	25	15	0	4	0%	0.5	0.3	0	
38	14	51	25	15	5	4	0%	0.5	0.3	0	
39	15	46	25	15	10	4	0%	0.5	0.3	0	
40	16	40	25	15	16	4	0%	0.5	0.3	0	
41	17	51	25	15	5	4	3%	0.5	0.3	0	

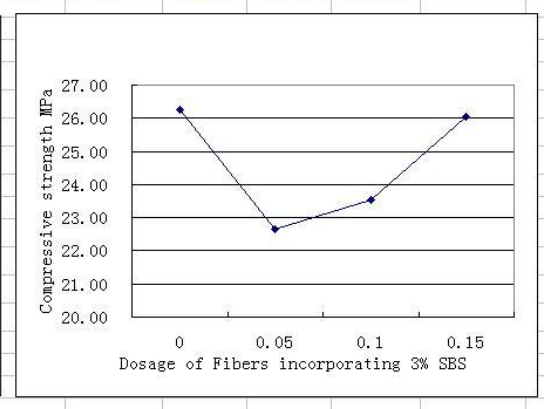
b) The second mix design

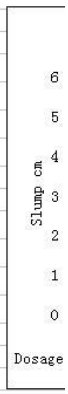
6	40	25	15	16	4	0.03	0.5	0.38	0.05		1.72
7	40	25	15	16	4	0.03	0.5	0.38	0.1		2.21
8	40	25	15	16	4	0.03	0.5	0.38	0.15		1.80

选用数据对比表

No	Fly ash	Cement	Lime	Shell ash	Gypsum	SBS	Sand/Ash	W/C	Fiber(%)	reduce agen	(MPa)
16	40	25	15	16	4	0	0.5	0.38	0		2.36
9	40	25	15	16	4	0	0.5	0.38	0.05		2.44
10	40	25	15	16	4	0	0.5	0.38	0.1		2.65
11	40	25	15	16	4	0	0.5	0.38	0.15		1.94







Data shows the incorporting fiber leads to both Flexural strength and Compressive strength decrease. It is incredible.

c) The result analyses

Microsoft Excel - 砖第3阶段配比

文件(F) 编辑(E) 视图(V) 插入(I) 格式(O) 工具(T) 数据(D) 窗口(W) 帮助(H)

宋体 12

B1 Mixture of the third experment

	A	B	C	D	E	F	G	H	I	J	K
1		Mixture of the third experment									
2		Fly ash	Cement	Lime	Shell ash	Gypsum	SBS	Sand/Ash	Water	Fiber(%)	educe agent (g
3	1	560	210	350	224	56	16.8	700	420	0	7
4	2	560	280	280	224	56	16.8	700	420	0	7
5	3	560	350	210	224	56	0	700	420	0	7
6	4	560	350	210	224	56	5.6	700	420	0	7
7	5	560	350	210	224	56	28	700	420	0	7
8	6	560	350	210	224	56	16.8	700	420	0.7	7
9	7	560	350	210	224	56	16.8	700	420	1.4	7
10	8	560	350	210	224	56	16.8	700	420	2.1	7
11	9	560	350	210	224	56	0	700	420	0.7	7
12	10	560	350	210	224	56	0	700	420	1.4	7
13	11	560	350	210	224	56	0	700	420	2.1	7
14	12	560	350	210	224	56	16.8	700	420	0	7
15	13	784	350	210	0	56	16.8	700	420	0	7
16	14	714	350	210	70	56	0	700	420	0	7
17	15	644	350	210	140	56	0	700	420	0	7
18	16	560	350	210	224	56	0	700	420	0	7
19	17	714	350	210	70	56	16.8	700	420	0	7
20	18	644	350	210	140	56	16.8	700	420	0	7
21											
22											

d) The third mix design

Figure 1 Cases of enhance CDIO competencies by completing a teamwork redesign project

REFORM EFFECT ACCORDING TO RESPONDSES OF STUDENTS

Based on the faculty observations through the project process, the students' abilities and the students' learning efficiencies were significantly enhanced after this reform.

A student wrote in a personal reflection, "Through this project I further realize the virtue of EIP-CDIO approach. In the approach we learned how to study, how to communicate and how to cooperate. I have gotten a deeper appreciation of a civil engineer. I realize that we need not only to posses a rich, comprehensive professional knowledge, but also, more importantly, to be professional in learning and conduct".

Another student wrote in his personal reflection: "It is true that do more, learn more. We should pay more attention to practical abilities, such as independent thinking self-learning. Teamwork is not a work easy to be done; each member of a team must have his own unique insight in order to complete the project perfectly. How to communicate effectively, how to screen the useful knowledge, and how to use knowledge are all great challenges for us. It is true that practice is the sole criterion for testing truth."

One student reported: "The teamwork redesign project of CEM makes us really go into the construction practice. We resisted at first doing this project because we thought the experiment being hard, dirty and tired. However, during the project process we really felt the joy of the harvest of working hard, and understood the knowledge more deep-set through learning from practice. Here, I show my thanks to Teacher Li for providing us the good guidance, and I also thank my classmates for their good ideas to amend my project."

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DESIGNING ACTIVE LEARNING EXPERIENCES FOR A FIRST-YEAR INTRODUCTION TO CHEMICAL ENGINEERING MODULE: LESSONS LEARNT

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ABSTRACT

This paper summarizes the experience of implementing CDIO framework into a 3-year Diploma in Chemical Engineering curriculum at Singapore Polytechnic, focusing on the Year-1 module, *Introduction to Chemical Engineering*. This introductory module was initially introduced in April 2008 to all first year Chemical Engineering students at Singapore Polytechnic.

The paper firstly compares the more active and experiential learning approach advocated by CDIO with more traditional approaches to teaching, which continue to be the main stay of teaching in the Polytechnic. Secondly, it goes on to describe the approach taken by the module team when developing the Introduction to Engineering module, which aim to expose students to the real world of chemical engineering, showing the diversity of practical applications and familiarizing them with key developments and challenges in the field. Emphasis is placed on designing out-of-classroom activities to provide meaningful active learning experiences that build around a brief but integrated curriculum, including a simple design-built experience.

Finally, from initial evaluation, based on staff observations and reflection, as well as student feedback via questionnaires and blogs, the paper shares the learning experiences of the team and present framing for future CDIO curriculum development.

KEYWORDS

Chemical engineering, CDIO, active learning, experiential learning, design-build experience

INTRODUCTION

The Diploma in Chemical Engineering course adopted the CDIO framework as the basis to revamp its curriculum, and as part of the revamp effort, a new module entitled *Introduction to Chemical Engineering* is introduced. Details of the curriculum revamp have been covered in detail elsewhere (Cheah, 2009)[1]. This paper focused on the work done on the module, documenting the development aspects of course design that deviates from traditional practice as well as the key lessons learnt.

The module *Introduction to Chemical Engineering* is designed for target Year 1 students, to expose the discipline to the newly enrolled students fresh from their O-Levels. The introduction of this module into the chemical engineering curriculum is a direct response to the requirement of CDIO Standard 4 which specifies that an introductory course should be included in an engineering curriculum to provide the framework for that engineering practice in product and system building, as well as to introduce to students the essential personal and interpersonal skills.

The importance of this apparently simple requirement cannot be understated. Many of the students selected the course via online application without making the trip down to the institution for course counselling during the Joint Admission Exercise. Instead, they merely relied on general information provided by course speakers during one of the school promotion talks prior to the O-Level Examinations. The module introduces students to the chemical engineering profession, the chemical industry, roles and responsibilities of a chemical engineer; and supplemented with activities designed to offer some appreciation of the kind of job that a typical chemical engineer does. The aim is to give the students a greater appreciation at an early stage, of their course of study, and hopefully will kindle their spirit for learning chemical engineering. The best approach to achieve this aim is to design the curriculum using active learning.

INSTRUCTIONAL STRATEGIES IN SINGAPORE POLYTECHNIC

Singapore Polytechnic follows a 2-semester Academic Calendar system. All full-time diploma programs in the polytechnic are 3 years in duration, and are completed over 6 semesters. Most diploma programs follow the modular system in the so-called flip-flop model. This means that any intake of students is typically divided into 2 cohorts, one in each stage, namely Stage A and Stage B respectively. Students in Stage A will complete a set of modules in one semester, while that in Stage B will study a different set of modules in the semester. The following semester, students from these two stages will swap the modules that are being studied.

Broadly speaking, the main instructional strategies used in the Polytechnic consist of a combination of 3 components, namely Lecture, Tutorial and Practical, in the so-called LTP model. Practical refers to the hands-on component of learning, which typically consists of experiments in laboratory or workshops. The curriculum are all designed around the LTP models, with the curriculum hours distributed between these 3 components, or between L and T for modules without the practical component. The advantage of this approach is that it facilitates the timetabling for each course.

As a general practice, the First Year lectures and tutorials are usually conducted in small class sizes of 20-24 students in media classrooms rather than in lecture theatres. This is to ensure adequate attention can be given to all students so as to ease the transition from secondary school to polytechnic education.

THE TRADITIONAL TEACHING APPROACH VS ACTIVE LEARNING

Until recently, the most common instructional strategy used in this polytechnic, much like other institutions of higher learning (IHLs), is the traditional lecture. A traditional lecture is a highly efficient means of presenting a large amount of information to a large number of students. However, simple presentation of information does not constitute transfer of information from the lecturer to the student. During a traditional lecture, the only one who is really active is the lecturer – talking, writing on the board, showing transparencies, asking questions and often supplying the answers when there is no response from the class. The students are passive – watching, listening and maybe taking notes, but seldom actively thinking about the material being presented. Typically, students sitting passively in a lecture will tend to drift away and, the longer they sit, the more this is likely to occur. After a while, the lecture can become no more than “background noise”.

Thorndike[2] (1910) had long ago recognized the limitations of the lecture model. It is now well established that information that is transferred will be of no use to a student if it is not

retained. Lastly, information also needs to be integrated and transformed into knowledge if that information is to be generalized to solve new problems.

A number of alternative instructional strategies are currently being practiced and promoted in IHLs as a means of overcoming this limitation. These include (but are not limited to) cooperative learning (Johnson, Johnson, & Smith[3] 1991a, 1991b; Millis & Cottell[4], 1998), case teaching (Christensen & Hansen[5], 1987), classroom assessment (Angelo & Cross[6], 1993), writing across the curriculum (Young & Fulwiler[7], 1986), and writing to learn (Young[8] 1997). These strategies fall under the general rubric of active learning. Bonwell and Eison[9] (1991) note that while definitions of the term "active learning" vary, most agree that, when actively engaged, students are involved in more than just listening to the lecturer talking.

Active learning is anything that happens in a class that engages students with the learning material being presented. Students might be called on to work individually or in small groups for brief periods of time to answer questions, brainstorm ideas, conduct some research, or to think of questions about the material just lectured on. At the end of the allotted period, the lecturer calls on several individuals or teams for their responses, then collects more responses from volunteers, and moves on when the correct answer has been obtained and it seems clear that the students understand it.

COURSE DESIGN

The course development team set out to design this course with active learning in mind. The team wanted to expose students to the world of chemical engineering using a combination of lectures, tutorial and laboratory activities. Also from the onset, it is clear that this module cannot follow the flip-flop model. It is of utmost importance that all students fresh from their O-level be exposed to the module in Semester 1, so that we can stimulate their interest in, and strengthen their motivation for, the field of chemical engineering by focusing on the application of relevant core chemical engineering disciplines.

Another benefit of requiring all students to take this module in Semester 1 is that all students will be equipped with the necessary knowledge in two of the most important topics in any engineering studies, which are units and dimensions, and basic engineering measurements. In the flip-flop model, half the students will not have learnt these topics until they reach Semester 2. This posed great difficulties for these students in Semester 1, having to struggle with these concepts while at the same time learning other topics such as energy balance and thermodynamics.

In terms of technical content, the material covered in this module is very elementary. The module introduces students to the chemical industry in general, with special emphasis on Singapore.

To supplement the practicals, the module also includes an industrial plant visit to expose students to a real-world manufacturing plant where they can see first-hand the scope and size of operation of a typical chemical engineering company. Students get to see how the raw materials are transformed into useful products through various unit operations such as fermentation, distillation, filtration, etc. It also serves to provide students with the right perspective on the nature and type of working environment, as well as the importance of various plant utilities such as cooling water, steam and compressed air.

Lastly, to provide an integrated learning experience incorporating various soft skills, a mini Design-Build Experience (DBE) was introduced at the end of the module study. The inclusion of the DBE is consistent with CDIO Standard 5 which stipulates that a curriculum should includes two or more design-build experiences, including one at a basic level and one at an

advanced level. For this module, the DBE comes in the form of a Do-It-Yourself (DIY) project whereby students are required to work in a team of 3 to 4 members to fabricate a water filtration kit. This project has injected some elements of uncertainty into the students' work where the filter can be constructed in various ways and there is no right or wrong answer. This module therefore serves to provide them with a more authentic view on technology and engineering in the real world context.

PRELIMINARY FEEDBACK

As this module was conducted for the first time, student feedback has been obtained for evaluation to identify the impact of the curriculum changes and possible improve aspects of the module. A small group of students have volunteered in providing this feedback on a blog using a questionnaire. The questions used are:

1. In this week's *Introduction to Chemical Engineering* lessons, what task / activity / experience improved your understanding or ability in any of the following skill areas such as "Thinking", "Managing your learning", "Communication" or "Teamwork "?

2. Briefly describe the task / activity / experience.

3. What was good about the task / activity / experience that helped you to understand and / or learn the skill?

4. Other comments, e.g. How can you learn these skills better?

From the initial data, based on staff observations and reflection, as well as student feedback via blogs with questionnaires, the following section of the paper shares the key learning experiences so far, and our present framing for future CDIO curriculum development.

INFUSION OF CDIO SKILLS

At the polytechnic level, it was decided that we started with introduction of 3 CDIO skills – namely (2.4) Personal Skills and Attitudes, (3.1) Teamwork, (3.2) Communication and (4) Introduction to Engineering; every diploma is at its liberty to try out integration of other skills as well. By starting small, the team gained valuable experience on how to integrate the basic CDIO skills into a technical curriculum. This provided the team members with the necessary confidence to explore integration of other skills on their own. The lesson learnt here is that to be familiar with the ways to integrate a particular CDIO skill so that other skills can be incorporated similarly without too much difficulty. The challenge has shifted to the ability to peg the content at the level comfortable to Year 1 students, and to do so without being carried away and incurring too much additional curriculum hours. A brief introduction on CDIO is also covered in this module.

Another important intention is to get students to get accustomed to occasions whereby the lecturer will not necessarily cover all tutorial questions in class. Students typically expect to obtain all the "right" answers from the lecturer. Edstrom et al (2003) noted that students often have a "right-or-wrong" view on technical knowledge. This is similar to the Year 1 students who went through the O-Level examinations prior to joining the polytechnic education. In preparation to the O-Level examinations, 10-year series book is available for students to practice similar examination questions. This book contains the past 10 years O-Level examination questions with model answers attached at the back of the book. By

continuously practicing these exercises, the students are accustomed to getting the "right" answer and not able to think outside the box. The most frustrating part is that students tend to be satisfied when they have arrived at the correct answer, regardless of the process in which the answers were reached. The application of knowledge is limited.

In the engineering curriculum, often the fundamental concepts and principles are interlinked in one way or another and applied in various contexts. Thus, the team has designed tutorial questions and activities which require the application of fundamental knowledge and some forms of system thinking before the final answer can be reached.

Furthermore, students also feel uneasy with vague questions or questions with multiple possible answers as their prior education experiences do not contain these exposures. Thus, when they enter the polytechnic education system, many of them have difficulties in coping with the curriculum that emphasizes more on the application of concepts, as opposed to regurgitating facts and number crunching.

Students who have undertaken this module during their first semester studies acknowledged that the CDIO skills have benefited them, as supported by the student feedback as follows:

> "The activity allows me to experience what is it like where a group of engineers sit down together to discuss on the addition of a new equipment to the plant, thus improving my communication skills with my peers."
>
> "While doing the experiment, I find that I could better communicate with my group members. This helps me to understand my group members better thus allowing the experiment to be carried out without much problems occurring."

The student feedback served as indications that the module design approach was carried out appropriately. As a result of adopting CDIO Standard 4, this introductory module has provided the framework for engineering practice in product and system building. The students felt that this module stimulated their interest in chemical engineering, as illustrated through the student feedback as follows:

> "The good thing is that the experiment gave us a small hole to peek into the real job on how even a small pump requires lots of information and also the people needed to contact about the new pump. The bad thing is that it doesn't feel like doing an experiment."

BETTER ORGANISATION AND ADMINISTRATION OF THE CURRICULUM

The module is designed as a 45-hour module. The 45-hour coverage is divided, for convenience of the Lecture, Tutorial, Practical (L:T:P) classification, as 1:1:1, which means that each week, there is one hour of Lecture, one hour of Tutorial and one hour of Practical. The actual conduct of the lesson, however, deviates from this.

The concept of units and dimensions and basic engineering measurements are taught in the Lecture hour. The Tutorial and Practical hours are used to reinforce the concepts taught in Lecture. Practical lessons are only conducted after 7 weeks. This is to ensure students to gain a good grasp of the fundamental knowledge first because these knowledge are requisites in other engineering modules.

As the one-hour Practical has been timetabled after the one-hour Tutorial, this creates a 2-hour time slot which could be use for conducting tutorial lessons or laboratory activities. With this flexibility, laboratory activities were designed to enable students to understand the roles

and responsibilities of a chemical engineer, expose themselves to the real world of chemical engineering, practice the application of theoretical knowledge and familiarise with developments and challenges in the field. From the eighth week onwards, students carry out their laboratory activities during this 2-hours time slot while the Lecture continues as per normal.

In addition, the team realized the usefulness of lesson plans. In the past, lecturers tend to resist the use of lesson plans as their preparation is viewed as too time consuming, plus the attitude that "of course I know what I am teaching, why should I need one?". When the module was first rolled out, it was taught by the team of two lecturers, i.e. the paper's authors. In the future, it is hoped that other lecturers will undertake the teaching of this module as well, so that everyone is familiar with the intended learning outcomes and subsequently better reinforce them in their own respective modules. It is also a common phenomenon that different lectures can approach the same topic in different manners.

In our situation, the main objective is to ensure that all six classes of students will receive the same knowledge about CDIO skills that is intended to impart on them. The module was primarily designed to acquaint new students with the discipline and learn soft skills in a technical context, and not so much on testing technical knowledge. Therefore, there is a strong need to "standardize" the course materials in terms of intended learning outcomes, especially in the laboratory activities. To this end, the team is convinced that a lesson plan is crucial to ensure that every lecturer can impart the intended teaching points to all students. The lesson plan also serves to alert the lecturers to the correct demonstration of the desired learning behaviour by students.

USE OF A RANGE OF ACTIVE LEARNING METHODS (INCLUDING E-LEARNING)

The module team made use of readily available information in the World Wide Web (WWW). For example, information on what chemical engineering is all about or what a chemical engineer does, where a chemical engineer works, etc can easily be obtained from university websites. Information of unit operations and plant utilities are readily available from vendor companies and chemical engineering companies. Ethics and code of practice can be obtained from websites of Institution of Chemical Engineers or National Society of Professional Engineers.

This generation of students are IT savvy. They also possess their own laptop in line with the Singapore Polytechnic's initiative to adopt the utilisation of notebooks in the curriculum. Tutorials exercises have been designed to appeal to the Internet-savvy students. The exercises require students to make extensive use of the WWW to search for relevant information and write their answers using their own words. Through the student feedback, the students have found that these exercises were enriching as illustrated as follows:

> "Those questions are relevant to our future study or career. Besides that, those practical questions are research based – allow us to experience research especially via internet."

From the past, students have demonstrated that they could not differentiate factual from fictional information searched from the WWW, especially technical information. Thus, it was necessary educate the students the right approach starting from the beginning of their polytechnic education.

Besides, opportunities were also created to allow them to share knowledge through discussion threads made available in Blackboard Academic Suite, an e-learning platform in the WWW.

For example, using the Bhopal Disaster, the team posed some basic information on the Blackboard site, and students are required to read them and then carry out further search using the WWW. A classroom discussion was then held and students were asked to express their views. Students are also asked to challenge their classmates' viewpoints as well as defending their own. However, most students probably do not remember much about the discussion after the discussion has ended, except the studious ones who have taken some notes. Thus, a discussion forum was created for students to carry on the debate beyond the stipulated lesson time. With the availability of discussion threads in the WWW, students post their viewpoints and arguments at the website. Other students from other classes who have been given the access will be able to read these threads and learn from one another. As long as the threads are maintained in the website, students can always refer to it as and when it is needed at their own time.

It was also observed that there were some students who rarely contribute to discussions in class. They are normally shy or lack of confidence to speak out in front of an audience or they are just plain quiet students. Lecturers are usually concerned with these students as it is difficult to ascertain whether these students are following the discussion in class or their minds have drifted away. However, when the students are required to pen their thoughts in the discussion thread, these quiet students were more motivated to contribute one on their own, although the exercise can be done in group of 3 to 4 students. This could be one of the many ways for lecturers to reach out to students who seldom express themselves in class and indirectly check for their grasp of concepts.

Students generally prefer activity based or case study type of exercises as it helped them to learn better and apply some form of system thinking. Hands-on learning with the pilot plant allows them to practice what they have learnt in theory. The way the activities are facilitated also plays an important role to ensure that students are given the opportunities to think first before concluding the final answer or making a firm decision. Here is what the students have to say:

> "We faced a few questions when drawing the flow diagram. We penned our questions, and our lecturer gave us cue instead of direct answer – this allows us to think."
>
> "One thing good about this experiment is that is allows me to do critical thinking, thus it allow me to think more in an assistant engineer point of view rather than in a SP student point of view."

However, there are always room for improvements as there were also comments from students that some of the activities were too easy and boring. More interesting tasks should be incorporated, such as:

> "I would like to have more problem base activities, some relevant or common problem that will occur in our real working area."
>
> "I think these skills could be better learnt if we were given a chance to run the plant that has a situation in it and the group has to solve the situation. I think through this type of activities the group can then fully exhibit the following skills: Thinking, Managing your Learning, Communication or Teamwork."

When the activities were designed, it is not the team's intention to create experiments as per se. The laboratory activities were crafted to allow the students to experience the engineering practice in smaller scales. However, some students still could not recognise the fact that the

activities in this module are not experiments. This is mainly because experiments are still being carried out in other modules.

INTERGRATION OF CDIO SKILLS IN OTHER MODULES

Using an outcome-based approach in assessment of learning outcome, it helped to promote clearer and creative thinking in curriculum development. It is again the experience of the authors that, on more than one occasion, a new idea emerged during brainstorming sessions to overcome a particular problem with the implementation plan. In one instance, the team faced with the possible clash of usage of equipment with another diploma for one of the practicals. The practical of concern involved that of measurement of hydrostatic pressure. After some deliberations, it struck the team that the desired learning outcome can be achieved by using another mothballed pilot plant that was not in use and waiting to be written-off. And once the new idea takes root, the team proceeded to come up with more new ideas to use the pilot plant for the practical of other modules in subsequent years, specifically for level measurement in the Year-2 module *Process Instrumentation*, and level control in the Year-3 module *Process Control*. Similarly, the practical on rotameter calibration makes use of the same pilot plants as another Year-2 module *Chemical Reaction Engineering*.

Motivated by these achievements, the team subsequently made use of other pilot plants with low-utilization rates, for example the Active Pharmaceutical Ingredient (API) pilot plant and reverse osmosis pilot plant. This not only boost the usage of these expensive pilot plants, but also exposes students early to different types of unit operations in chemical engineering. Having some familiarity with these plants early in their course of study, it is hoped that students can recall the concepts that they learnt in Year 1 when they perform some experiments on the same pilot plants in Year 2. Hopefully this will address some of the common problems of students not remembering what they learnt or failing to see the relevance or connection between different modules.

FUTURE WORK

The team, having familiarized with the work done with the integration of the first 3 skills, saw opportunities to incorporate aspects of (2.5) “Professional Skills and Attitudes” and (4.1) “External and Societal Context” into the module as required by CDIO Standard 4. In this regards, coverage of (4.1.2) “Impact of Engineering on Society” and (4.1.4) “Develop a Global Perspective” can be achieved through assignment and classroom discussion of the Bhopal Disaster.

In a similar manner, the team also exposed students to ethics – specifically the coverage of (2.5.1) “Evaluate the Impact of Values and Ethics” and (2.5.2) “Demonstrate Professional Behaviour at Work and in Society” – via a case study on a Singaporean chemical engineer on attachment in a foreign country where drinking is permitted in the workplace. Likewise, (2.5.3) “Staying Current on Emerging Research and Practices in Your Field” focuses on the discussion of impact of biofuels on the environment especially food production, and reinforce the roles and responsibilities of chemical engineer to solve the problem via innovative means, e.g. using algae.

CONCLUSION

The CDIO framework has indeed benefited our students and made engineering education more interesting. The significant factor when developing this introductory module is proper design of laboratory activities and questions. The types of question include case studies,

questions that require some information searching from the WWW, concept questions that involve system thinking and managing their own learning. By having a variety of learning activities, students are given the exposure to be versatile.

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DESIGNING AND USING AUTHENTIC ASSESSMENT OF STUDENT CDIO SKILLS

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ABSTRACT

This paper presents a rationale for learner outcome assessment and an overview of the methods, instruments, and issues that instructors should consider when they design and use assessment of student CDIO skills. It argues the majority of actual assessment practices should be revised to satisfy learner needs, and to improve student learning and performance. To increase their performance, students need educative assessment, which has at least two essential qualities: firstly it is anchored in authentic tasks; secondly it provides students and teachers with feedback and opportunities they can readily use to revise their performance on these or similar tasks (Wiggins, 1998). This is known as authentic assessment and is intended as a richer and more stimulating method for assessing student learning. It provides students with complex and real world situations to be solved.

Authentic assessment requires students to act upon open-ended situations like a professional, by mobilizing their knowledge as well as their broad CDIO skills and attitudes. Only minor adjustments are made to fit any resources constrains (budget, time, and space). Also, continuous faculty feedback plays an essential role, since it allows students to improve before the final demonstration of their skills and competencies. In this sense, assessment is part of the learning process. Hands-on projects offer a natural setting for authentic assessment in engineering education. However, there are some issues one should consider before turning to this method. Specifically, authentic assessment requires well organized planning to help design and outline adequate assessment instruments, foresee effective feedback mechanisms, with the intention to foster student learning and success.

Hence, implementing authentic assessment requires: 1) formulating clear achievement targets; 2) choosing a real-world task; 3) writing a complex task; 4) giving clear instructions; 5) preparing a grading rubric; 6) designing scoring keys. This paper offers helpful information, practical advice, and handy examples to help instructors improve their methods for assessing student learning, particularly within the CDIO curricula.

KEYWORDS

Authentic assessment, rubrics, outcomes, competencies, team-work

INTRODUCTION

One very interesting and highly pertinent decision taken by ABET (the US Accreditation Board for Engineering and Technology), was to shift their accreditation criteria on what is learned rather than what is taught (ABET, 2006) [1]. This decision, seen as no less than revolutionary when it was introduced in 1997, is not a trivial matter, and for faculty and programmes to assume the transition is quite challenging. This implies changing from a teaching paradigm toward a learning paradigm, putting the focus on what students should know and what they should be able to do with their knowledge. The paradigmatic shift changes the question from "how will I teach this" to "how will students learn how to use this, and know when to use this".

This new approach has inspired many other accreditation boards worldwide to go about similar changes. For instance, Canada's accreditation board is contemplating adopting an equivalent approach as its southern neighbour. This new approach has also directly or indirectly motivated initiatives to transform the way engineering schools think of training their students. Therefore, many institutions and engineering programmes realized that sticking to old methods wasn't going to help them achieve the new ABET criteria. Indeed, this new educational paradigm required some innovative thinking and a different way of doing things.

The international CDIO initiative is certainly a convincing example of this evolution. Not only does it fit with the new criteria, but it also addresses the need for engineering curricula to pay more attention to broader skills such as communication and team work, to include active pedagogies that allow experimental hands-on approach, and to give the chance to develop effective life long learning.

Although ABET provides the criteria, many efforts are still needed to define what constitutes good practice for assessment. This article's aim is to provide guidance for faculty on engineering assessment practices. It addresses the need to use authentic assessment which appears to be close to ABET's approach to focus on outcomes. The first part of the paper describes what constitutes authentic assessment, and explains the knots and bolts of how it can be applied in a course. The second part of the paper presents two situations where authentic assessment has been implemented, and offers some solutions for the supervision of team work within project-based courses. The first situation is from the Product Design and Development (PDD) degree at Queen's University Belfast. It offers a solution for communicating with students and supervising the team work in a project. The second situation addresses the challenges instructors must face with supervising large groups in the Mechanical and Materials Engineering programme at Queen's University at Kingston.

What is authentic assessment?

Authentic assessment proposes students realistic situations, where tasks and problems refer to the reality of the professional life or to everyday life, and where they must combine knowledge, skills and attitudes in order to solve the problems. For Tardif (1997) [2], authentic assessment tasks are contextualised and do not refer to an artificial or made up situation. They require judgment and innovation, so students must use their knowledge and their skills with caution and effectiveness in order to solve the tasks properly or to come up with an elaborate answer. This answer can require a personal approach, a certain amount of creativity, or some form of innovation when compared to a rather standardized answer generally awaited through traditional assessment. Students should not simply produce an answer "*in abstracto*", try to guess the right answer, or replicate a learned by heart single right answer. Instead they should take into account several situational, circumstanced or conditional aspects as they exist in the working world, like rules and regulations, ethical aspects, a limited budget, an imposed data-processing environment, and uncontrollable

human behaviour like resistance to change. These conditions can be made contiguous to the required answer, and can affect the nature of the answer or work to be produced.

In this approach, students are evaluated in a constructive and iterative manner, resembling real life situations or in a professional context. Wiggins (1993) [3] lists several characteristics for authentic assessment: It must be realistic, it requires judgment and innovation, it asks students to do instead of to say, to repeat or reproduce, it simulates workplace situations, and allows consultations of resources, feedback and improvement.

What's more authentic assessment proposes students relatively complex tasks, where team work and a number of operations are often necessary to succeed. Solving these complex tasks requires appropriate integration of material from various courses and some iteration before attaining the anticipated result. Feedback from the professor is needed to improve performance. Thus assessment becomes an integral part of teaching. Many times during the semester, students will request feedback from the professor (or colleagues) for the improvement of their final performance. Thus a key ingredient to authentic assessment is allowing students to make errors and learn from them. Feedback is done in a context of transparency, not of secrecy, and based on clearly stated public criteria. It is continuous and provides students with a clear vision of what excellent work is like in order to help them improve future performance.

In contrast, traditional assessment, generally carried out in the form of an exam (mid-term and final), does not comprise this characteristic of realism and complexity, nor does it offer any regular instructor feedback intended for the improvement of performance. Indeed, mid-term and final exams are usually one-way, no turning back summative tests, where students are very often asked to reproduce a certain amount of information they have learned by heart or to solve a rather narrow, unique-right-answer problem. The students have very little information on what will be on the exam. The instructor has very little information on how well the student will perform. Traditional assessment focuses on information recollection, and mobilises little if any analysing, judging and critical thinking skills.

How to use authentic assessment process of competencies?

We propose a five step process for designing effective authentic assessment of competencies. This requires: 1) organizing and planning the process; 2) conceiving and producing the instruments; 3) foreseeing feedback mechanisms; all this in order to 4) allot a grade to each student; and finally trying to 5) continuously improve the process.

Organizing and planning the assessment process

The first step of the process is a preparatory stage, when considering all the factors of the teaching situation and analyzing their influence on how you project to assess the students. This is done by answering the following questions: Where does the course stand within the programme (first year, first semester or last year, last semester?). Is it an elective or compulsory course? Which students and how many students usually sign up for the course? What are the contents of the course, and what is their degree of difficulty? Which specific professional actions or behaviours is the course preparing the students for? Most importantly, what are the competencies or the skills that are needed to be assessed?

The answer to these questions will have an impact on the decisions regarding student assessment. For example, the complexity of a task will be different depending if the course is intended for freshmen, sophomores or upperclassman. The number of students in the classroom will directly impact the extent of the assignment, the number and the size of the teams. After taking into account all of this information, it is possible to choose the most

adapted combination of instruments which will be used to authentically assess students' competencies and skills.

Choosing an assessment instrument

The second step is conceiving and producing the assessment instruments. Assessment instruments can be classified according to their level of authenticity. A lower level of authenticity category includes examinations that call only upon memory: generally multiple choice exams, short answer exams, cookbook type laboratories, homework, drill and practice exercises, and theoretical papers. In our opinion, these types of examinations should no longer exist in universities because of their artificial nature, and their poor capacity to develop competencies. A higher level of authenticity replicates how people actually confront problems and performance challenges in the field. The following are examples of higher level authenticity instruments: team projects, professional work simulations, case studies, long answer exams within a professional setting, clinical evaluations, artistic creations, mock trials, internships, etc. These instruments are perfectly adapted to an assessment of competencies in authentic situations.

There are two elements to this step, the first is writing the performance task, the second is building the rubrics (whether informational or scoring rubric). Writing a relatively complex assessment task that provides students with a challenging ill-defined problem or situation similar to the ones professionals face at work, allows them to demonstrate what they have learned in their very own personal way. This means there is no one right answer and students must use higher end cognitive capacities like inquiring, reasoning and developing plausible hypotheses to solve the problem or situation they were presented. Authentic assessment should also allow them to make mistakes and try over, because that is how learning takes place. Instructors can help students expand and perfect their competencies by pointing toward more sophisticated and effective ways of doing things.

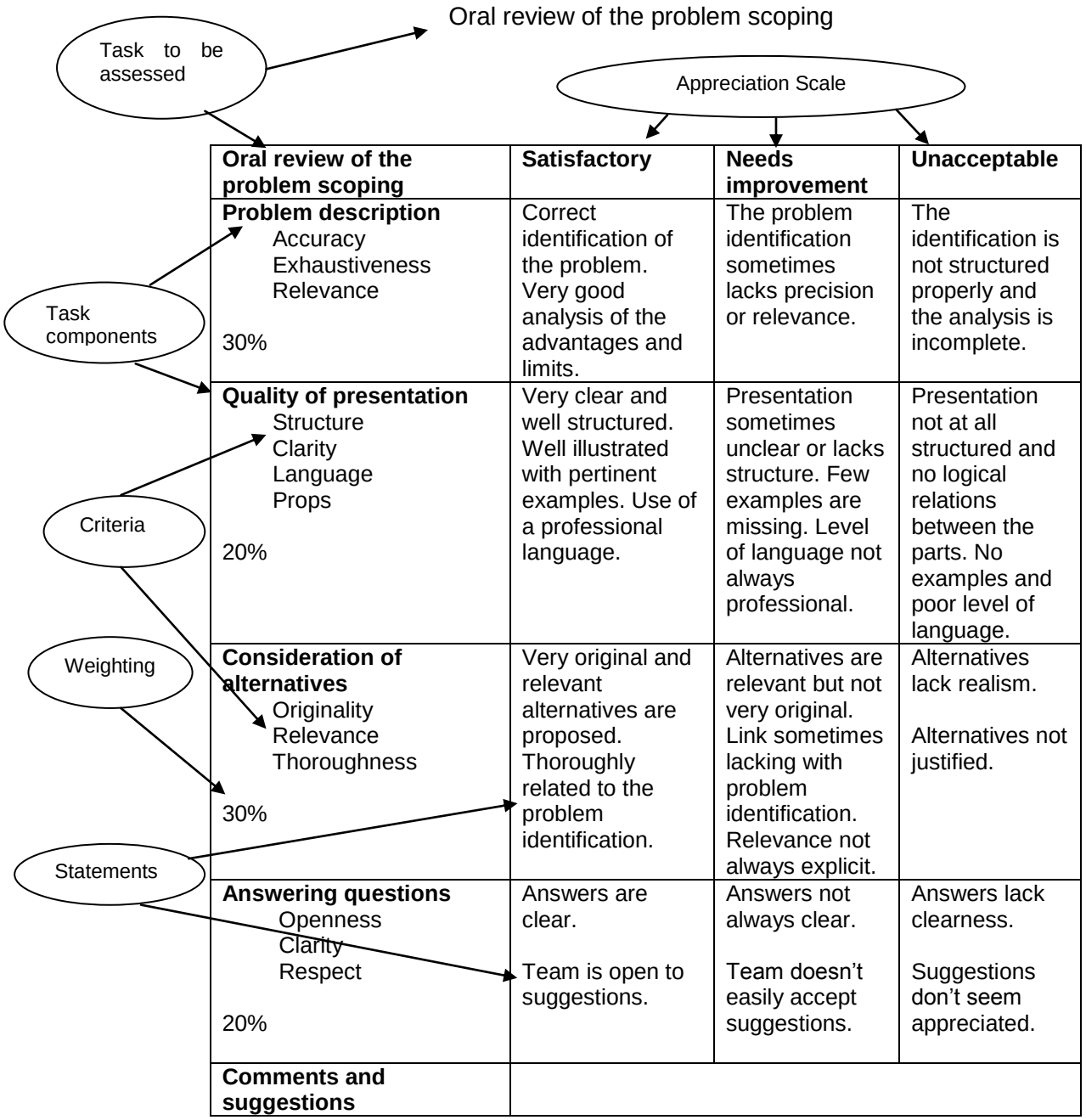
Using an ill-defined problem does not mean students should be left in total absence of direction. Some guidance will be needed in order for them to know what is expected from them. Hence, identifying specific responsibilities and tasks to be accomplished will help them organize the work and increase productivity. For example, defining the steps to follow, the operations to realize, the outcomes to produce, and setting a schedule to respect will definitely contribute to their success. Furthermore, writing clear instructions and communicating them is crucial for quality work. The more precise and clear are the instructions, the better chances will the work handed in meet up with your expectations. This will also facilitate supervision of student work as well as its correction.

The instructions can define team size, how teams will be made up, sharing responsibilities, requirements for intermediate and final reports, requirements for the oral presentation, the bill book and the handover dates, how to get consultations with the instructor, and the performance criteria that come in the assessment rubric.

Assessing student work is always a delicate exercise because of the possible bias du to subjectivity of human judgment. However, this is only a problem when judgment is based upon fuzzy or undisclosed criteria. In fact, assessing student performance using well-specified criteria enhances the reliability of the judgment. That is where rubrics come in handy, allowing explicit listing of criteria important to assess performance. What's more, rubrics can help distinguish between levels of performance for each criterion. In this sense an assessment rubric gives clear guidance of what constitutes successful performance, especially for anything prone to subjective grading. In the following sections we will describe the different elements that compose a rubric.

A rubric usually contains information allowing students to know what is expected from them, and providing descriptive feedback that helps them improve performance. A rubric contains the criteria and the levels of performance, but it should also specify the task that is being assessed, the task components, the weighting allotted to each component, an appreciation scale, and statements describing the performance levels. There should also be space for constructive written comments. Figure 1 gives an example of a rubric and its elements (Prégent, Bernard, & Kozanitis, 2009) [4].

Figure 1. Example of an analytical rubric and its different elements



Oral review of the problem scoping	**Satisfactory**	**Needs improvement**	**Unacceptable**
Problem description Accuracy Exhaustiveness Relevance 30%	Correct identification of the problem. Very good analysis of the advantages and limits.	The problem identification sometimes lacks precision or relevance.	The identification is not structured properly and the analysis is incomplete.
Quality of presentation Structure Clarity Language Props 20%	Very clear and well structured. Well illustrated with pertinent examples. Use of a professional language.	Presentation sometimes unclear or lacks structure. Few examples are missing. Level of language not always professional.	Presentation not at all structured and no logical relations between the parts. No examples and poor level of language.
Consideration of alternatives Originality Relevance Thoroughness 30%	Very original and relevant alternatives are proposed. Thoroughly related to the problem identification.	Alternatives are relevant but not very original. Link sometimes lacking with problem identification. Relevance not always explicit.	Alternatives lack realism. Alternatives not justified.
Answering questions Openness Clarity Respect 20%	Answers are clear. Team is open to suggestions.	Answers not always clear. Team doesn't easily accept suggestions.	Answers lack clearness. Suggestions don't seem appreciated.
Comments and suggestions			

Task definition corresponds to the professional action that needs to be accomplished or to the skill to be developed. In the figure 1 example, two professional skills are being assessed; the capability of giving a clear and well structured oral presentation as well as the capability of analysing a problem and suggesting plausible alternative solutions.

The task components are the more detailed professional tasks required during the oral presentation of the problem scoping. In the example, the components are: 1) problem description; 2) quality of presentation; 3) consideration of alternatives; 4) answering questions.

An assessment criterion is an indication, an attribute, or a benchmark that allows qualifying every component of the task. The number of criteria per component may vary from one to three. In the example, the criteria are: accuracy, exhaustiveness, relevance, structure, clarity, etc.

The weighting is the numerical value, generally given in percentage, allotted to each component of the task. The percentage indicates the weight of each component on the final grade. This valued information helps students adjust their work. In the example, 60% of the weight goes to technical skills, and 40% of it goes to communication skills.

The appreciation scale is a qualitative continuum containing levels of achievement used for judging the quality of the work; this for every task component and its corresponding criteria. The appreciation scale continuum spans from exceptional all the way to an unacceptable performance.

The number of levels is a personal choice, and depends on what better suits the situation. We suggest using a qualitative only scale to assess student's work in progress. A three level scale seems perfectly adequate for this matter. It tells students if their work so far is satisfactory or not, and gives them hints for improving, without judging the level of excellence. Indeed, a student may not be willing to continue his efforts or will not look to improve his work if the instructor considers it excellent. This way, a work considered as satisfactory will make him understand that he has well begun, without however having reached the excellent or exceptional level.

The statements describing the performance levels clearly indicate the quality of the performance for each task component. The rubric should have well defined statements that best describe the quality of the performance for each criterion and level of excellence. The statements should be short, explicit and unambiguous. This is what will probably take the most time during the conception and the writing of the rubric. Therefore they should only be written once all the task components, the criteria and the levels of the appreciation scale are chosen. For example, a satisfactory presentation will be judged as so when it is "very clear and well structured, well illustrated with pertinent examples, and using a professional level language."

Information of the level of performance for each component wouldn't be complete without additional written comments intended to support students' progression. Constructive comments are always welcomed and have a positive effect on motivation. For any shortcomings, they will appreciate concrete suggestions for improvement, useful documentary resources, or consulting an expert that can assist them with better understanding the aspects to be corrected.

Advantages for using rubrics

Using rubrics has at least four advantages: objectivity, equity, transparency, and standard setting within the programme. Rubrics make assessment and grading more objective, consistent, and defendable. Turning to explicit criteria avoids judgement that is subjective, emotional, and random. It also avoids judgement based on the comparison of students' work. This reinforces the equity of judgement; all student work is assessed equally, using the same components, criteria, and appreciation scale. Rubrics support transparency in the communication between the instructor and the students. By making the rubrics publicly

available, students are aware of what is expected from them right from the beginning of the semester. The transparency also helps reduce disputes concerning the grade. Finally, when all the instructors within a department or a programme share their rubrics with one another, it makes it easier to identify some common standards, and gives a clear idea of the quality of the work that is expected throughout the entire programme. This information can be very useful to heads of department, instructors, and any stakeholder interested by student assessment.

Types of rubrics

There are many different types of rubrics, we will however only cover two of them in this paper; the analytical rubric which is used mostly for feedback purposes, and the holistic rubric used for certification and grading at the end of the semester.

An analytical rubric usually holds a higher number of task components. However, an instructor can choose the degree of detail of the appreciation scale by adding sub components that give a more precise description. The goal is to guide the students' work in the most precise manner. An analytical rubric is generally used with any new complex tasks. Instructors will use it for giving feedback to students, but it can also serve as a self-assessment or a peer-assessment instrument.

The holistic rubric has a more global or general character. In this rubric, the task components are not as detailed as in the analytical rubric. The statements describing the levels of performance are more succinct. This type of rubric is generally used for summative assessment of final work, since students have been given the opportunity to improve their work with previous feedback from an analytical rubric.

Here are a few tips for conceiving and writing an assessment rubric. Firstly, if there are many tasks to assess, it is preferable to write more than one rubric. For example, during a project students may be asked to orally communicate during a formal design review, to write a complete report, and to test the prototype they built. In this case, the instructor should write three assessment rubrics, one for each of these tasks. However, writing a rubric is time consuming, it can take up to two hours, and the first draft may not be completely satisfactory. A few iterations and some help from peers or from an assessment expert will give a more satisfying product. Furthermore, this effort invested will be very profitable when comes the time to give student feedback or during the final correction.

Foreseeing feedback mechanisms

Supervision of student work in progress is an important part of the assessment process, mostly because students can come away with insights about their progress in learning. Indeed, instructor feedback is what allows students to improve their skills and develop their competencies, keeping in mind that adequate feedback should help, not hurt. Students need continuous feedback in order to improve the quality of the work. With this intention, here is some advice that can help enhance the quality of the feedback. First of all, feedback remarks should be phrased in a detailed, precise, and constructive manner. By referring to the instructions given at the beginning of the semester, to the intended learning outcomes, and to the competencies, feedback information provides direction for learners and reveals if they are on the right track.

Second, Huba and Freed (2000) [5] refer to feedback as intermediate when it is given during the development of a project, as opposed to final feedback. The different types of rubrics mentioned earlier are very useful to judge the quality of work at various stages of development. Rubrics help students understand the standards by which they will be evaluated, and focus on the characteristics that will be graded. Feedback discussion

sessions should be scheduled in a timely manner, during, as well as after assessment. Feedback information should be delivered orally or in written format, and look at sharing information and exploring alternatives, not giving advice or imposing solutions. Helpful feedback focuses on specific characteristics rather than generalities, and is directed toward observed student work and behavior, not those you infer.

Finally, questioning students is a powerful tool to help them develop an understanding of what they have learned so far, and what they still need to work on. Open-ended questions help develop their critical thinking, as well as their metacognitive abilities. Metacognition is one of the most important ingredients in the learning process. Some examples of open-ended questions are: Why did you choose x instead of y? How do you know that this is the right way of doing x? What was the hardest thing you had to overcome in order to do x? What are the implications of your conclusions to x? How can you improve the x process by using the y model? Etc.

Allotting the final grade

Each institution has its own marking system, some are literal (for example: A, B, C, D) and some are numeric (for example: 65%, 75%, 85%, 95%). When a literal marking system is in place, there is usually a numeric value associated with each letter used to calculate the grade point average. For allotting grades, instructors will use the scale provided by their department. Table 1 presents an example of equivalence between a literal marking system and its numeric equivalent.

Table 1. Equivalence between a literal marking system and a numeric grading system

Excellent	**Very good**	**Good**	**Insufficient**
A+ = 4.3	B+ = 3.3	C+ = 2.3	D+ = 1.3
A = 4.0	B = 3.0	C = 2.0	D = 1.0
A - = 3.7	B - = 2.7	C - = 1.7	E = 0

In reality, even though the marking system is literal, many instructors will begin by allotting a numeric score to each student, and will then convert it into a literal mark. The probable reason for this behaviour is that it isn't easy to add letters (B + C- + A =?) and come up with an average. Nevertheless, we suggest using a literal marking system for all grades to be allotted. The example in tables 2 and 3 illustrates how to assign a grade by using a literal system. The final grade was allotted using rubrics for three homeworks (HW) and one project for student X, student Y, and student Z. The steps to allotting a grade are the same for one assignment or for various assignments. For every assignment corresponds a weighting established by the instructor. In this case HW1 is worth 15%, HW2 and HW3 are each worth 20%, and the project weighs in at 45%, for a total of 100%. Taking student Z as an example, let us see how we came up with B- as the final mark. Table 3 helps understand the process.

Table 2. Example for allotting the final mark

Students Weighting	**HW1** 15%	**HW2** 20%	**HW3** 20%	**Project** 45%	**Total**
Student X	B-	B	A-	A	**A-**
Student Y	C	B-	B	B+	**B**
Student Z	C	C	B-	B	**B-**

Table 3. Example for calculating the final literal mark

Results – student Z	Weighting	Grades
HW1 = C	15%	**C =** (2.0) X 15% = 30
HW2 = C	20%	**C** = (2.0) X 20% = 40
HW3 = B-	20%	**B- =** (2.7) X 20% = 54
Project = B	45%	**A** = (3.0) X 45% = 135
Total	**100%**	**Total** = **259 /100 = 2.59 = B-**

1. In the left column appear the literal grades for student z, as well as the weighting for each means of assessment.

   In the right column, the literal grade is transposed in its numeral equivalent based upon the values of table 1. (Ex.: **C=2.0**).

2. It is then multiplied by the weighting value (Ex.: **C = 2.0 X 15%)**

3. We get the results in the right column.
   (Ex.: **C = 2.0 X 15% = 30**)

4. We then add up all the results from the right column:
   30 + 40 + 54 + 135 = 259

5. We divide that total by 100 (the total weighting)
   (Ex. 259 /100 = 2,59)

6. By looking up the literal equivalent of **2.59**, in table 1.

7. The final operation is to transform the numerical result into its literal equivalent, in this case a B-
   (Ex. 2.59 = B- = (2.7)

In this example, student's Z final numerical score is 2.59, putting him between the 2.7 mark for a B- and the 2.3 mark for a C+. Can we allot him a B-? We believe the answer should be yes, because it would be unfair to allot him a C+, since 2.3 is under his 2.59 mark. However, this decision belongs entirely to the instructor, and depends on the knowledge and appreciation he has of each student. For example, a student that has shown constant efforts for improvement can merit a better grade.

Continuously improve the process

At the end of the course we suggest instructors take some time to assess the entire assessment process and look for areas of improvement. The purpose is to ensure the validity and fidelity of the student assessment process. There are several methods instructors can use to analyse and reflect upon the situation. It is important to review all the steps of the assessment process by asking oneself relevant questions. Table 4 presents some open-ended questions that can help with the reflexion and improvement process. We also suggest three other very simple and easy to use methods. The first one is to analyse students' results to the various assessments and try to identify any difficulties they encounter. These difficulties can be related to some eventual weaknesses in the assessment process. The second method is to analyse the results of students' course and instructor evaluation. Quantitative results as well as written comments can provide relevant and worthy information.

The third method consists of meeting a few students, after the final results are handed in, and discuss with them desirable improvements. This discussion will point to very concrete and operational aspects drawn from the student experience.

Table 4. Examples of open-ended questions for continuous improvement.

Planning and preparing the assessment *Taking into account your teaching context,* ▪ Were the competencies to be assessed well targeted? ▪ Do they have to be reformulated? Is it necessary to add some or remove some? ▪ Were the most important contents targeted for the assessment? ▪ Do the students refer to them sufficiently at the time of realizing their work? ▪ Do the selected instruments allow adequate assessment of the targeted competencies?
Improving the instruments ▪ Are the tasks to be realized clearly presented? ▪ Are the responsibilities and the instructions clearly stated? ▪ Are the components and the criteria sufficiently explicit? ▪ Is the rubric clear, univocal, and complete? ▪ Is the appreciation scale suitable?
Improving feedback ▪ Does the assessment process as a whole allow feedback and the continuous improvement of work by the students? ▪ Do students receive sufficient support? ▪ Did the students find the feedback sufficiently detailed, precise and constructive? ▪ Did the discussions take place in a reciprocal open-to-criticism atmosphere? ▪ Are your personal availability, your appointment system and your assistants' availability enough for supporting students? ▪ Is the balance between the collective supervisions, the team supervisions and the individual supervisions adequate? ▪ Is the meetings schedule appropriate for all parties?

The next section deals with two issues instructors might have to address with authentic assessment situations. The first issue brings up the challenge of implementing and assessing project based courses with large enrolment groups. The second issue relates to the challenge of properly communicating with all team members during the development of a project.

An assessment perspective from Queen's University at Kingston

In Mechanical and Materials Engineering (MME) we have a broad consensus that our graduates should be well prepared to participate in conceiving, designing, implementing and operating real products, systems or processes as a central element of their professional education. This can be a challenge to implement with a typical enrolment of 140 to 160 students per year in MME. Each of our three options (General, Materials, Biomechanical) requires students take a core based on at least one authentic experience each year. Still, the majority of courses retain a traditional format with midterm(s) and final exam providing the bulk of the marks and assignments weighted just high enough to motivate students to complete them.

In first year students take APSC 100, a common core course across the entire engineering faculty that incorporates group projects aimed at solving practical problems. Groups of 6 to 8 students are directly supervised by a senior undergraduate student TA while working on a problem for a "client," usually a faculty member. Multiple different problems spread the load over multiple faculty members and allow some student choice according to personal areas on interest.

In second year students start a specifically MME curriculum, including an open ended design course (MECH 215) and an active learning measurement lab (MECH 215, Activating a Second Year Measurement Lab Sequence, 5th International CDIO Conference, Singapore Polytechnic, Singapore, June 7-10, 2009). The design course includes two group project segments, the first focused on competition among groups to each successfully complete the same (usually whimsical) task within a set of physical and time constraints. The second segment is a Client Based Design (CBD) project in which each group (typically 6 students) is assigned to a client with a real world design problem. All these clients are external to the course and include faculty members, local organizations and businesses, and industry, selected in part for their patience with novice designers. The groups are supervised and coached through the process by a team of Grad student TAs and (preferably more than one) faculty instructor.

In third year students complete a mechanical design course (MECH 323) closely focused on the traditional and important elements of machine design, gears, shafts, bearings, etc. that many people picture whenever they hear the word “design” in a mechanical engineering context. Student teams each work on their own design for a specific subsystem such as a gearbox, where the requirements are defined in detail and the results are quite similar, team to team. This is the most traditional of our design offerings, yet it also includes teams, potential for innovation, and multiple satisfactory solutions.

In fourth year students have a wide variety of options for design and research projects, however the program requires each student complete a conceive and design exercise, typically as part of a group of four students in MECH 460. Ideally, each MECH 460 group would have an individual client from industry with a practical problem requiring a solution, and the experience would closely replicate real world engineering practice. In actuality, we have a little over half of our teams working with industrial clients, about a quarter working on sub tasks for competition projects like SAE Baja or Formula cars, and the remainder working with faculty members. All projects must have a clear design requirement, as distinct from a research or literature survey focus. In addition to a client, each group has a faculty supervisor for guidance and evaluation.

Students have the option for much more authentic experience than the compulsory core through the design stream that starts in third year and culminates in a full year interdisciplinary project in APSC 480, or through the TEAM experience in APSC 400, both of which match student groups with industrial clients who commit to a significant level of cash sponsorship. These students self select for interest and ability and clients receive genuine value from the process.

All of these courses require a higher commitment of resources than traditional classroom courses. Some of this is direct cash costs for travel, communications, and materials to interact with industrial clients at a distance, however the vast majority is personnel time for technologists, machine shop, teaching assistants and faculty to work closely with students in small groups of 4 to 6 at a time rather than in lecture halls of 140 or more at a time. This resource commitment is diffused through the department by involving many faculty members as project supervisors. Spreading the load is a response to budget realities, but adds complications to the assessment approach.

Anecdotal Experience

Although not formally quantified, there is clear anecdotal evidence from observation of students working in projects in the different years that they do, as a group, advance substantially in CDIO curriculum areas over the course of their degree. It is also clear from comparisons with other groups of students that participation in our program correlates with that advancement. However, we lack the measurements we need to conclude that our

program is responsible for that improvement, let alone to identify which elements contribute most to reaching those objectives. That information is essential to scientifically improving our offerings and to scientifically allocating more of the resource pool to those elements that contribute most. Getting that information is not the focus of this work and there's evidence that efforts to measure actual outcomes (Bill Lucas, MIT, self efficacy ref) can be seriously confounded by any association with the assignment of grades.

Past accreditation based on teaching content has been very much a bean counting exercise, with individual faculty members deciding which category a particular teaching hour falls into and accreditation visitors doing due diligence by auditing actual course materials, assignments, and exams for content. As accreditation organizations move to outcome based criteria, it is likely that they will accept measures that focus on student learning.

Assessment Objectives in the MME Context

In the context of our authentic activities assessment has to meet objectives that are sometimes contradictory:

- Summative results for various learning objectives that:
    - Accurately rank order students on a scale
    - Show that individual students have met the objective for pass/fail
    - Show that groups of students have generally met some objective for accreditation of the program or budget justification
- Cost effectiveness
- Perceived fairness
- Motivate students
- Normative results that help students develop their abilities
- Authentic experience

Opinions of engineering education stakeholders differ substantially on the relative importance of these objectives, or even whether they should even be on the list, however, just about all of our stakeholders require summative results and sometimes place substantial weight on them. It is therefore a temptation to concentrate on getting the summative results right and to address the other objectives only where they don't interfere with that primary objective. This is certainly the traditional approach, still taken in most engineering science courses and student grades in those courses provide a clear indicator of purely technical abilities.

Within our design stream we have elected to focus first on the authenticity of the experience and delivering normative guidance, and then address the other goals where they don't interfere with those two objectives. In designing an authentic experience with authentic assessment we have replicated, as far as possible, some important elements of engineering practice within a consulting services model:

- Clients define the task, independent of the course instructor. The task is typically incompletely specified at the outset and the students define it in consultation with the client. Requirements may change over the course of the project. Different teams have different clients and different projects.
- Students work in teams, with a TA or faculty member in the role of engineering supervisor. The supervisor provides regular advice on technical questions, managing the project, and managing the client. It is crucial that any one supervisor not have too many project groups so that the advising process does not become formulaic.
- There are formal checkpoint assessments at proposal, detailed design, and fabrication stages, where clients and supervisors provide feedback before the project continues.

- In addition to evaluation of the final product by the immediate supervisor, the results of the project are assessed by faculty who have not been directly involved in the project.
- Peer feedback is used both during the project to identify and address team dysfunction and at the end of the project for summative evaluation of individual contributions.

This authenticity brings many advantages. Students get regular, project specific feedback from both the client and the supervisor and must resolve potentially differing opinions, making it clear there's no single right answer. Multiple iterations are possible on the same design issue. Supervisors get personally invested in the success of the team and the individual team members thus the normative evaluations flow much as real world guidance from an immediate supervisor or senior colleague would. Final course marks are determined in ways similar to success in employment.

This authenticity also brings disadvantages bundled with the advantages. Supervisors and clients who are personally invested in the project cannot be expected to be fully objective in assessing its success, nor can anybody directly involved be expected to be fully objective on the relative contributions of the various team members. It is a virtual certainty that discrepancies in contributions will not be fully reflected in final course mark variations within teams, and that varying supervisor bias will colour the scores between teams.

Such individualized assessments are costly in the time of both the supervisors and the independent secondary evaluators.

Students often see the evaluation process as unfair and different students have different ideas of what would be fair.

With clients and projects varying among teams and from year to year it is difficult to assess the general quality of the learning experience, or the resulting learning outcomes as they are intentionally not uniform.

An Imperfect Solution

As in professional practice, no evaluation and reward system will provide unequivocally objective and correct results. The best we can aim for is useful feedback to students, a reasonable reflection of performance in their record, a perception that we sought to be fair, and opportunities that motivate students to improve their results. In MECH 212 and 460 we seem to be succeeding in all of these, with the possible exception of an absolute measure of performance for individuals.

In MECH 212 the first project is uniform across the class and multiple judges evaluate the results according to a rubric that is developed collaboratively with the students. Although the second project problem varies from team to team, a detailed rubric for evaluation of deliverables is available, along with exemplars of good results from previous projects. For students whose designs fail in testing, the "Bank Account Model" of course marking allows redemption. Although they don't get the chance to re-do a project, students can propose bonus projects to improve their marks, so the course mark is limited only by the amount of work students are willing to do. Failure analysis of a design and/or a design process provides an ideal bonus project for those most in need of them. Overall course marks are high, as is student satisfaction with the experience and the fairness. Useful feedback is evident in iterative improvement of work product.

In MECH 460 the rubrics for the deliverables are more open ended to reflect the breadth of project variations, however detailed marking guides and exemplars are provided for each

element. Multiple assessments by different faculty with feedback for improvement at the proposal stage, and in the final presentations in advance of report submission provide opportunities for improvement of work product. Subjective elements in the marking scheme and an end of term peer assessment allow the course coordinator to address fairness issues with a broad perspective. Overall course marks are high and the vast majority of teams have a positive experience with a high quality outcome. The diffuse structure of the course means that occasional teams achieve poor results from the combined dynamics of team members, client and supervisor, an unfortunate, but truly authentic outcome. Usually these situations can be caught by coordinator intervention following the early term peer assessments in which students do not hesitate to point out issues with their client or supervisor.

Although the final marks in either course do not appear to be a good indicator for selecting students for success in future authentic tasks, they do show participation in an authentic project course where most groups eventually produce high quality original work, as evidenced by their final reports. That quality shows that assessment structure does provide adequate motivation and perceived fairness to work hard on meeting objectives. These projects provide students with an opportunity to shine and with a concrete result they can show to potential employers as evidence. Collectively, those reports provide anecdotal evidence of outcomes for accreditation.

Operating project activities within an authentic framework requires that students participate in a series of processes that eventually lead to a product, with normative feedback along the way. Exposure to the activity provides an important learning opportunity that most students take good advantage of. By putting authenticity first we create the conditions necessary to reach many of the CDIO syllabus learning objectives.

Ideally we would have independent assessment of learning outcomes in individuals and that is a direction we are pursuing in courses that are part of our optional specialization in design, for inclusion in the general curriculum.

Example of authentic assessment from the Product Design and Development (PDD) degree at Queen's University Belfast

Project 3P (MEE3052) 24 week duration, groups of 4 or 5 typically.

This major project carried out in the 3rd year of the degree is an advanced team design build and test (DBT) project which combines technical and commercial elements typically found in industry. Students are required to develop a product from the identification of a problem / customer need through concept development, product design specification, detailed design, prototyping, testing and finally to a plan for manufacture. The teams also develop an associated marketing plan for their product in a concurrent module.

The groups are required to plan their activities and must schedule regular formal design review meetings with their supervisors. It the latter stages of the project these often become weekly events. Agendas must be distributed in advance along with minutes of the previous meeting, as is standard practice in industry. The teams can request that the supervisor chairs the meeting but are encouraged to take on this role, and that of secretary, on a rotating basis to gain experience. These formal meetings demonstrate professional practice in the context of the project and the supervisors can provide immediate feedback in the way a design manager might do in the workplace. Action points such as task assignments with deadlines are typical outputs from these meetings and help organize the progress of the project.

These projects represent 2.5 of 6.0 modules in stage 3 of the degree program and even at the frequency of 1 design review meeting per week there is still a lot of activity which can take place between these formal meetings. It is not feasible for the supervisors to be with all

of the groups they are involved with all of the time. In order to provide a facility for supervisors to stay informed the web based “Google Groups” tool is used. Group access is by invitation only and is managed by the supervisor (a member of faculty). As well as a threaded discussion forum there is a shared file space and an area where “pages” can be developed collaboratively. Group members receive notification of activity by email and can chose between instant notification or to receive a digest email with activity over a 24 hour period collated into a single email. Supervisors generally receive the digest version and can provide near immediate feedback to the group. These digests conveniently provide a transcript of activity from which individual members contributions can be assessed both in terms of quantity and quality. A metric has been devised to convert these contributions into weekly grades which form part of the overall assessment.

Table 5: Grade Descriptors for Online Contributions to Google Groups

Grade	Description
0	no entry / absent from meeting
1 - 3	brief note of activity
4 - 6	detailed description of own work done
7 - 10	as 4 - 6 above plus evidence of engagement which has helped to progress the project as a whole

Each contribution is marked according to the scheme described in Table 5. Students are expected to make 5 such contributions per week. All contributions are averaged and 0.5 added for each contribution in excess of the expected 4. Similarly 0.5 would be subtracted from the average if only 3 contributions have been made. Students are made aware of the supervisor’s grading of their contribution at the midway point of the project along with a summary of a peer assessment exercise.

The 0809 stage 3 students were questioned about a number of aspects of the Project 3P module including their opinion of the use of Google Groups. It is clearly seen as an effective communication tool and has a marginally positive effect in terms of encouraging a consistent work rate. There is a slightly more mixed opinion however about whether it reduces the need for face to face meetings and it is best to consider it as supplementary to the design review meetings rather than as a replacement.

Table 6: Stage 3 QUB PDD Opinions Regarding the Use of Google Groups

	STRONGLY AGREE	AGREE	NEUTRAL	DISAGREE	STRONGLY DISAGREE
The Google Groups facility assists communication between team members	12	5	2	3	0
Google Groups reduces the number of face to face meetings necessary to manage the progress of the project	4	3	5	8	2
Knowing that my online contribution is being assessed on a weekly basis encourages me to work consistently throughout the semester	2	8	5	5	2

CONCLUSION

Authentic assessment of competencies proposes to move away from traditional practices which far too often require from students the repetition of an awaited good answer or learned "by heart" answers, as students say so themselves. Thus, authentic assessment requires conceiving instruments capable to evaluate students' competencies in realistic and complex situations. These situations simulate real life professional tasks. The production of the assessment instruments needs the identification of a complex task, accompanied with clear instructions in order to guide its achievement. Students are asked to apply their critical thinking, and a certain dose of originality. Furthermore, students are entitled to making mistakes and learning from them with proper instructor feedback. Writing a rubric and communicating clear and explicit criteria will help the assessment process as well as the students learning process. Appropriate use of authentic assessment, because of its ongoing formative nature, will eventually help instructors save time by accelerating evaluation of final student performance. Nonetheless, various constraints can make the instructors' work more complicated, like time constraints, high student enrolment, and adequate individual support. With these challenges that may lie ahead, instructors will need to reflect critically and design more effective assessment methods and instruments, within the authenticity mindset.

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DEVELOPING AWARENESS AND COMPETENCIES OF CDIO SKILLS THROUGH PBL APPROACH

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ABSTRACT

This study describes the educational experience of the students' perceptions to the teaching of CDIO skills through a problem based approach. It is a small-scale study in mathematics module of a group of second year Mechanical and Manufacturing students from the Singapore Polytechnic. It highlights the key changes that the author has implemented in her classroom practice and the findings to date. Findings from the research suggest that the self directed learning component in problem based learning has led students to acquire CDIO skills such as teamwork and problem solving skills. The implications of the findings from the survey have been used to formulate appropriate teaching strategies for the continued development of the module.

KEYWORDS

Problem based learning, CDIO skills, Mathematics.

INTRODUCTION

In recent years, certain courses from the four schools of Singapore Polytechnic (SP)- School of Mechanical and Manufacturing Engineering(MM), School of Chemical and Life Sciences(CLS), School of Electrical Engineering(EEE) and School of Built Environment(BE) implement the Conceive-Design-Implement-and-Operation(CDIO) initiative into their curricula in phases. Three CDIO skills; namely

- Personal Skills and Attitudes (initiative and willingness to take risks, perseverance and flexibility, creative thinking, critical thinking, curiosity and life long learning, time and resource management, etc)
- Teamwork (forming effective team, team operation, team growth and evolution, leadership, etc)
- Communication (written communication, electronic communication, graphical communication, oral presentation, etc)

have been selected for the first phase of integration into their curricula. Mr Low Wong Fook, principal of Singapore Polytechnic (SP), during his speech in Staff Rally 2007, urged staff to infuse some of the selected skills into the diploma modules. He said:

> *...To interpret CDIO a little more flexibly and more broadly so that we can all use CDIO to make learning more integrated, more meaningful and exciting for our students. ...Basically, a CDIO-based curriculum is one that is organized around fundamental, whatever the discipline, but interwoven with student projects which encourage active, experiential and group learning.* [1]

The teaching of Mathematics in SP typically involves transmissive practices of mere reproduction of knowledge to learners. Lecturers show students how to answer questions and solve problems related to mathematics. However, lecturers tend to omit the problem-

formulating stage where students need to handle facts and procedures to develop their own questions and investigate by themselves. In my opinion, students just memorise formulae and procedures but do not fully understand or be able to use it. Instead, students must be encouraged to go beyond the memorization of facts, and to move towards learning how to apply their knowledge in problem-solving [2]. Students educated for the world of 21st century must develop habits of thinking, researching, and problem solving to succeed in a rapid changing world [3].

How can we develop awareness and competencies of CDIO skills for SP students? My proposed approach is to adopt Problem-Based Learning (PBL) approach.

Problem-based learning (PBL) is a student-centered pedagogy that uses a problem trigger to drive the learning activities. It orients students from fact-collecting toward meaning-making [4,5]. The modern history of problem-based learning begins in 1969 at the medical school at McMaster University in Canada, and gained impetus in 1984 when the Report of the Project Panel on the General Professional Education of the Physician recommended less emphasis on lecture-based instruction and more on independent and problem-centered learning [6, p.156]. Its intellectual history is far older. Today PBL is used in a variety of institutions and disciplines [7,8]. For example, in Singapore it has been implemented in Temasek Polytechnic and Republic Polytechnic.

Many education reform movements have embraced PBL owing to its positive benefits [3] as

- PBL deals with problems that are as close to real life situations as possible
- PBL promotes students' active engagement in learning
- PBL promotes an interdisciplinary approach
- PBL requires students to make choice about how and what they will learn
- PBL promotes collaborative learning
- PBL helps raise the quality of education

I feel that the benefits of introducing PBL for students are many, not least in terms of their individual development as learners. Learning is not primarily a process of accumulation information and then stored for later use. It is more effective when learners are active in the learning process, assuming responsibility for their learning and participating in making the decision that affects it. PBL is a significant way forward to create an environment in which students are able to find the meaning of information for themselves.

The introduction of PBL approach involves shifting responsibility to students for their own learning and thus developing effective learning strategies. The emphasis should be on the development of students' minds - to develop the power of thinking, flexibility in thought process and ability in problem solving.

Reflecting on the evolving needs of engineering students to learn mathematics for applications in other disciplines, and to understand the connections between mathematics and engineering or everyday life, there is a call for all programmes of higher education to be geared towards developing the PBL method of instruction. I have been considering ways on how I could help to provide students with the opportunity to apply their knowledge and to gain the appropriate skills to perform the necessary tasks effectively in an actual working environment. Clearly, the PBL approach provides a structure for discovery that helps students internalize learning and leads to greater comprehension [3]. It also turns out to be the appropriate educational method to infuse some CDIO skills into students' learning of mathematics.

I was encouraged by Marincovich's [9] support of teachers new to PBL to start off something small and low-risk - to teach 'hybrid' forms of PBL rather than pure PBL. At this juncture, I

would like to highlight that the main aim of this small-scale research study was to offer a PBL approach in mathematics as a complementary strategy to enhance the effect of the traditional didactic lectures. It is a preliminary study yet, nevertheless, it can provide a very useful first taste of PBL for many students.

THE RESEARCH

The aim of this research sets in understanding how PBL develop awareness and competencies of CDIO skills in the context of the engineering students in this study.

In achieving this aim, the research is guided by the following research questions:

- What are the views of students about their PBL experience?
- To what extent does PBL experience promote students' learning in terms of team work and cognitive development?
- How can PBL allow integration of mathematical formulae and theories into real life scenarios?

METHODOLOGY

To implement the PBL format successfully, the students were given a brief overview of how PBL would be carried out. They were told to work in a small group on a real life scenario project. They were expected to participate actively. To incorporate collaborative learning, students were to group themselves in running order of the serial number from the class register with the intention to have heterogeneously mixed in terms of ability (This is to avoid the more academically able and motivated learners to form their own group). Each group consisted of 3-4 students. The group membership remained unchanged throughout the whole project. There was a leader from each group. He or she had to constantly provide feedback to the tutor of their progress for the entire PBL process. This was to help the tutor to have a closer monitoring of students' progress. Such team formulation is designed to enhance teamwork that is part of the CDIO skills.

After team formulation, students were given seven weeks to complete the project. The initial part of this project was carried out during the first three weeks of the tutorial sessions where 30 minutes were set aside for students to work on it. Students were encouraged to discuss the problem with team members and tutor was to assist in the facilitation as students needed scaffolds when they conducted systematic inquiry [10]. The problem was designed and structured in such a way that it consisted of many smaller parts. When students were unable to answer any of the parts, they were asked to investigate further and submit the results in the next tutorial session.

In the second phase, students learnt to map their own strategies to accomplish the work on hand. Students became self-directed learners working within the constraints of resources and time [11]. Most of the groups worked independently in carrying out their plans. Finally they needed to interpret the results obtained.

By doing it this way, students are exposed to a real life problem and they are challenged to solve problem with proper facilitation from the tutor. Thus, they need to have perseverance and flexibility in overcoming challenges, creative and critical thinking for coming up with ideas, self directed learning for acquiring new knowledge, and integration of prior knowledge to solve new problem. The CDIO components on personal skills and attitudes are thus exercised.

At the end of week 7 each group needed to submit a written report and each individual was required to write a report on his/her effort in terms of his/her contribution, reflection and areas for improvement concerning their PBL experience. Students were also required to complete peer evaluation forms to assess individual contributions within the group.

The written presentation, which includes e-communication and graphical communication, helps in improving their CDIO skill on communication. Reflective learning and holistic assessment by self and peer evaluation also meet CDIO skills.

The population of the researched subjects for this study was all the 67 students taking Engineering Mathematics IIA in Semester Two of academic year 2008/2009. They were from School of Mechanical and Manufacturing Engineering in Singapore Polytechnic.

FINDINGS

At the end of the semester, a survey is conducted to solicit students' feedback. The goal of the survey is to find is there any gap between the PBL theory and the practice in classroom. The instrument used in this study was a 12-items questionnaire that measured the views and perceptions of students towards the PBL method of instruction. The questionnaire consisted of 11 items on a 5-point Likert scale and an open-ended question. For each of the 11 items the students were asked to indicate from the scale of "1"(strongly disagree) to "5"(strongly agree).

Among the 12 questions, question 1 is about their perception about the problem trigger. Questions 2-6 are about teamwork. Questions 7-9 are about their cognitive development. Questions 10-11 are about knowledge integration and application. Question 12 is an open-ended question asked for general comments about the PBL project.

Based on the data collected from the 67 respondents, I categorized the findings into summary tables in percentages to enable easy interpretation. The tables below and their interpretations will attempt to answer the three research questions posed in my study.

Research Question 1: What are the views of students about their PBL experience?

Table 1
Item Related to Challenging Level

	Item	Strongly disagree	disagree	Neutral	Agree	Strongly agree
1	The PBL problem was challenging	9.0%	9.0%	25.3%	37.3%	19.4%

This PBL project started with an RL circuit mirror a real life problem. Initially the students had difficulties in generating questions and formulating their own problems. The students struggled with uncertainty as they tried to craft the questions. A substantial high number (57%) of the respondents found the problem challenging as shown in survey questionnaire Item 1 in table 1. Below were some of the comments made by the students:

- *We need teacher to push us and help us during the PBL. After the help from teacher, we are able to solve the PBL.*
- *We need tutor to help us kick start the project*

Research Question 2: To what extent does PBL experience promote students' learning in terms of team work and cognitive development?

Table 2
Items Related to Team Works

	Item	Strongly Disagree	Disagree	Neutral	Agree	Strongly agree
2	I have learnt how to work cooperatively with peers to plan, develop and work out the solutions	3.0%	1.5%	29.9%	32.8%	32.8%
3	I have learnt how to motivate group members, to keep the morale high no matter what happens.	3.0%	3.0%	38.8%	32.8%	22.4%
4	I am aware of my role and the contribution to the team	0%	5.8%	31.4%	31.4%	31.4%
5	Group interaction enhance my learning in Maths	3.0%	7.5%	28.3%	35.8%	25.4%
6	The assignment was mainly done by one or two members	22.4%	21.0%	38.7%	16.4%	1.5%

Table 2 reveals students thought quite strongly of the potential improvement upon team work skills even though they were not free to choose their own members. 65.6% of the students agreed that they learnt how to work cooperatively with peers to plan, develop and work out the solutions. More than half of the respondents believed that they learnt how to motivate group members and to keep the morale high no matter what happens in the learning process. 62.8% of the students were aware of their role and their contribution to the team in completing the project. 61.2% of the respondents felt the group interactions enhanced their learning. About 18% of the students admitted they relied on friends for assistance. From my experience, this 'free-rider' phenomenon always happens regardless whether it is in PBL scheme or in a conventional learning environment. In general, respondents thought that this PBL project helped to build teamwork skills and to enhance their learning. These were supported by some comments made by respondents on how they worked as a team to complete the project at the end of question 5.

- *manage time and help out with thinking for solutions*
- *Delegate tasks evenly for teammates*
- *Call for meeting to solve the problem*
- *consult tutor, research, refer to notes*
- *encourage each other, never say the word 'wrong' or 'impossible'*
- *listen before speak*
- *keep on trying and tell each other not to give up*
- *support, contribute ideas, split work equally,*
- *identify problem, brainstorm of solution*

Table 3
Items Related to Cognitive development

		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
7	I have improved my reasoning and problem-solving skills	0%	5.9%	35.8%	32.8%	25.4%
8	I increased/improved ability to think independently	1.5%	7.4%	42.8%	32.8%	16.4%
9	I have developed research skills (eg. some software to sketch graph)	4.2%	16.6%	33.3%	14.6%	31.3%

There was not very strong agreement of the potential of improvement upon cognitive development through PBL approach as shown in Items 7-9 of Table 3. Only 58% of respondents felt that PBL helped them improve reasoning and problem-solving skills. About

half of the students agreed that they had increased or improved their ability to think independently, while only 46% of them found searching for answers to the learning issues exciting.

Research Question 3: How can PBL allow integration of mathematical formulae and theories into real life scenarios?

Table 4
Items Related to Connection/Integration/Applications

		Strongly Disagree	Disagree	Neutral	Agree	Strongly agree
10	I better understand the connection between different mathematics topics and the real world problems	1.5%	9.0%	29.8%	32.8%	26.9%
11	I am aware that the assignment is an application problem related to the modules I have learnt in my course (*e.g. circuit theory…)*	1.5%	6.0%	19.4%	43.3%	29.8%

Generally, the students' responses skewed right agreeing that they

- *better understand the connection between different mathematics topics and the real world problems*
- *aware that the assignment is an application problem related to the modules I have learnt in my course (e.g. circuit theory…)*

DISCUSSION AND RECOMMENDATIONS

Table 1 gives good ground for discussion on the issue pertaining to students' lack of understanding about the fundamental concepts. It is a possible obstacle for them to tackle the PBL problem and may thus impede their later progress of the whole exercise if they cannot complete this stage. It is similar to the situation pointed by Wee and Kek [11] where learners are more challenged in the problem formulation stage. Even the better students commented on the high intellectual demand that they were not comfortable with. Students needed the constant reassurance from tutors on whether they were heading in the right direction. While it is difficult to write PBL activities to suit every student's level, tutor's support which is highly valued by students is believed to be a stepping stone for students who are particularly weaker conceptually.

The reason for the perceived difficulty could be:

- Students are used to traditional learning style as passive receiver of information, and feel it is a big change to be active learners
- Students are not taught how to model a real life problem

For these reasons, at this stage, I feel that this group of students would still not be ready for a course that is purely PBL format. Probably, a gradual and controlled introduction of the actual experience of working within the framework should be encouraged and built in, and more scaffolds and help on modelling part are necessary.

From the comments of the last question, it was shown that they formed expectations about the uses of PBL in their learning. Some of them reacted positively to it while others did not. Those positive comments can be seen from the following narrative comments collated from the Item 12 in the survey questionnaire.

- *I think that PBL assignment should include the design of the circuit designated in circuit-maker. More credit marks(10%) so that students will feel that it is important assignment.*
- *PBL question is complicated without the help of tutor. It is too indirect in many of the questions and my group had some difficulties solving the problem.*
- *The PBL is very effective way to make us realize that the module is for us to make use of the maths equation to solve the problems in some other modules like circuit theory , Electronics (to find currents….)*
- *Everything are fine to me.*
- *It was just the right thing I need.*
- *It is a bit tough to handle without proper understanding of both circuit theory & maths.*
- *Tough but helpful.*
- *PBL assignment is power.*
- *The PBL is suitable for us overall.*
- *Looking forward to seeing PBL like that.*

Some of the students reacted negatively to the whole project and were unhappy and felt discouraged and demoralized as illustrated by their comments below:

- *Was not very effective.*
- *The PBL is a waste of time.*
- *No more PBL, want maths game.*
- *PBL should have more interesting topics.*
- *No more PBL, if you still want it, must go through with us at first properly.*
- *Give easy question.*

Some students did not take PBL seriously as can be seen from the sub-standard works submitted by them. They tend to leave everything to the last minutes and thus they are unable to complete the assignment. Thus, they resorted to copying assignments from other groups. Whereas, some of them simply dashed off their assignment as just another meaningless academic exercise to be disposed off with as little effort as possible and with minimal personal involvement. In this case, I perceived the students lack the motivation and discipline in PBL learning. PBL require students to be active, self-directed learners. It is no wonder that the shift to PBL represents unwelcome change for some students.

It is clear from Table 2 that many students are able to identify the potential improvement upon teamwork skills arising from the PBL approach. This study indicated that the PBL approach helped students feel more confident in their ability to handle teamwork. Students felt that group interactions enhances their learning; they learnt from each other and worked together to solve the problem. However, the question remains as to whether this increased confidence will enable them to actually achieve the success they now believe is possible for them. On this issue, I have no hard data. Nevertheless, anecdotal evidence is available. I felt many students work effectively and collaboratively in teams to learn mathematical concepts and solve problems. Some even acquired leadership skills through leading their own team or through helping others with their research. These efforts were reflected in students' report as well as through the active participation in the discussion and group interactions.

From the survey in table 3, students did not think strongly of the improvement upon cognitive development through this PBL approach. While it is hard to conclude that this small-scale PBL project has much impact on building thinking and reasoning skills, I have found that some students were able to meet my expectation of the critical-thinking questions in the project.

The results from table 4 indicate respondents were aware of PBL project promotes an interdisciplinary approach. The very nature of this RL circuit project required students to be able to read, write, analyse, think, research, calculate and present the solutions. Not only that, students must be able to understand the connections among different mathematical topics and their applications in the subject of circuit theory in order to accomplish the task. It is hard to say that student understanding of mathematics has greatly improved since the introduction of PBL approach, however; from my observation, students could communicate and present mathematical ideas accurately using mathematical symbols, notations, words and graphs. Students seemed to appreciate more on the learning of mathematics as they could make connections between what they were learning in mathematics and other subjects. Hence, PBL approach is an effective way to show students the connections between and among the subjects, helps them make greater sense of their schooling as a unified whole, and helps them use their knowledge of one field to increase the understanding of another area [3].

The general responses from both closed and open-ended questions seemed to yield mixed feelings about PBL amongst students. In this project, students only experienced a very small scale of PBL instruction within a closely prescribed and directed curriculum where students do not have enough practice to reach the stage of "familiarity". For a successful implementation, there is probably a need for a further project with full un-restricted introduction of PBL within a module. In addition, the PBL program must be ill-structured in response to the outcomes of research so as to help students achieve the skills and confidence they will require. In short, they must also be self-motivated and interested in accelerating the study in spite of all the many "competing interest" he or she is facing.

The survey also shows the challenge students faced in the PBL process. For problem trigger, they generally have difficulty in handling real life problem. For teamwork, not everyone find it comfortable in discussion. For knowledge discovery, it may be a stretch for them to have self directed learning and be creative and critical in thinking.

In one way, these obstacles are normal as it is in the process they develop their full capacity of CDIO skills, not just absorb knowledge in classroom. In another way, it suggests a lot for improvement of the approach and teachers' role for facilitation. For example:

- For problem trigger, since students are seldom taught on modeling part and system thinking, more scaffolds and guidance are needed from teacher;
- For teamwork, scaffolding is also needed to shift the individual, competitive diagram to teamwork and cooperation
- For problem solving process, facilitation skills are needed for teachers to help students embark on self directed learning

The key is to take a balance between challenge (new pedagogy, new problem, new learning style, new assessment, etc) and support so that students are developed yet not over challenged. Thus, facilitators play a very crucial role in the PBL process.

With further improvement to the pedagogy, implementation and design of the research question and full support from the management, I think there is a possibility of achieving some of the benefits. The skills that PBL can develop include:

- Skills in working with others(collaboration);
- ability to continue to learn from learning;
- ability to identify problems and work creatively towards solutions.

CONCLUSION

Overall the project can be regarded as a form of a staging post on the road to the development of a full-scale PBL scheme. We have made progress, yet a lot more can be done with better results. In the long run, we hope:

- To use the experience gained to plan a more extensive programme for other courses, especially to part-time courses where the academic background of the student is more varied;
- To allow students to explore a wide variety of learning experience and to allow them to carry out their studies largely in their own time and their own pace;
- To cultivate a positive learning attitude so that students are able to take responsibility for their own learning; and
- To encourage lifelong learning.

The implications of the findings from the survey have been used to formulate appropriate teaching strategies for the continued development of the module. No doubt the project implemented was small but I strongly believe through this mode of study, students become more aware of how the knowledge they are acquiring can be put to use [12]. Finally, it is hoped that this account of one mathematics lecturer's experience will be of interest in a wider context.

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Development of a Requirement Specification for CDIO Workspaces

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ABSTRACT

A systematic approach for developing the requirement specification, or design brief, of new learning spaces is presented. The process involves the identification of all the learning events and the mapping of these events onto appropriate learning spaces. When combined with class sizes, the result of this exercise can be used to generate the requirement in terms of learning space. The requirement specification is further enhanced through the identification of the physical resources required in each learning space. The overall analysis shows that informal learning events, such as those typical in project-based learning, require a much more diverse range of learning spaces and physical resources than the traditional approach to learning, typified by lectures and tutorials. As there is a general trend towards learning through more informal methods this has obvious resource implications if more progressing learning environments are to be developed and supported.

KEYWORDS

Learning space, workspace, design, specification, requirements

INTRODUCTION

The traditional approach to engineering education has predominately been lecture-based with hands-on activities provided through engineering laboratories. In common with other disciplines, engineering is now moving towards a model of education in which the learning takes place in a more active and collaborative environment. This was summarised well in a JISC publication, which states that, "A learning space should be able to motivate learners and promote learning as an activity, support collaborative as well as formal practice, provide a personalised and inclusive environment, and be flexible in the face of changing needs" [1]. The CDIO initiative is also clear on the importance of the learning environment, with one of its twelve standards indicating the important of providing workspaces to support hands-on learning of conceiving, designing, implementing and operating products, processes and systems [2].

While the need for new types of learning spaces is generally recognised, the process of designing the spaces is less well understood. Much of the published work has focused on the review of existing facilities accompanied by general guidance on the design of spaces [1-4]. Although, some guidance on the design process has been provided by Crawley et al. [5] who describe the development of the first CDIO workspace at MIT and describe a process for designing these spaces. The authors also discuss the concept of learning modes and higher level educational modes, and how these are used to inform the design process.

This paper follows on from the work of Crawley et al. [5] to describe a process for defining the requirement specification both formal and informal learning spaces using the concept of learning events and how these may be mapped onto different types of learning space and physical resource.

ESTABLISHING THE FRAMEWORK

Defining the Learning Events

The first stage in the development of a requirement specification is cataloguing the generic learning events which take place or have been identified as future activities. There will be a range of obvious learning events that all institutions support; such as lectures, laboratory classes, etc. However, it is worth spending some time over this phase of the process to ensure that all learning events are captured and included in the panning process. An example of such an exercise is presented in Figure 1.

	Learning Mode	**Learning Event**
Formal Learning Modes	Lecture mode	Lecture
		Software demonstration
		Interactive lecture
	Tutorial Mode	Tutorial session
		Computing practical
		Studio session
		Workshop session
	Laboratory Mode	Demonstration laboratory
		Experimental laboratory
		Product testing
		Site visit
Informal Learning Modes	Project Mode	Report / presentation
		Design project
		Research project
		Team project (minor)
		Team project (major)
		Linked project
	Extra-curricular mode	Self-directed learning
		Outreach activity
		Design competition
		Design-build competition

Figure 1: Cataloguing and Categorising Generic Learning Events

It would be difficult to prepare a definitive list of learning events as they will be subject to local terminology and interpretation. Therefore it will often be more appropriate for the designer to construct their own list of learning events, specific to their own environment. Perhaps the more significant aspect of Figure 1 is the higher level grouping of learning events into learning modes and then further grouping into either formal or informal. The learning modes present a more generic description of the learning events, which will have greater relevance across geographical regions. For example, learning events categorised in

the lecture mode will predominantly involve the transmission of information by the teacher, with limited or no involvement from the students. Whereas the Laboratory Mode will involve significant hands-on activity by the students will limited intervention by the teacher.

The learning events have been categorised at the highest level into either formal or informal. While the distinction between these is not always clear, it is a convenient way of distinguishing between activities which are either teacher-led (formal) or student-led (informal).

Defining the Learning Spaces

The types of learning space required will be less sensitive to geographical and cultural differences, but nonetheless should be defined with regard to the local situation. Experiences staff should be brought together to construct a list of learning spaces required to support the learning process. It is useful at this stage not be constrained by the list of learning events already developed, as the relationship between the two will become apparent later in the process.

On completion of the learning space list, a second list of physical resources may be compiled. This can often be constructed by reviewing the requirements for each type of learning space, but, again, this should not be a constraint on the list. It is also possible to imagine the resources required without regard for the type of learning space they would be used in.

		Resources											
		White board	Projection screen	Digital projector	Computer	Network connection	Printer	Tools (cardboard)	Tools (electrical)	Assembly area	Photocopying	Access control	Supervision
Learning Spaces	Lecture Room	x	x	x	x	x							
	Tutorial Room	x											
	Studio	x						x				x	
	Computer Lab		x	x	x	x	x					x	
	Teaching Lab	x											
	Workshop								x	x		x	x
	Meeting Room	x			x	x	x					x	
	Social Area											x	
	Library										x		

Figure 2: Mapping Resources onto Learning Spaces

On completion of both lists, they should be mapped onto each other to give a resource requirement for each individual room or room type. An example of this process is presented in Figure 2. A range of learning spaces is presented down the left column and some common physical resources are presented along the top. The physical resources have then been mapped onto the different learning spaces. This is probably a more robust method of specifying the rooms as the designer is encouraged to consider the requirement for each listed physical resources in each room. Whereas, if each type of learning space is considered in isolation, there is a possibility that resources may be missed.

Mapping Learning Spaces onto Learning Events

Following a similar procedure to that shown in Figure 2, it is now possible to map the learning events onto the learning spaces and hence complete the framework required to define the requirement specification. An example of this procedure is shown in Figures 3 and 4.

			Learning Spaces								
			Lecture Room	Tutorial Room	Studio	Computer Lab	Teaching Lab	Workshop	Meeting Room	Social Area	Library
Formal Learning Modes	Lecture Modes	Lecture	x								
		Demonstration Lecture	x								
		Interactive Lecture				x					
	Lab Modes	Demonstration lab					x				
		Experimental lab					x				
		Operate mode									
		Site visit									
	Tutorial Modes	Tutorial session		x							
		Computer session				x					
		Studio session			x						
		Workshop session						x			

Figure 3: Mapping Learning Spaces onto Formal Learning Modes

Figure 3 shows the mapping of the formal learning modes and Figure 4 the informal learning modes onto the learning spaces. When compared, Figures 3 and 4 present an interesting proposition; that the formal learning modes predominantly have a one-to-one mapping of learning event to learning space, while the informal learning modes have a one-to-many mapping. The informal learning modes are more representative of the active and interactive

learning that has been shown to be more effective and are therefore an important pointer in the development of learning spaces.

			Learning Spaces								
			Lecture Room	Tutorial Room	Studio	Computer Lab	Teaching Lab	Workshop	Meeting Room	Social Area	Library
Informal Learning Modes	Project Mode	Design project			x	x					x
		Team project (minor)			x	x	x	x			
		Linked project			x	x	x	x			x
		Research project			x	x	x	x			x
		Team project (major)			x	x	x	x	x	x	x
		Report/Presentation				x			x		x
	Extra-curricular	Self-directed learning				x					x
		Outreach			x	x	x	x			
		Design competition			x	x			x	x	x
		Design-build competition			x	x	x	x	x	x	x

Figure 4: Mapping Learning Spaces onto Informal Learning Modes

DEVELOPING THE SCHEDULE OF ROOMS

Cataloguing the Learning Events

The second phase of the process moves away from the theoretical aspects of the specification and onto the realities of the existing or proposed courses. The first task is to list every learning event that will take place. This process can be exhaustive, although with the unknowns inherent in the process it is probably acceptable to construct the list based on a representative sample. For example, it would be possible to list every single class that takes place over a semester or year, however, as most weeks in an academic timetable are similar it may be sufficient to analyse an average week or a worst-case-scenario week. The bulk of this list will be composed of scheduled classes, but it may also contain unscheduled events, such as private study or extra-curricular activities.

Once the list of learning events is constructed, detail, such as class size, demand, etc., should be added. The learning events are then mapped onto the learning spaces to provide a learning space requirement for that particular event. Figure 5 shows an extract from a larger list, to illustrate the point.

Summarising the Requirement Specification

On completion of the cataloguing exercise it will be possible to begin summarising the information into a format suitable for the requirement specification. The output of the learning event catalogue will be a list of classes of a particular size that will require a particular type of learning space. Figure 6 shows such as a list of courses which require a studio for particular elements. The class size is presented in the first column, the load (number of hours required per week) in the second and the cumulative load on the room in the third.

Module Name	**Class Size**	**Weekly Demand (hr)**	**Lecture Room**		**Studio**	
			(%)	(hr)	(%)	(hr)
Creative Design Skills 1	30	3		0	100%	3
Engineering Design 1	150	3	33%	1		0
Engineering Mathematics 1	155	3	67%	2		0
Introduction to Aerospace Engineering 1	40	3	20%	1		0
Introduction to Mechanical Engineering 1	110	3	20%	1		0
Introduction to Product Design 1	30	3	20%	1		0

Figure 5: Cataloguing the Learning Events

Studio		
Class Size	*Load (hr)*	*Cum. Load (hr)*
2	0.9	1
10	3.0	4
10	6.0	10
25	1.5	11
25	3.0	14
25	2.3	17
27	0.9	18
30	3.0	21
30	3.0	24
40	1.1	25
45	0.9	26

Figure 6: Classes requiring a Particular Type of Learning Space

The class size and cumulative load are important to the determination of the capacity and number of rooms required to support the learning events. In terms of the potential of a room,

it may be that a room has the capacity to host 36 hours of classes per week, but because of timetabling constraints the timetabled utilisation of a room is unlikely to exceed 80% during a typical week. This then reduces the potential for a room to 29 hours/week, which is the figure against which the cumulative load is compared. In the example shown in Figure 6, the total demand (cumulative load) on the room in a typical week is 26 hours; therefore one room should be sufficient to meet the demand.

The capacity of the room will be determined by the class size of the learning events. It is possible to scale the class size to account for attendance rates, but it may be unwise to scale by anything less that 95%. In addition, as class sizes for future years are largely unknown, it is probably best to err on the side of caution and stay with an attendance rate of 100% or more. On first inspection, the figures presented in Figure 6 would seem to indicate a room capacity of 45, although in this particular case the classes with 40 and 45 are both capstone project groups and are unlikely to all attend at the same time. Therefore in this case a room capacity of 35 may be more appropriate.

If the same process is conducted on each of the other learning space types identified, it will be possible to draw up a comprehensive list of room types, with numbers and capacity of each type (Figure 7). This list may then be combined with the physical resources required to complete the requirement specification necessary to drive the design process.

1 No.	75 seat lecture room
1 No.	110 seat lecture room
1 No.	225 seat lecture room
1 No.	25 seat class room
2 No.	32 seat class room
1 No.	50 seat class room
1 No.	35 seat studio
1 No.	25 seat computer teaching room
2 No.	45 seat computer teaching room

Figure 7: Schedule of Rooms

DISCUSSION

The provision of appropriate learning spaces is an important element in the transformation of engineering education. Learning spaces can be created by either re-tasking existing spaces or building new spaces. Obviously, the first of these options will be more common, although the process of specifying either is remarkable similar.

Regardless of the size of the project, it is unlikely that anyone from outside the immediate learning environment could draw up a specification without substantial input from the faculty. The process of drawing up the specification is quite straightforward, although requires intimate knowledge of the organisation and can be a lengthy process. However, as opportunities to redevelop/create estate are few-and-far-between it is worth spending time on the process to obtain a satisfactory outcome.

When drawing up the specification there will be a natural tendency to develop solutions rather than requirements. This should be avoided as it will impose unnecessary constraints

on the design process. Similarly, existing constraints, for example available space and funding, should not be allowed to unduly influence the development of the specification. The specification should be a statement of the needs irrespective of constraints. The design phase will highlight whether or not the specification can be achieved and if necessary compromises can be made during the design phase.

Finally, most development work will include external professional involvement. It may be representatives from the institution's estates division on smaller projects or architects, quantity surveyors, services engineers, etc. on larger projects. No mater who, it is useful if the lead faculty has at least some experience of building works. Fortunately, many engineers are in this position, so this post should not be difficult to fill.

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DEVELOPMENT OF CDIO SKILLS THROUGH THE CONCEPT OF 'SMALL BUSINESS PROJECTS' IN ELECTROMECHANICS

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ABSTRACT

Bachelors in electromechanics at University College Ghent receive a broad training during which they have to develop several projects. In the second year, they can choose a generic project, proposed by the teaching staff, or they can start their own "small business project" (SBP), in cooperation with Flemish Young Enterprises [1].
During a SBP students learn to create, manage and develop their own junior company which they use to market their own original idea and product. The whole business is based on their junior business plan, which is coached and checked by real business people, 'godfathers'. The students decide themselves about their service or product after an intensive brainstorm workshop, a market exploration, a profound marketing study and a brief financial study. The chosen service or product fits in their curricula. The students have to organise every aspect, every management division from financial to the general management on their own, just like in a real business. They even have to create their own profit! Every SBP project group has the support from their own teachers, an SBP-coordinator and a business-godfather [1].
There's a match between the philosophy of CDIO and the philosophy of small business projects. The paper shows how students can get real life experience in entrepreneurship during their training. At the same time they get the broader scope of the CDIO lifecycle.

KEYWORDS

CDIO skills, electromechanics, small business projects, project based learning.

ABOUT THE PROFESSIONAL BACHELOR STUDY PROGRAMME ELECTROMECHANICS AT UNIVERSITY COLLEGE GHENT

University College Ghent is a Flemish autonomous institution of higher education. Its 13 faculties offer a wide variety of study programmes ranging from fine arts and music, over teacher training, health care and science to translation studies. This range is the widest in Flanders [2].

University College Ghent has 24 professional bachelor programmes, 14 academic bachelor programmes and 21 master programmes on offer. Nine of these study programmes are unique in Flanders. With its 15,257 students in the academic year 2007-2008 it is now the largest college in Flanders.

The Faculty of Technology is one of these 13 faculties. It offers 6 professional bachelor programmes: Chemistry, Wood Technology, Textile Technology, Fashion Technology, Real Estate and Electromechanics [3].

These professional bachelor degrees are mainly practice-oriented study programmes, which prepare students directly for specific professions in industry and commerce. During their training students acquire the necessary general and specific knowledge, skills and competences.

The professional bachelor study programme in Electromechanics leads to the degree of bachelor in the field of applied engineering and technology. The programme links up with secondary education and consists of 180 ECTS-credits, which corresponds to a traditional three-year curriculum. On average the study programme welcomes 350 students spread over the three years of the entire study programme.

The professional bachelors in Electromechanics receive broad training in the disciplines of mechanics, electricity and electronics. After their first year students have three main subjects to choose from: automation, electromechanics or heating-ventilation-airconditioning-cooling.

Within University College Ghent the professional bachelor degree in Electromechanics grants access to a master programme on condition that a bridging programme is undertaken first (66 ECTS-credits). This bridging programme comprises course units helping the students to acquire the general scientific competences and the basic scientific knowledge necessary to undertake the master programme. After successfully completing the bridging programme students receive a certificate giving access to the corresponding masters in applied engineering.

PROJECT-BASED LEARNING WITHIN OUR STUDY PROGRAMME

After the restructuring of higher education (bachelor-master) in Flanders the Faculty of Technology thoroughly revised its vision on education. In this new vision (2006) emphasis is put on:

- competence-oriented education,
- interdisciplinary approach,
- practice-oriented learning,
- self-reliant learning.

In collaboration with the education development specialist of our faculty, this new approach was developed, implemented and refined [4].

Within the Electromechanics study programme the concept of project-based learning plays an important part. For this reason interdisciplinary projects have become specific course units in the first and in the second year of the programme.

Through this project-based learning students acquire knowledge, (interpersonal) skills and attitudes by analyzing and solving problems in an active way. Moreover they also have to rely on competences acquired in other course units. Theoretical and practical knowledge obtained during lectures and laboratory practice is applied to real-life problems.

The interdisciplinary projects are organized in the first as well as in the second year of the curriculum, both in the second term (twelve weeks) of the academic year. One day per week is exclusively scheduled for project work. The Electromechanics programme has a pool of approximately fifteen project coaches (lecturers) who guide the project groups during the

whole process. For their technical coaching students can rely upon two technical advisers, consultation happens on a voluntary basis.

The coaches, together with the technical advisers, propose and describe the generic project assignment and determine the technical specifications. For the first-year-students' project the specific knowledge and skills of these students are taken into consideration. A survey held during the first term inquires about their previous training, the subject of their final project in secondary education and their individual interests or suggestions.

At the kick-off meeting of the first interdisciplinary project students attend a sensitizing presentation about:

- the meaning of project-based learning,
- the purpose of project-based learning,
- the requirements and expectations regarding students and coaches,
- the methods of evaluation.

This presentation also incorporates some directions because coaches experienced that this way students get into action faster and feel more confident in their new role. On the other hand, prolonging a strict guidance is not recommended as creativity is a key competence in the project.

At the kick-off meeting students receive a manual which comprises the following aspects: the general principles of project-based learning, the project phases, professional planning techniques and information concerning evaluation.

The following table summarizes the past generic projects of the first and the second year of the entire study programme.

Table 1
Past generic projects

	First year	Second year
2004-2005	Weather station	/
2005-2006	Compost master	Elektromobile Self-supporting fishbowl Sun boiler
2006-2007	Euro Counter	Sumobot or Anty-project* Terrarium
2007-2008	PMD - Waste is food for me	Experimental music instrument - Waste is food for music ADB-engineering** Passive house
2008-2009	Air Rocket	Be weatherwise Fire at Mokum Ice palace

* In the academic year 2006-2007 students worked on the ANTY project proposed by the *Vrije Universiteit Brussels*. They designed and manufactured movable robot arms as part of an automated soft toy called 'Probo'. Probo is an intelligent soft toy that helps long-term sick children to communicate with their parents and friends by means of a webcam and screen integrated in the belly of the toy.

** In the academic year 2007-2008 students of the main subject Automation carried out a project commissioned by the company ADB Engineering. This company intended to bring onto the market safety vests with light-emitting strips guaranteeing the wearer absolute safety. These strips needed a charge of 150 Vpp to lighten. Students had to study the power supply for the vests and adjust it in order to comply with the following demands: transfer from 4 x AA to the necessary 150 Vpp, rechargeable via a car cigarette lighter, blinking adjustable.

The Electromechanics programme committee decided to use the same project manual both in the first and in the second year of the entire study programme.

The manual was extended with several appendices: an overview of professions and functions, assessment criteria, useful documents (a number of templates e.g. for agenda and minutes of group meetings, for action plan, for individual log book) product specifications and the evaluation forms.

The way the generic project is conceived and implemented matches the basic principles and philosophy of CDIO. However, the complete CDIO lifecycle could even be more prominent should the project assignment not be determined beforehand, so the students would have the freedom to choose, design, develop and market their own technical concept.

In their second year students can take up this challenge by opting for a Small Business Project as an alternative to the generic project. In this way we wish to stimulate the development of specific CDIO skills even more.

SMALL BUSINESS PROJECTS (SBP)

In the second year of the entire study programme students can opt for a Small Business Project instead of the generic project. The SBPs are organized in cooperation with the Flemish Young Enterprises (Vlaamse Jonge Ondernemingen = VLAJO) [1].

About VLAJO

In cooperation with the Flemish Government Flemish Young Enterprises offers an important contribution in the renewal of the offer in Flemish Education willing to stimulate students for entrepreneurship. Here for Flemish Young Enterprises brings schools and enterprises together in a win-win relation willing to contribute to Flanders' prosperity [1].

Figure 1. Flemish Young Enterprises is an independent, not for profit education association. Flemish Young Enterprises has the purpose of enabling young people to learn about the world of work and to develop attitudes and skills for personal success, lifelong learning and employability through the real experience of running their own company.

The common aims of Flemish Young Enterprises are:

- To foster an understanding of the world of work and a spirit of entrepreneurship through the principle of 'learning by doing'.
- To encourage young people to think internationally in their business affairs.
- To develop international contacts between Achievers in member countries.
- To organize activities which promote and develop the cross cultural European dimension.

The first initiatives to set up an organization were taken in 1977. Since then, up to 50.000 students in Belgium have participated in the program alone, supported by volunteers from a cross-section of several hundred businesses of varying size.

The unique features contributing to the appeal and success of the program are the principle of "learning by doing" and business leadership. Volunteers from the business world join forces with teachers to guide and support the Young Enterprise Companies. These student companies sell shares, conduct market research, produce and market products just as real enterprise do [1].

SBP concept

Students brainstorm to find a product they wish to make and sell. Based upon a detailed business plan and a market study they investigate the feasibility and the saleability of their idea. The financing is secured through selling shares or by looking for sponsorship. Within the SBP an organizational structure is set up with a commercial, technical, financial and administrative manager supervised by a general manager. Thanks to the SBPs students get a clear view on several aspects of entrepreneurship and on starting one's own business whilst still training. The focal point is developing an attitude of entrepreneurship. 'Godfathers' from the business world assist them in this learning process [1].

SBP phases

VLAJO composed a start-up kit that helps students find their way when developing a project. For VLAJO emphasis is put on writing out a business plan, in principle physical production is not imperative. Our Electromechanics study programme uses the start-up kit, but we expect our students to develop a specific technical product, this in the spirit of the CDIO lifecycle model.

Phase 1 : Brainstorm, getting the idea about the product or service to be delivered > Conceiving

Students who do not opt for the generic project but for the SBP are entirely led by their spontaneous creativity. So the first phase is of the utmost importance for the future success of an SBP. A thorough preliminary study of the possibilities is necessary and this facilitates the translation of the concept into a business plan. After a brainstorming workshop students with a specific idea (a group of four to five students) present this idea to a 'godfather' company. Eventually they present their proposal to the project coaches and technical advisers, they decide whether the SBP is accepted or not.

This first brainstorm phase matches the Conceive phase in the CDIO lifecycle.

Phase 2 : Starting up/ setting up business plan > Design

In this phase the project group or team draws up a business plan. A professional business plan contains all the information necessary for potential investors. It has a clear structure

comprising a corporate identity, an HRM-organization chart, a market exploration and a financial study.

Students in Electromechanics always have to develop a technical product in their SBP (In a different study programme students can develop e.g. a service or a trade). Already in phase two they are working on the specification and development of their product.

We see here a clear link with the Design phase of the CDIO lifecycle model.

Phase 3 : Operational phase, from prototype to manufacturing > Implementing

During the operational phase students manufacture and test their product. At the same time prospecting is carried out. They also have to verify whether the product complies with specific safety regulations or whether a specific certifying is needed before it is delivered.

We see here a clear link with the Implementing phase of the CDIO lifecycle model.

Phase 4 : Closing phase/ commercializing > Operating

The closing phase, as VLAJO puts it, is rather business oriented. This phase describes the so-called liquidation of the company (settling accounts, paying invoices, paying out shareholders, stock liquidation, ending the SBP). Finally, students receive a certificate presented by VLAJO.

Furthermore, within our study programme we want our students to reflect upon maintenance service, repairs, upgrades and continuous product improvement. The possibility of a spin-off is also examined.

The following table gives an overview of the past SBPs and the percentage of participating second year students within the Electromechanics study programme.

Table 2
Overview Small Business Projects

	Title SBP	Percentage participating students
2005-2006	E lab LightDEC TouchMaster Pro Rower	12,2%
2006-2007	Can Crusher HandAid M.I.D. Promo Inno TLC Technics Coctail Cooker	18,5%
2007-2008	Modulight Smart Plants Eco Modif Dream Corp	17,7%
2008-2009	Cutting Edge FAC inventors TTS Technical Training System	13,7%

Except for the SBP-business plan, which is assessed by VLAJO, the same evaluation procedure is used for the generic project as well as for the SBPs. A distinction is made between process evaluation and product evaluation.

Evaluation

Process evaluation

Team work and working process are assessed by means of an individual logbook, a reflection report (the student reflects upon his own functioning within the team) and an analysis of the strengths and weaknesses of the team. This team evaluation is effected as a co-assessment (student and coach assessing together).

Besides this, every team member is expected to fill in the Belbin questionnaire. Belbin investigated the psychological laws and patterns influencing good team working and introduced the term “team role”. An individual team role profile is linked to a digital evaluation form used for self and peer assessment. By means of this evaluation form each team member assesses the work, the attitude and commitment of himself and his fellow team members. The results are discussed with the coach by the end of the project at the last team meeting. By comparing his team members’ assessment to his own assessment the student is able to reflect upon himself and his learning process. This process evaluation accounts for 35 % of the total evaluation score.

Product evaluation

Each team draws up a tender or quote and a professional planning, this accounts for 15 % of the total, the evaluation of the end product accounts for 35 % and the written report for 5 %. Finally each team gives a short presentation concerning the project work, followed by a defence, this accounts for 10 %. The ‘godfather’ company attends the presentation of the SBP.

ADVANTAGES AND POINTS OF INTEREST CONCERNING SBPs

Advantages

- Participation on a voluntary basis, so the motivation of the students is strong
- Concept of learning by doing
- Stimulation of problem-solving thinking
- Stimulation of creativity
- Teamwork – team spirit
- True-to-life learning
- Business aspects are highlighted
- Entrepreneurial skills are accentuated

Points of interest

- Limiting the number of team members to five students per group to avoid ‘parasites’
- Improving the time management to avoid neglect of other course units
- Making engagements clear about who does what [1]

JUNIOR ACHIEVEMENT EUROPE AND WORLDWIDE

Flemish Young Enterprises is a leading member-organization in a dynamic international network: member of Junior Achievement -Young Enterprise Europe [5] and member of Junior Achievement Worldwide [6].

Figure 2. JA-YE Europe

Figure 3. JA Worldwide

CONCLUSIONS

The four steps in the lifecycle of a Small Business Project show a striking similarity with those in the CDIO product lifecycle. We consider the business aspects and the accent on entrepreneurial skills within SBPs an important added value. Business administration and management skills are a common thread throughout the SBPs. Because our students actually develop and manufacture a technical product, SBPs are an ideal learning experience which enables them to develop the specific CDIO skills.

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DEVELOPMENT OF CIVIL ENGINEERING DESIGN SKILLS THROUGH ACTIVE LEARNING

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ABSTRACT

In 2008, the Department of Engineering at the University of Liverpool launched the ***Liverpool Engineer*** initiative, which comprises an educational framework incorporating the principles of CDIO to develop multi-faceted engineers ready to meet the professional needs of the 21st century. Active learning is at the core of the Liverpool Engineer learning and teaching philosophy. For Civil Engineering students, the development of open-minded design skills is fostered through a series of three progressive Design-Build-Test projects, introduced in the first year of their academic studies. Students work in their tutorial groups (typically six students) to develop a series of model cardboard bridges, which are designed to carry realistic serviceability and ultimate loads with acceptable deflection and without collapse, respectively. The new Active Learning Laboratory was completed in 2008 and provides an ideal environment and facility for these projects, with an overall capacity for 280 engineering students (all disciplines). The structured progression of the bridge design projects allows students to experiment with and explore the properties of tension and compression members fabricated from cardboard. Their findings are compared with the anticipated loads in the members (derived using computer structural analyses with user-friendly graphics and animation) to allow them to develop a complete bridge structure and to make an assessment of its factor of safety. The truss geometry and member properties of the first 'Icebreaker' bridge are tightly constrained. For the second and third bridges, the student groups have an increasing degree of freedom to develop their own concepts and structural solutions to the problem. The paper will focus on the student experience and will discuss some problems and pitfalls encountered with their understanding of structural behaviour.

Keywords

Bridge, build, analyse, test, stability, strength, design

INTRODUCTION

The Department of Civil Engineering at the University of Liverpool merged with the Department of Engineering in 2006 to form a more coherent and integrated Department of Engineering. Emerging from this integration was the adoption of CDIO learning and teaching principles across all the engineering disciplines. In 2008 ***Liverpool Engineer*** initiative was launched, incorporating the principles of CDIO, to develop multifaceted engineers ready to meet the professional needs of the 21st century. This initiative coincided with the completion of a major building development at the University known as the Active Learning laboratory. This laboratory comprises a brand new state-of-the-art teaching facility that can accommodate all 280 engineering first year students, using purpose-built work benches. There is audio-visual equipment to allow academic staff to speak simultaneously to the entire student cohort on two floors, when required for announcements or introductory talks.

For Civil Engineering students, the development of open-minded design skills is fostered through a series of three progressive Design-Build-Test projects, introduced in the first year of their academic studies. This is a significant departure from the traditional introduction to a Civil Engineering degree programme, which would typically concentrate on the introduction of engineering science principles but with very little practical design experience in the first, and often the second years. The traditional approach was very successful in developing engineering analysts, but the outcome of these courses was often that students lacked practical skills, an understanding of structural behaviour or the ability to apply engineering judgement. These aspects were often left to be developed later in their careers, when working in practice. CDIO principles, incorporating active learning, have been adopted to bring forward the development of these more practical design skills. Students will graduate with a better appreciation of the relationship between engineering principles and practical design and more ready to face the challenges of a professional engineering career.

The first project, known as the 'Icebreaker' takes place over four afternoons in the very first week of the academic year when students first arrive at the University. Students work in their tutorial groups (typically six students), which presents an ideal opportunity to get to know their fellow tutees and to start working as a team at the start of their University life. This initial project is followed by two further progressive projects, which build on the skills learned (or not in some cases) during the ***Icebreaker*** project. Students develop skills of structural member selection and the design of structural form.

All three projects are based on exercises developed by Stephen J Ressler at the United States Military Academy [1]. The exercises have been now been run for the last three years at the University of Liverpool. A number of developments have been introduced to improve the student experience. However, the main principles of the project remain faithful to the original concepts.

In this paper the three progressive stages of the projects will be described. Key learning points will be highlighted and some of the typical problems encountered by the students are described

WEEK 1 – THE 'ICEBREAKER'

The ***Icebreaker*** project takes place during the afternoons of Monday, Tuesday, Thursday and Friday of the students' first week of their engineering degree programmes. All engineering disciplines participate in the same project, comprising Civil Engineering, Mechanical Engineering, Aerospace Engineering and Manufacturing Engineering students. At the start of each session the students are given a set of the briefing notes and a brief introductory talk. The project involves the building and testing of a simple single-span truss bridge made from cardboard cut from standard manila file folders. This material was chosen because it is cheap, readily available and provides a surprisingly good and repeatable structural behaviour. The project comprises a build and test exercise to a predetermined or constrained design. The geometry, sections and static loads are all provided and there is no opportunity provided for modifying the design.

Principal tasks of the 'Icebreaker' Project

Students work in groups of six (typically their tutor groups). A series of tasks (see Figure 1) were set to guide students through the component testing, analysis, fabrication and overall structural loading of a model cardboard bridge. The first task is to fabricate a set of tension and compression members to dimensions given in the briefing notes (see Figure 2).

Fabricate tension strips, strengthen ends

⇩

Fabricate compression tubes, strengthen ends

⇩

Test to failure tension and compression components

⇩

Analyse bridge structure to determine component forces

⇩

Determine component factor of safety and overall FoS

⇩

Fabricate tension and compression components for bridge

⇩

Fabricate gusset plate joints

⇩

Assemble bridge

⇩

Load bridge to serviceability and ultimate limit states

Figure 1. Icebreaker project tasks

Tension members comprise bars of three different widths, while the compression members comprise tubes of two different cross-sections and three different lengths. The briefing notes give instructions of how to fabricate these members from the plain card file folders. Each group is provided with a special tube folding device that had been developed over previous years. This device enabled cardboard to be folded around one of a series of formers to create an accurate and reproducible tube member. The students then tested these sample members on a lever test machine (see Figure 3) to determine their load carrying capacity. From this testing, students learn that the strength of a tension member depends on its cross-section area, while the strength of a compression member depends on both its cross-sectional shape and length. Students observe the difference between a local, concertina mode of buckling failure and a global buckling failure. Experimental results were subsequently used to calculate the overall load carrying capacity of the completed bridge by comparing them to the loads in each member determined by a simple structural analysis computer package (Dr Frame-2-D [2]).

Figure 2. Fabrication of tension and compression members

Figure 3. Compression testing machine

The groups were provided with a design for the main truss of the bridge in the form of an A1 drawing, which they could use as a template for the assembly of the various tension and compression members. The members are connected using cardboard gusset plates and glue (see Figure 4).

Figure 4. Truss assembly

Students are given access to the 'Dr Frame' structural analysis software with simple instructions on its use and how to model the truss bridge design (see Figure 5). This is an easy to use analysis package, which gives very good visual results. Using this information students were able to analyse a side truss of the bridge, to determine the axial loads in the members under a range of load cases, without any prior knowledge of structural analysis. This worked well and from the results, the groups were then required to calculate the safety factor of each the member of the bridge and to use the lowest value to give the factor of safety for the whole bridge.

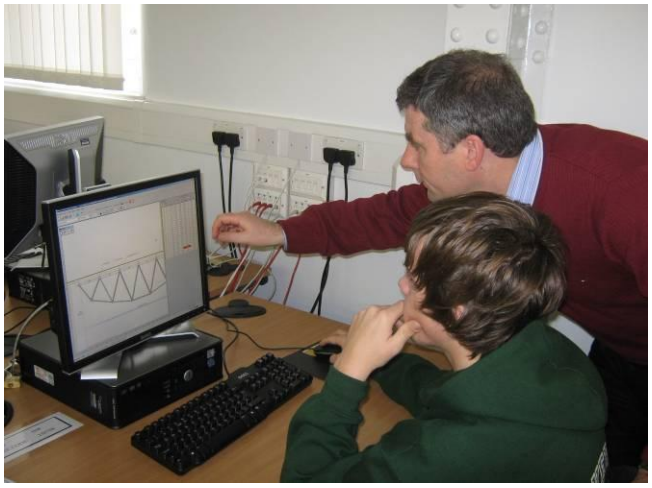

Figure 5. Dr Frame structural analysis

The groups were required to plan and to divide up the tasks (member fabrication, testing, analysis and assembly) to build the bridge within the allotted time ready for a showpiece testing session on the Friday afternoon. The project was designed as an introductory exercise to develop a range of important personal and professional skills. Students were motivated by the practical aspects of the project, clear goals and working in a team and being treated as professional engineers.

Some problems encountered during the 'Icebreaker'

There were a few problems with the use of the tube folder. Clear step-by-step instructions were provided on how to use the tube folder. However, they were not always read carefully, sometimes resulting in badly made seams on tubes and twisted sections. When assembling the main side trusses, some groups did not follow the instructions to use a piece of tracing paper over the drawing during the glueing procedure. This caused the fabricated members to be stuck to the drawing and made it much more difficult to lift up the assembled truss without damaging it. Each group was provided with a quality guillotine for cutting out cardboard members. There were also a few safety issues with students choosing instead to use scissors and the shape knife provided for cutting out the members.

A number of the groups omitted the strengthening collars recommended for the ends of the compression member test elements. This lead to a premature local failure of the tube ends and consequently the section strength was under-estimated. In addition tensile tests were sometimes carried out on the wrong sized bars. Occasionally, there was some confusion over whether a member was being tested in compression or tension due to arrangement of the lever-testing machine. There were examples where excess gravel ballast was suddenly dumped into the loading bucket at the often sudden point of failure.

The tension/compression test machine incorporated a steel retaining stay, which allowed the lever arm to be firmly propped while delicate cardboard test members were positioned and restrained. Some groups even proceeded with tests while the retaining stay was still in place, indicating that they were not always thinking or questioning the reality of the test they were undertaking. Not all of the plotted results of the compression members (load capacity v length) were the correct shape. Some plotted results curved upwards instead of downwards, indicating an increase in compressive strength with member length.

However, the one issue that caused the greatest confusion was the re-occurring of the factor of 2 in calculating the factor of safety. First, the testing machine included a mechanical advantage of 2 between the applied load and the test piece (see Figure 3). Some groups failed to realise that the strength of the member was twice the load of the applied ballast at failure. Second, more than one group forgot that the analysis related just to one of the two trusses in the bridge and consequently over-estimated the loads in the members by a factor of two. Finally, there were a number of examples where students did not take account that tension members were made from two parallel flat bars on each side of the truss and that the total tensile load in the truss member was to be shared between the two bars.

Testing of bridges at the end of the 'Icebreaker'

On the Friday afternoon there was a ceremonial testing of all bridges in front of all of the Civil Engineering groups (see Figure 6). All groups completed their bridge models and presented them for testing along with a calculated factor of safety and an assessment of the critical truss member. Not all of these factors of safety were within the expected tolerance of the anticipated factor of safety of 2.1.

Figure 6. ***Icebreaker*** ceremonial testing

Most bridges carried their design load of 5kg (representing serviceability limit state) and many carried the added overload of 3kg (representing ultimate limit state) successfully. Where they did not, the most common cause of failure was in the tension members located at the bottom of the truss. Where the parallel bars were of uneven length, it became obvious during loading that one was slack while the other was tight. This of course led to premature failure when the tight bar fails, carrying the entire load that had been assumed to be shared between two equal bars.

WEEK 2 – TWO WEEK CREATION – PART 1

The second stage of the project is known as the ***Two Week Creation - Part 1***. This takes place in the last week of Term 1 immediately before the Christmas break. The usual timetabled lectures were cancelled for the full 5 days. The project was again carried out in the Active Learning Laboratory.

The project consisted of the construction of a second bridge. The main difference with the Icebreaker bridge was that they were given a different geometry – this time a Warren Deck truss with the structure below the deck level. In addition the design load for the second bridge was a more realistic rolling load travelling across the span rather than a static load placed at midspan. Students again analysed the structure using Dr Frame software to determined loads in all the members. They then used these results to select their own member sizes, based on the capacities they had measured during Icebreaker testing. However students were given access to a greater range of tube folder formers. This enabled the fabrication of a much greater range of compression tube sections. Students were instructed to determine by testing the strength of any new section size they wanted to use. This increase in choice of the compression member section enabled a significant optimisation in the design of the bridge to be carried out.

Loading was carried out using a 6 kg weight with wheels, representing a rolling truck load, that was pulled across a hinged aluminium road track, sitting on the top chord of the truss, by a simple pulley system (see Figure 7). There was again a 3.8 kg overload that was tested with a second passage of the truck across the deck.

Figure 7. ***Two Week Creation Part 1*** testing

For this bridge truss fabrication the students produced their own drawings of the main trusses along with schedules of all the member sizes required. The drawings were needed as a template for the assembly of the bridge.

In addition to the Dr Frame structural analysis, students were also required to use the West Point bridge visualisation software [3] (see Figure 8), which produced a structural model set in a visually realist setting of an urban river crossing. This software gave an exaggerated visual assessment of the deflected shape of the bridge under self weight and applied vehicle load. In addition under load the truss was coloured with a blue/red indication of tension or compression loading in each member of the truss. The software package also gave an immediate indication of the relative cost of any design choices or changes. Although the prices given were almost an order of magnitude less that realistic 2009 values and were quoted in US dollars, they did nevertheless give a useful indication of the relative cost efficiency of the designs.

Figure 8. West Point Bridge visualisation software

Students fabricated the members using the techniques learned in the ***Icebreaker***. Some groups optimised the member production into a very efficient production line process.
Bridge assembly was generally efficiently undertaken. A design change was deliberately introduced halfway through the project week, requiring a small modification to the geometry of the truss to enable it to fit within the bridge supports provided. This placed each group under a little pressure to modify their designs and provided an awareness that last-minute design changes can and do occur in real life. The test supports and a long ruler were available throughout the week, so that the fit of the bridges within the test bed could be checked. Most (but not all) groups took advantage of this to check the fit of their designs and the quality of the fabrication. Some groups had to undertake late modifications to their bridge fabrication on the day of testing to enable positioning on the non-adjustable bridge supports provided.

Some problems encountered during the Two Week Creation – Part 1

There were few technical problems with either the design or the construction of this series of bridges. Most of the problems that did occur were related to the management of the production. Teams were required to decide on a Team Leader and a Portfolio Manager to ensure that activities were carried out efficiently. Although the vast majority of students were very engaged with the project, there were a couple of examples of where the team didn't gel together well. In these groups some students did not show up for sessions, increasing the workload on the rest of the group.

The production of the A1 drawings was sometimes a bottleneck, resulting in periods where the team was effectively waiting for one student doing the drawing.

Testing of Bridges at the end of the Two Week Creation – Part 1

Every group finalised the construction of the bridge and presented it for testing at the ceremonial testing on the Friday morning. The groups were again required to declare the calculated factor of safety in advance of the testing and to identify the critical member with the lowest factor of safety. The weight of each bridge was recorded. This information was later used to determine which group had built the lightest bridge able to carry the load and overload. This group was declared the winner.

WEEK 3 – TWO WEEK CREATION – PART 2

The third stage of the project is known as the ***Two Week Creation - Part 2***. This takes place in the first week of Semester 2 immediately following the January examination period. The usual timetabled lectures were cancelled for the full 5 days and again the project was carried out in the Active Learning Laboratory.

The project objective was the design, construction and testing of a third bridge. This time the bridge was required to have twice the span but to carry the same truck load and overload. For the third bridge students were given complete freedom over design of the truss geometry and truss member sections. They were given some information/guidance on the range of types and applications of trusses used in real life bridgeworks. They used this together with their own initiative and design experimentation with the structural analysis packages to conceive their own truss geometry. This resulted in a wide range of truss geometries being adopted. Most groups selected Deck Trusses and Through Trusses but sometimes both! The latter demonstrating their very early stage in the understanding of structural behaviour. However, by this stage in their lecture studies they had covered frame analysis in Structures lectures. They should have appreciated that double chord trusses were an inefficient use of material. One student group in 2007 showed real initiative and imagination by rejecting the above and below deck truss options previously used. With no restriction on height given, they selected a truss comprising two very large compression members making a three-pinned arch, with tension members from the apex supporting every bridge deck hinge (Figure 9). Although the compression members were relatively heavy, the overall weight of the bridge was one of the lightest built.

Figure 9. Unconventional truss geometry

Students then analysed the structure, using Dr Frame, to determine the loads in all the members. This information was used to select member sizes. Using the results from the ***Icebreaker*** and ***Two Week Creation - Part1*** testing, but they still had facilities to fabricate and test any size and length of tube that they wanted. The students produced their own drawings of the main truss and schedules of the member sizes required. The drawing was used as a template for the assembly of the bridge.

By the time of this third week, groups were generally able to apply much better fabrication methods. All tubes were better made and the trusses were all offered up to the testing supports to eliminate any span fit problems.

Some Problems Encountered during the Two Week Creation – Part 2

Every group finished the construction of the bridge and presented it for testing at the ceremonial testing on the Friday morning. The groups were required to declare the calculated factor of safety in advance of the testing. The weight of each bridge was recorded. This information was later used to determine which was the lightest bridge that carried the load and overload. That group was declared the winner.

The biggest problem encountered for the third bridge was the poor connections detailed at the ends of the road carrying members (see Figure 10*).* This was in sharp contrast to the well designed and fabricated main trusses. The cross-members were not included in the design of the main trusses and little thought seemed to be given to this detail. Also little thought was given to the lateral cross-bracing that should have been providing lateral stability (see Figure 11).

Figure 10. Two Week Creation – Part 2 – End connection failure

Figure 11. Lack of lateral stability during testing

Generally, there was little effort put in to optimise the design. This was likely to be because most groups wanted to ensure that their bridge achieved the design load capacity (and the overload) and there was little incentive or reward for trying to minimise the weight of the design.

Some of the fundamental mistakes made included:

(i) Some of the bridges were asymmetric.
(ii) Tension members were provided where compression occurs.
(iii) Wrong number of cross-beams provided to support the roadway.

The majority of the bridges carried both the design 6 kg load and the 3.8 kg overload.

Where failures did occur, the most common causes of failure were:

(i) Breaking of tension members due to unequal sharing of the load (fabrication tolerances).
(ii) Collapse of the deck cross-beams that support the roadway (as a result of lack of attention to detail with the load not even reaching the carefully designed and built trusses) (see Figure 12). This was the fate of the bridge in Figure 9.
(iii) Damage during set-up caused by member misfit at the support.

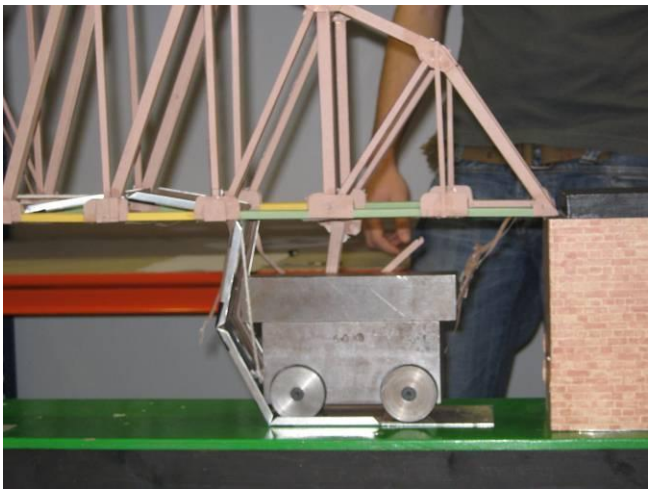

Figure 12. Collapse of the deck cross-beams supporting the roadway

CONCLUSIONS

The three stage cardboard bridge design and build project has proved to be a good project that works well and is very popular with the vast majority of students. The only recurrent costs are cardboard, paper and adhesives. Once setup, the project is also extremely cheap to operate four consecutive years. Overall the project provided a series of progressive design and building exercises with increasing design freedom. This project ties in well with the early Year 1 Structures lectures. It enables students to think about structural form and behaviour at a very early stage of their university academic life. It also provided numerous teaching points within a very practical environment. This project is a successful example of CDIO and the principles of the ***Liverpool Engineer*** in application of Active Learning. The

whole project benefits from the environment provided by the new Active Learning Laboratory facility at the University of Liverpool.

Students focused on the two-dimensional aspects of the bridge (as they had been taught in lectures), whereas many of the failures related to three-dimensional effects. It also highlighted in a very tangible way that many of the failures related to the details that they had not thought about rather than to their carefully considered designs.

There were many examples of lessons that were learned as the project progressed. These included improved fabrication and assembly techniques, improved end-details and checking the bridge fitted onto the test set-up properly. In some cases lessons were not learned, such as the common unequal length of bars in tension members, consideration of lateral stability and the details of the deck cross-beam connection.

In future the ambition and innovation of the details could benefit from an increase in the competitive aspect of the project. Maybe more emphasis and reward could be built into the project for achieving the lightest bridge that can carry the load.

In addition to the structural lessons, the three projects are help students develop many other personal and professional skills such as communication and team working, time management and project costs.

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Biographical Information

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DEVELOPMENT OF EVALUATION PROCEDURE FOR EFFECTIVE IMPLEMENTATION OF CDIO

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ABSTRACT

One of the challenges in modern engineering education is the demand for teaching of high quality where the subject is presented in an interesting and engaging way. By integrating and involving the students in the teaching process, the learning can be increased. At the Technical University of Denmark (DTU), the CDIO approach was started in the autumn of 2008 in the process of reforming the engineering education in order to educate the students to become more effective engineers. One of the goals is to effectively implement CDIO practices and reduce time for implementation. One of the ways to do this is to evaluate the students' view on the CDIO learning environment.

In order to get a high response rate from the students, it was decided to make the first student evaluation of the CDIO learning environment as a two page inquiry form with 16 questions on the front page and possibilities for individual comments on the reverse side of the page. In addition to the paper inquiry form there was the traditional electronic inquiry at the CampusNet. The two forms show significant difference in response rate since the paper inquiry form gave a response rate of 84% (=100% of all students attending the presentation day) compared to only 45% at the electronic inquiry at the CampusNet – giving the paper inquiry form a far more representative value.

Altogether, this material has given the CDIO staff very good material for the evaluation of the CDIO Design Build course and input for improvement and effective practices. In general the results show a very high satisfaction with the Design Build course and the students like the practical approach in the CDIO concept. The students are very committed and the course motivates them for added interest in studying constructional engineering.

KEYWORDS

Design Build course, evaluation, inquiry form, paper inquiry form, effective implementation

INTRODUCTION

Earlier the traditional standard format for lectures was a 45-minute teacher monologue. Research showed that this kind of teaching had a number of weaknesses, and there was a need for supplementing the lecture in the form of student activities [1] [2] [3]. Human beings are not able to keep the attention for more than around 15 minutes before concentration falls dramatically [1]. For this reason, it is necessary to vary the lecture activities. In the 21st century there has been an increasing recognition that teaching needs to have a higher priority, and it is necessary to put a lot of effort in the process of increasingly improving the quality of the teaching [4]. The result of this is that teaching in modern engineering education demands teaching of high quality, and the theory has to be presented in an interesting and engaging way. One way is to integrate and activate the students in the teaching process, and in this way the students can learn more.

The semester at DTU consists of a 13-week period prescribed for 5 ECTS courses, a two-week exam period and a three-week period prescribed for 1 ECTS course, usually as a more practical course, where parts of the theory from the 13 week period is used. At the Technical University of Denmark (DTU), the CDIO approach [5] [6] was started in the autumn of 2008 in the process of reforming the engineering education in order to educate the students to become more effective engineers. This paper deals with evaluation of the first CDIO course in the autumn 2008 in the first semester at the Department of Civil Engineering. CDIO is introduced as a Design Build course.

DESIGN BUILD COURSE

In the “Design Build course” the students had to build a model house. The demands concerning the house were that it had to be built in scale 1:20 as a model of a realistic house and had to be tight. In addition, it had to include a measurement unit, which could be connected to an outside measuring instrument. All the houses were placed on a plate of polystyrene in order to make the heat loss negligible.

Each group of students as part of the CDIO process had to design a house and from this implement the best solution chosen from a free focus area. This could, for example, be the best insulation, the most untraditional shape, alternative building materials or the most original house. After the model house had been constructed, the student had to operate it by measuring the heat loss for one month and compare these results to theoretical calculations of heat loss of the model house based on methods they had learned in a parallel course. The total calculated heat loss was calculated per Kelvin temperature difference in order to be able to compare theoretical results with measurements.

Figure 1. Students working on the model house – left. The final model of a house – right

QUESTIONNAIRE

For the last 12 years, the students at DTU have evaluated the courses they have attended. For the last 7 years this has been done electronically as an integrated part of the CampusNet computing and course administration system. The electronic evaluation system at DTU has been described in a former paper at the 1st CDIO conference [7].

One of the important reasons for creating an evaluation system of the engineering education system is to get an idea of how well the defined goals and objectives are met. By doing this kind of evaluations year after year, it is possible to get a relative quality measure for the teaching systems over the years. This evaluation can take place on several different levels, where one of them will be on course level. By introducing the electronical evaluation system on our CampusNet, there has been opened up for a more detailed number of evaluation data, which makes it possible to extract important information. However the negative side effect is that the students get tired of all these evaluation questions of all the courses – six courses each semester making it up to 12 evaluation questionnaires a year. The response rate varies a lot from course to course, and in many cases the response rate is rather low, which means it will not be representative. One way to get around this would be to make it obligatory for the students in order to pass their exams that they have evaluated their courses. The risk of this would be that the response is unserious.

In this investigation of the Design Build course there has been a focus on a high response rate as close as possible to 100% for the students attending a special teaching day where the students presented their work. The students were informed in advance that they had to attend at this specific day. The inquiry forms were handed out to the students, and they were asked to fill it out right away and after having done so the forms were collected. The result from this was a 100% response rate of the students that were attending this obligatory presentation. The missing students were not included in the evaluation. It was discussed whether they should be contacted to fill out the enquiry form, however, in order to secure their anonymity, it was decided not to include them, since the answers could be affected by the fact that they could be recognised. If one looks at the response rate of the total number of students, only 16% were not included because they did not show up for this obligatory presentation. Since 100% of the students attending the presentation day answered the enquiry form, the results are very representative.

In addition to the paper inquiry form, there was also the traditional electronic inquiry at the CampusNet. The two forms showed a significant difference in response rate since the paper inquiry form gave a response rate of 84% (100% of all students attending the presentation day) compared to only 45% at the electronic inquiry at the CampusNet – giving the paper inquiry form a far more representative value.

The paper questionnaire was made as a two-page inquiry form with 16 questions on the front page and possibilities for individual comments on the reverse side of the page. The answers are ranked from very good (positive) (5) to very bad (negative) (1) in order to simplify the students` answers and be able to quantify the answers. As a consequence of other questionnaires, with too many questions, resulting in lack of answers or unserious responses, it has been considered important to simplify the inquiry form. In addition to the inquiry form, students will be selected for personal interviews in order to give more detailed information about the CDIO evaluation. Similarly, an inquiry form for the evaluation of the teaching staffs' views on the implementation of CDIO has been developed.

Evalueringsskema – BYG-Diplom: Design-Build-Projekt
Efterår 2008

Følgende spørgsmål vurderes på skala fra 1 til 5, hvor 5 er bedst – og 1 er dårligst

			5	4	3	2	1	
1.	I hvor høj grad har kurset bevidstgjort dig om processen fra udvikling af ide til udførelse?	**Meget**						**Lidt**
2.	Har du har fået tilstrækkelige virktøjer til projektarbejdet?	**Tilstrækkelig**						**Ikke nok**
3.	Engagerer undervisningen/projektet dig?	**Ja i høj grad**						**Nej slet ikke**
4.	Har undervisningsformen i dette kursus motiveret dig til yderligere interesse for at studere til bygningsingeniør?	**Ja i høj grad**						**Nej slet ikke.**
5.	Hvad synes du generelt om projektets indhold?	**Meget godt**						**Meget dårligt**
6.	Hvordan er dit samlede faglige udbytte af projektet?	**Meget godt**						**Meget dårligt**
7.	Hvor meget har projektarbejdet udviklet dine samarbejdsevner?	**Meget**						**Lidt**
8.	Integrerer projektforløbet de øvrige fag på semesteret?	**Meget godt**						**Meget dårligt**
9.	Hvordan har samarbejdet været i din gruppe?	**Meget godt**						**Meget dårligt**
10.	Oplever du at kurset giver en bred introduktion til ingeniørarbejde og bygningsingeniørstudier?	**Meget godt**						**Meget dårligt**
11.	Hvad er dit udbytte med hensyn til egen problemafgrænsning for projektet?	**Meget godt**						**Meget dårligt**
12.	Hvad er dit udbytte med hensyn til design af løsninger til projektet?	**Meget godt**						**Meget dårligt**
13.	Hvad er dit udbytte med hensyn til udførelse af projektet fysisk?	**Meget godt**						**Meget dårligt**
14.	**Hvad er dit udbytte med henyn til måling og drift af projektet?**	**Meget godt**						**Meget dårligt**
			Antal		M	K		
15.	**Hvor mange er der i jeres gruppe?**							
			0-1/2 time	1/2-1 time	1-2 timer	2-3 timer	3-5 time	>5 timer
16	**Hvor mange timer har du arbejdet med projektet forudsat de 4 skemasatte projekttimer pr uge?**							

Nedenfor opfordres du til at komme med mindst én ting om hvert af de følgende 3 punkter:

– Jeg værdisætter:

– Jeg kritiserer:

– Jeg foreslår:

Nedenfor kan du komme med supplerende oplysninger til de enkelte spørgsmål, hvis du ønsker det. Vær venlig at skrive spørgsmålsnummer foran, hvis du vil uddybe et enkelt punkt.

Figure 2. The two-page questionnaire in Danish as it was distributed to the students. Front page to the left and reverse side to the right.

The two-page questionnaire is shown in figure 2. The front page of the questionnaire contains the questions specially designed for this course. The questions will be gone through later in this paper. A mistake was made by not putting in a “turn the page” note. 17% of the students never got to the reverse side of the questionnaire.

The reverse side of the questionnaire contains, first of all, the possibility for the students to make personal comments – see figure 2 to the right. The following is the text of the reverse side of the two-page questionnaire in Danish – translated into English:

> Below you are requested to write at least one opinion of each of the following 3 items:
>
> - I appreciate:
> - I criticize:
> - I recommend:
>
> If you want to, below you can add further information to the specific questions. Please note number of question if you wish to clarify something.

The simplified form of the questionnaire makes it easy and fast for the students to answer the evaluation questions.

The inspiration and development of the questionnaire is based on personal interviews with students during the course in order to select the right questions and how to perform the questionnaire in order to get the highest number of answers from the students.

ANALYSIS OF THE QUESTIONNAIRE

Below is a going through of some of the questions of the questionnaire – in figure 5 you can find all the specific percentages for each of the questions of the questionnaire.

Unfortunately the electronic inquiry at the CampusNet was not coordinated with the paper inquiry form. The consequences of this were a missing opportunity to make a good comparison between the two inquiries, especially looking into the fact that the paper inquiry form included 84% of the students compared to the only 45% at the electronic inquiry at the CampusNet. This would definitely have been of great interest to do.

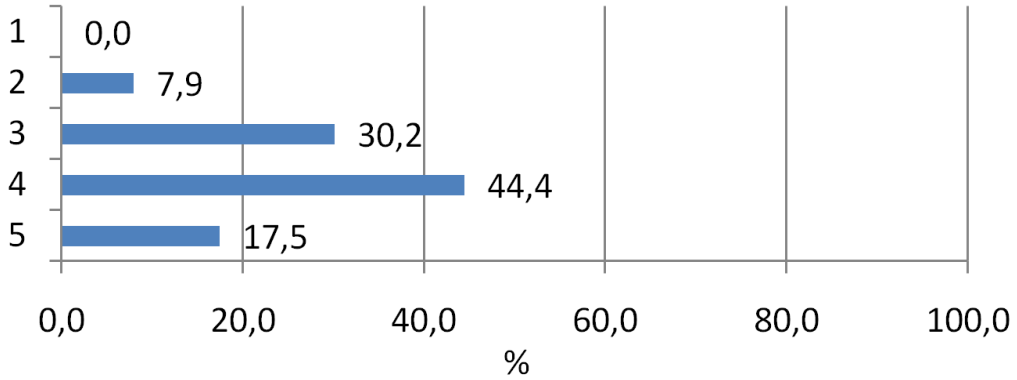

Figure 3. Results from question 1 – To what extent did this course make you conscious of the process from conceiving an idea to the implementation? The scores are ranked from very good (positive) (5) to very bad (negative)(1)

1. To what extent did this course make you conscious of the process from conceiving an idea to the implementation? – See results in figure 3. The philosophy behind the concept of CDIO is to make the C, D, I and O visible and form part of the teaching frame progress. The teaching has to show a picture and authentic elements have to be brought into the teaching in the CDIO Design Build course. In the first question, where the students have been asked: to what extent did this course make you conscious of the process from conceiving an idea to the implementation? – 62% gave the score 4 or 5, 30% average 3. Only 8% gave the low score 2 and 0% the lowest score very bad – 1. The results from this question show that the course seen from a CDIO point of view has been a great success since 92% gave from medium to the highest score.

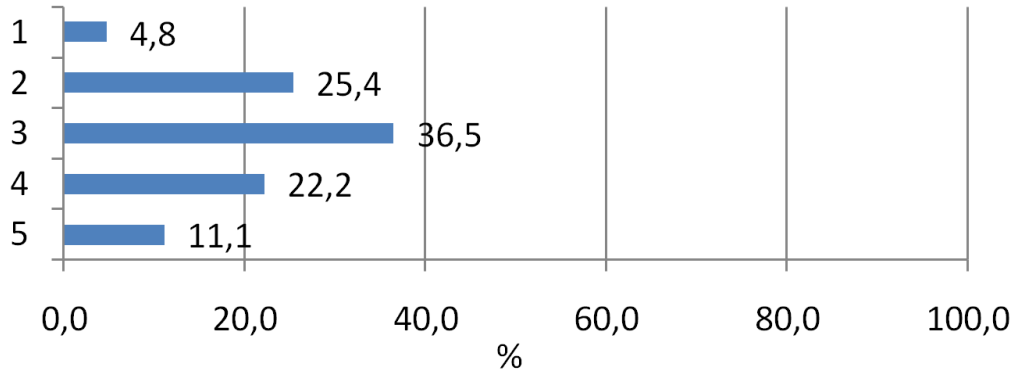

Figure 4. Results from question 2 – Did you get adequate instruments/tools for working with this project? The scores are ranked from very good (positive) (5) to very bad (negative) (1)

2. Did you get adequate instruments/tools for working with this project? – See results in figure 4. The results of this question follow a normal distribution with 37% at average 3 and approximately 24% at the scores 2 and 4 each. The conclusion from this is that the instruments for working with this project have been insufficient – however the formulation of

the question is rather unclear since it can be misinterpreted. The word “værktøjer” in Danish can be understood as a tool like a hammer the students need to build the model of the house – however, the word “værktøjer” can also be understood as an instrument, for instance describing how to write a report. The inspiration for this question came from a personal interview with two of the students in order to get ideas about how to build up the questionnaire. The students complained that they were working on the project on a practical level, but they lacked instructions how to build up the report since they were only told to take notes. Based on this inspiration from the students the question was proposed. As seen from the above, the question has been formulated unclearly and can be understood as two different questions: 1 – tool like a hammer and 2 – instrument like instructions.

This is an example of how difficult it actually is to make a good questionnaire – it is most important to make sure that the students will not misinterpret a question. The result from this question cannot really be used for anything since the students from personal interviews indicate that they have been satisfied with the practical physical objects and have been dissatisfied about the information of how write a report. See also question 7.

3. Did the lessons/project make you commit yourself? – 75% gave the score 4 or 5, 20% the average score 3. Only 5% gave the low score 2, and 0 % the lowest score very bad – 1. From this it can be seen that 95% of the students find themselves committed to the project by giving the score from medium to high. This shows that the CDIO concept commits the students in the engineering education but also that the students who are maybe not so book-learned but rather prefers practical education can use the CDIO concept.

4. Did the teaching method of this course motivate you for added interest in studying constructional engineering? The concept of CDIO is to integrate and involve the students in the teaching process and make them more interested in the study. The scores show that the CDIO concept used in the course has been a success in respect to making the students interested in studying to be an engineer, since 74% of the students gave the score 4 or 5, 20% average 3 and only 5% gave the low score 2 and 0 % the lowest score very bad.

5. Overall what do you think of the contents of the project? – 27% gave score 3, 51% – score 4 and 10% the highest score 5. The results show a high satisfaction with the project since 88% gave a score from 3 to 5 with the maximum at score 4.

6. How is your total professional, technical benefit of the project? – Average positive score: 48% gave score 3, 37% – score 4 and 3% – score 5. It looks as if the students’ total technical benefit from the project could be better, and there might be a need for working on that.

7. How much did working with this project develop your interpersonal skills? – Average positive score: 38% gave score 3, 40% – score 4, adding up to 78%. 14% gave the poor score 2, which, compared to the other answers, are relative high. Incorporating tools for the students to develop better interpersonal skills could be a good idea, especially since this is the student’s first course at our university. This is an obvious subject to include in a course like this, since the corporation here and as an engineer is so important. See also question 2 and 9.

8. Did the project process integrate with the other subjects of the term? – The project was planned to integrate the theory from the other courses in order to support the design build project. The results show a reasonable success rate: 35% gave score 3, 43% – score 4 and 14% – score 5.

9. How was the teamwork in your group? – The teamwork in the groups seems to have worked very well since 32% gave the score 4 and 40% the highest score 5. Compared to the results in answer 7 (development of your interpersonal skills), the result seams to give

approximately 1 point higher score. This can be a result of the Scandinavian tradition, where the students work very much in groups in the gymnasium before they start at the technical university, and as a consequence of this, the students had already a good skill for teamwork in groups.

10. Do you experience that the course gives you a wide introduction to engineering and studies of constructional engineering? – 29% gave score 3, 44% – score 4 and 14% the highest score 5. Altogether adding up to 87% giving a score from 3 to 5 shows a high satisfaction. This can be an important issue for the students' decision concerning whether to continue their study to be engineer or change study. The answer also indicates that the CDIO course is a good alternative to the traditional teaching.

11. What is your benefit with regard to your own problem delimitation for the project? This is the only question where both score 1 and 5 gave 0%. 64% gave the medium score 3 and 32% score 4 – giving a total of 96%, showing that the students delimitation seems to have worked satisfactorily.

12. What is your benefit in regarding the design of solutions for the project? – 41% each for score 3 and 4. – and 8% for score 5. This is a total of 90% – this is very good. In the design phase the students have their focus on creating a good design for the building, which includes drawings, plans and calculations that all together describe what will be implemented.

13. What is your benefit in regarding the physical implementation of the project? – 37% score 3 and 44% score 4 and 11% score 5. This is a total of 92% – The results show a good satisfaction by the students concerning the implementation stage in which the students transform the design into the small model on which they are measuring in the last operating stage.

14. What is your benefit in regarding the measuring and the operation(s) of the project?
38% gave score 3 and 45% score 4 and 6% score 5. This is a total of 89% – In the final stage, the students have been operating the model of the house, got measuring results and extracting the data from the model, and transformed them to their laptop. The responses from the students indicate satisfaction with this operation stage.

15. How many students were in your group? The groups have consisted of 3 or 4 members, with a majority of 4. The average has been 3.7 members.

16. How many hours a week did you work with the project in addition to the four scheduled project lessons? 0 - ½ h; 1-2 h; 2-3 h; 3-5 h; >5 h
A 5 ECTS course is prescribed for 9 hours per week, which means that an average answer to fulfil this should be additional 5 hours. Less than 13% answer that they work 3-5 hours more per week and only 1.6% (1 person) indicate more than 5 hours, indicating that only 14% work more than 7 hours per week compared to the prescribed 9 hours per week. This can to some extent be compared to the electronic inquiry at the CampusNet, where 64% answer that they work 9 or more hours per week. This is a very significant difference in answers between the two inquiry forms:

	> 7 h/week	9 h/week	> 9 h/week	≥ 9 h/week
Paper form	14%			
Electronic form		49%	15%	64%

86% work less than 7 hours per week according to the paper inquiry form compared to 36% less than 9 hours in the electronic inquiry form. It is very clear that the responses in the two inquiry forms are very different. One of the reasons deals with how the question is raised.

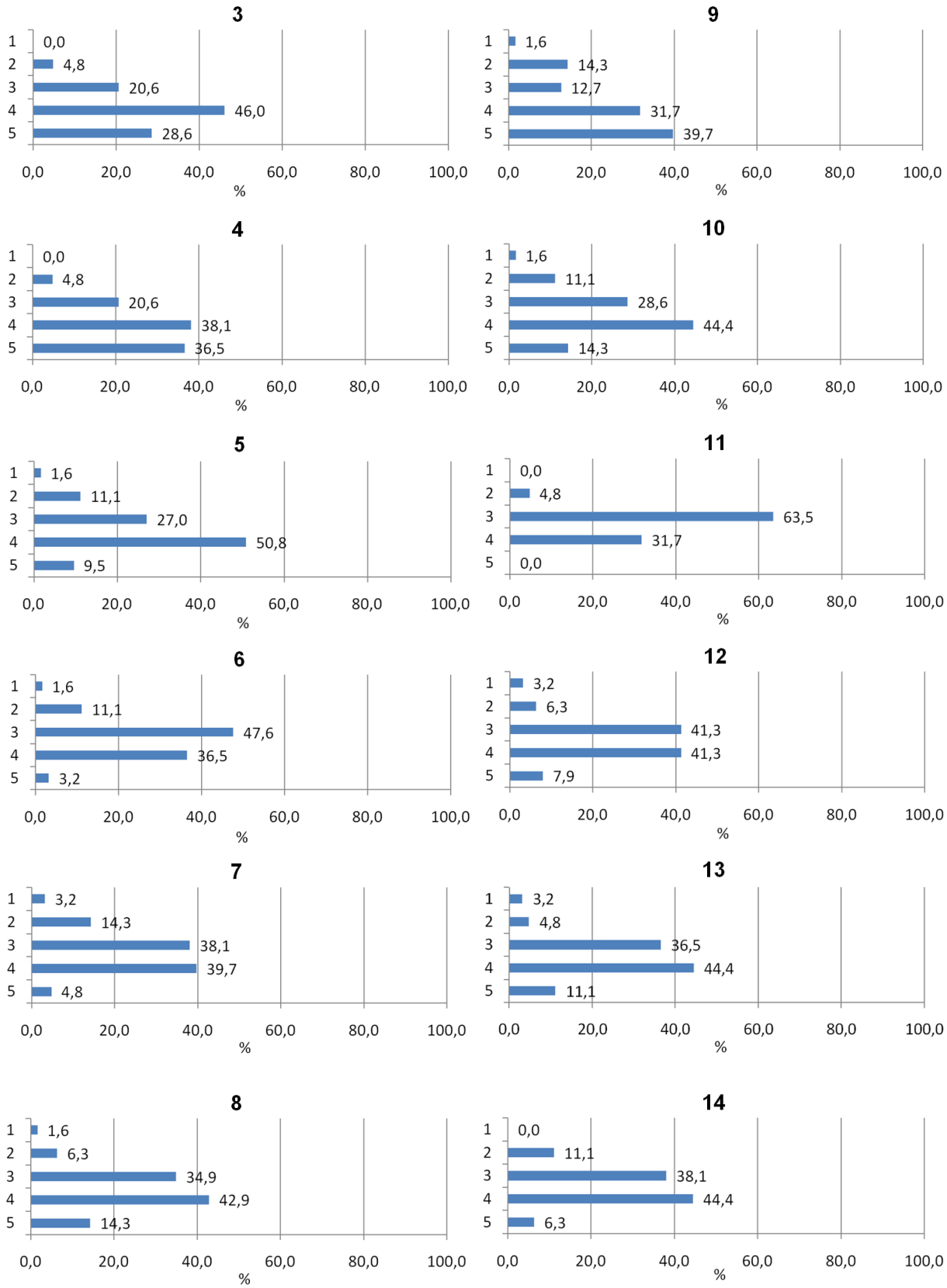

Figure 5. Results from questionnaire – The scores are ranked from very good (positive) (5) to very bad (negative) (1).

The question in the paper form: *"How many hours a week did you work with the project in addition to the four scheduled project lessons?"* In this case the student reflected directly about how many hours he/she was working, outside the university.

In the electronic form the question is: *"A 5 ECTS course is prescribed for 9 hours per week. I mean that my working load in the course is* (I have put score on below):

Much less	score 1	
	score 2	
	score 3	(9 hours per week)
	score 4	
Much more	score 5"	

As it can be seen from the question it is more diffuse in the performance of the question. 49% write approximately 9 hours per week. This looks like that the students tend to answer that they work the average number of hours per week even when they do not, according to the paper inquiry form. In personal interviews with some students, they told that they mostly work on the project when they are at the university. This indicates that the direct question of how many hours they work more gives the best answer.

This example shows how difficult it can be to raise the right question, and also how much the answer can differ. In addition, 84% have answered the paper form and only 45% the electronic form, which means that not the same relative percentages have answered the question.

CONCLUSION

The implementation of CDIO is a year long process according to experiences from other universities. In order to speed up the process at Department of Civil Engineering (Byg), Technical University of Denmark, a process for evaluation of the first CDIO course, which has taken part as a Building Design course, has been started. The evaluation has been done using a paper inquiry form in addition to the traditional electronic inquiry form at the CampusNet. The response rate from the two forms show significant difference since the paper inquiry form gave a response rate of 84% (=100% of all students attending the presentation day) compared to only 45% at the electronic inquiry at the CampusNet. This gives the paper inquiry form a far more representative value. Unfortunately the two inquiry forms were not coordinated properly in order to compare the results, and by this way get an idea about the extra benefit of making a manual collation of data from the paper form. However one of the questions concerning the students' working hours on the course per week could be compared and showed remarkable difference. In the paper form only 14% answer that they work more than 7 hours per week compared to the electronic inquiry form, where 64% answer that they work 9 or more hours per week. This is an extreme difference. If these results are compared with personal interviews, where students have earlier expressed that they only worked very few hours outside the scheduled 4 hour course time, this indicates that the result from the paper inquiry form is far more reliable than the answer at the CampusNet. In addition to this, the two results differ so much, that it is difficult to understand that both inquiries deals with the same course.

Altogether, this material has given the CDIO staff very good material for the evaluation of the CDIO Design Build course and input for improvement and effective practices. In general the results show a very high satisfaction with the Design Build course, and the students like the practical approach in the CDIO concept. The students are very committed and the course motivates them for added interest in studying constructional engineering. In addition the course is a good alternative to the traditional technical courses.

The students complained that they wanted better material in the early stage for writing a report since they were only told to take notes. There was also a lack of working space for the students when all were in the workshop and wanted a workbench. It seems that the students did not work the requested 9 hours per week and more work could be done in order to activate them outside the scheduled 4 hours weekly workshop. This could for example be information of how to write a report, co-operation, teamwork, communication, etc. This seems to be an important improvement since some of the negative comments from staff personal about CDIO are that they learn to little, and the general technical knowledge will suffer from the introduction of CDIO and the more project oriented teaching approach. Another improvement suggested by the author is in the beginning of the CDIO course on the first semester to introduce an introduction communication workshop for the new students [8].

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Biographical Information

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Development of professional Civil Engineering construction skills and health and safety awareness through active learning

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ABSTRACT

In 2007 the Department of Engineering at the University of Liverpool launched the Liverpool Constructionarium [1] initiative as a core component of the unique ***Liverpool Engineer*** [2] professional degree, based on CDIO learning and teaching principles. The Constructionarium is an immersive week-long experience in which students work in teams of 20 alongside industrial construction and design professionals on a series of real construction projects. The construction site working environment presents real health and safety hazards and associated risks and a significant risk of personal injury. This must be managed by the students in a professional manner and adopting the working practices and procedures of the industrial contractor.

The paper will present and discuss good practice procedures and will also discuss some health and safety incidents and near-misses encountered during the Constructionarium week.

Keywords

Construct, build, method statement, risk, hazard, professional, responsibilities

INTRODUCTION

The Constructionarium [1] is a full-week residential learning initiative in which students work in a realistic construction site environment to build real engineering projects. The students are grouped into teams of approximately 20 to form a small mini-company. Professional roles such as Project Manager, Liaison Officer, Site Engineer, Health and Safety Officer and so on are set up and students self-select their individual role. The students are supported by academic staff and staff from a collaborating construction company and consulting engineers. The University of Liverpool take the entire second-year student cohort to participate with the Constructionarium project early in the year, when inclement weather is common. The challenge presented by this initiative is how to handle around 100 inexperienced students working on a construction site with all its hazards and risks and to keep all operations safe and injury-free.

The construction takes place in the grounds of the National Construction College, located in Norfolk, in the south-east of England. A dedicated Constructionarium site has been set up which is permanently available for use by any UK university wishing to participate with the Constructionarium project. The site contains a number of conditions to expose students to the full range of construction challenges they will meet following graduation. These include a river gorge, a deep and a shallow lake, a dry dock facility and a large 20 m gap to be spanned, Figure 1. The individual projects present their own construction hazards, including working in excavations, working at height, working with construction plant and so on. It is imperative when planning and operating the construction projects with a large number of relatively inexperienced students that health and safety is paramount. The academic staff, construction staff and design staff must all work together as a team to ensure that all risks are minimised. This paper will discuss how health and safety is embedded into the Constructionarium learning initiative.

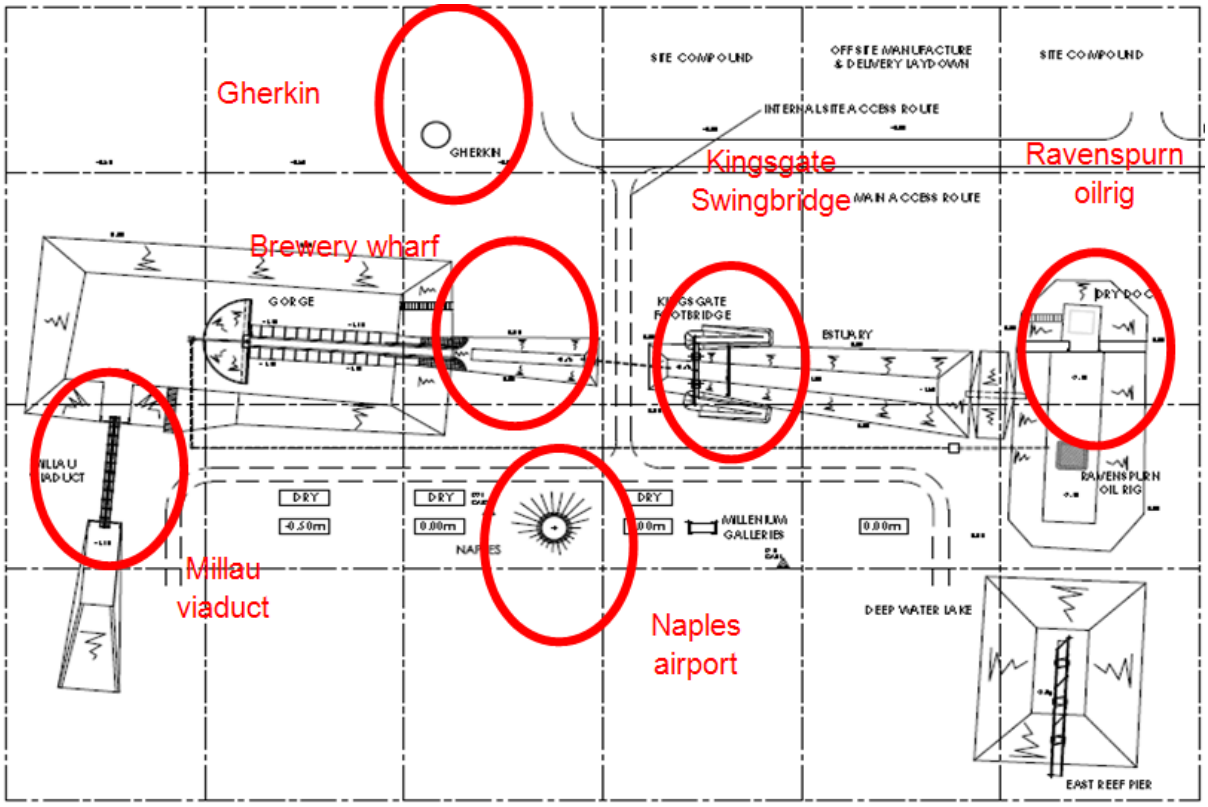

Figure 1 Constructionarium site

PROJECTS

A portfolio of construction projects has been developed by several universities initiating the Constructionarium. These are based on real life structures, which are scaled down to enable students to complete the construction within five working days. Projects which University of Liverpool has undertaken over the past three years comprise:

Ravenspurn oil rig
Kingsgate swingbridge
Brewery Wharf cable stayed bridge
Millau viaduct
Naples subway entrance and canopy
London Gherkin

Each project requires the student team to plan and execute the entire construction process from excavation of foundations and fabrication of timber formwork to steel-fixing, concreting, formwork striking and steelwork or structural timber erection. The projects are planned to finish with a grand finale on the last day, e.g. flotation of the oil rig into the lake and sinking on a predefined location. In addition to the construction processes, each student team must undertake full project planning and costing and must ensure that all site operations are conducted safely and with full written approval from the construction company, who have overall control of the project.

PRE-CONSTRUCTIONARIUM HEALTH AND SAFETY TRAINING

Before the Constructionarium week, students are engaged with a number of lectures, interactive exercises, coursework and formal induction to raise their awareness of health and safety on construction sites. An interactive virtual reality computer package [3, 4] is introduced in which students are encouraged to explore a fictitious construction site and identify hazards and their associated risks, Figure 2. As part of the preparatory coursework each student researches the real full-size structure on which their Constructionarium project is based and must report on the construction procedure and any associated health and safety issues. Immediately before the Constructionarium week, the collaborating Contractor presents a Health and Safety induction, which is a legal requirement before any site activities can be permitted. In addition the National Construction College has its own Health and Safety induction video, which all the students must watch.

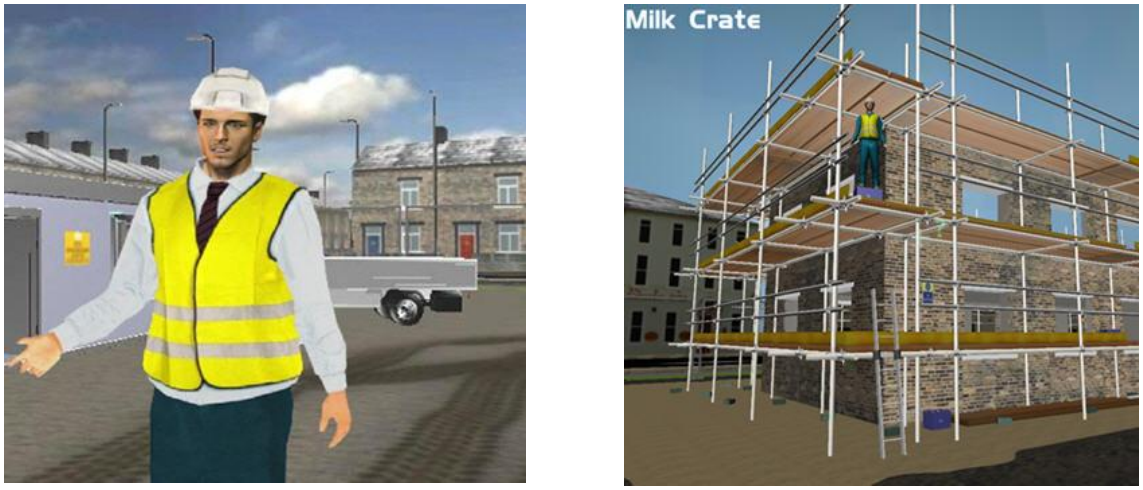

Figure 2 Construction site health and safety virtual reality package

PERSONAL PROTECTION EQUIPMENT

Personal protection equipment is provided partly by the students themselves and partly by the Contractor. All students must purchase their own steel toe-capped safety boots for use on site. The contractor provides high visibility jackets, construction helmets, safety eyewear and rubberised cotton gloves. These must be worn by every student at all times while on site. In addition for further activities some specialised PPE is required and supplied. Wood or steel cutting operations involving dust and noise are carried out by students wearing a suitable dust mask and goggles, together with ear defenders, Figure 3. Operations over water are carried out by students wearing personal flotation safety equipment, Figure 4.

Figure 3 Students with appropriate PPE using power tools

Figure 4 Use of flotation gear

CONSTRUCTION SITE PROCEDURES

Five or six members of each student team are selected to become "power tool operators". These are students who will use petrol or electric powered tools such as a timber ripsaw, steel/masonry cutter, drills and grinders. The students are given basic training and issued certificates by the National Construction College to ensure that they can use these tools safely. Following this training, these are the only students permitted to use any power tool for the rest of the Constructionarium week. They are identified by a bright coloured helmet sticker, which ensures that supervisory staff can control the safe use of power tools. However, hand tools such as hammers, saws and shovels can be used by any student, Figure 5.

Figure 5 Student with PPE using hand tools

At the start of the project, each team must prepare an overall plan of the method and the sequencing of the construction operations. This is then submitted for approval to the Contractor. For every subsequent operation to be carried out on site, the student team must prepare a written Method Statement together with its associated Risk Assessment. No activity is allowed to proceed without written approval from the Contractor of the Method Statement and Risk Assessment. This process is identical to that used when the students begin their professional career working on a real construction site and it provides a valuable introduction into how an inherently risky construction site can be operated safely. Students learn to differentiate between a "hazard", i.e. a dangerous situation (e.g. open water), and a "risk", i.e. the possibility of an accident occurring from a specific event (e.g. drowning). The use of Method Statements and Risk Assessments to control and manage all operations provide real risk awareness and enhances safety. It is not simply a "box-ticking" exercise.

GOOD PRACTICE

Using the training and procedures described, University of Liverpool together with two different Contractors, Edmund Nuttall [5] and Morrisroe [6] and design consultants Mott MacDonald [7] have successfully run 12 individual Constructionarium projects safely and without serious injury. Students have experienced working with heavy construction plant and

excavations, Figure 6. Manual lifting of heavy items has been carried out using sufficient student numbers and correct lifting procedures, Figure 7. Potential injury has been avoided during steel-fixing by using the correct procedures, PPE and safety caps on all steel bar ends, Figure 8. Students have worked at height using suitable safe access facilities, Figure 9 and have worked with corrosive materials (concrete) using correct training and PPE, Figure 10. Students have worked safely with ground excavation using appropriate construction procedures, Figure 11.

Figure 6 Working with construction plant

Figure 7 Manual lifting

Figure 8 Steel-fixing

Figure 9 Concreting

Figure 10 Working at height

Figure 11 Excavation work

HEALTH AND SAFETY INCIDENTS AND NEAR MISSES

The challenge of getting 100 students to work safely in a construction site environment has been considerable. It is inevitable that some minor incidents and near misses will occur but it is important to learn from these events to prevent recurrence. Events which have involved both University of Liverpool students and students from other universities, working with a different Contractor have included:

- A student using a steel-saw to cut through reinforcing bars and while wearing nylon trousers. The cutting sparks (Figure 12) melted the trousers and caused minor burns to the leg. All students had previously been advised to wear clothing made from natural fibres. This will be more closely monitored in future.

Figure 12 Cutting using steel-saw

- A student was observed using a hand saw to cut through a piece of timber while awkwardly positioned. This resulted in him working with his arms crossed so that his left forearm was close to the hand saw blade. He was stopped and advised how to position himself and cut the timber safely.
- A student used a power ripsaw to cut through a large sheet of plywood. The plywood was poorly supported and both the student and the plywood and fell to the ground. During the fall the ripsaw was still activated but the safety guard came up and prevented any damage or injury. The student was reminded of his training regarding how to support timber effectively before cutting.
- A student used a length of string of inadequate strength to pull on a structural timber member. The string broke and the student sat down heavily. Although this was a very minor incident, the entire Constructionarium site came to a halt for over one hour as medical services were brought in to ensure there was no serious injury. All students were advised that they must adhere to the approved Method Statements and not improvise procedures on site using inappropriate materials.
- Using a hand saw with excessive force caused the blade to bow and jump out of the cutting slot. Although the student was wearing safety gloves, the blade caused a deep cut to the thumb. This was a difficult accident to foresee. Although safety training is given in the correct use of power saws, it was incorrectly assumed that students could use hand saws safely. The use of PPE mitigated the injury. This incident is being used as a case study with the health and safety training for future students.
- A similar small accident occurred with a student nailing timber. He missed the nail and hit his own thumb with the hammer. On this occasion the student was not wearing safety gloves as instructed and some minor bleeding occurred. Correct use of PPE would have mitigated the injury, which in any event was quite minor. This incident was used to illustrate all students the need for wearing PPE at all times on site and for taking care when using tools.
- A potentially serious incident occurred when two students stepped over a safety barrier and walked on a bridge structure which was not properly secured and in an unstable position. Sharp sightedness and quick action from supervising staff prevented this situation turning into a major accident. Subsequent discussion revealed that the students knew that stepping over a safety barrier was wrong but they had not appreciated the seriousness of their actions. It is vital that although all students should enjoy the Constructionarium experience, they should not be allowed to let their enthusiasm overrule their judgement and health and safety training. It had not been anticipated by supervising staff that students would deliberately step over a barrier placed to keep them safe.

PROGRAM REVIEW AND ASSESSMENT

The Constructionarium is a new initiative which has provided students with an invaluable hands-on experience of construction site working practices and methodology together with management/planning/costing procedures and team working skills. The embedment of health and safety into every practical construction activity has been essential to ensure a safe working experience. This reflects practices that students will encounter when they begin employment in the construction industry.

This module cannot be compared directly with the previous student experience because there was no comparable implementation of this active learning. However some modules have been reduced in content to make space and avoid replication. For example students no longer manufacture a large reinforced concrete beam in the laboratory for testing. In place of this there is plenty of site concreting experience associated with Constructionarium. The

students test in the laboratory a precast reinforced concrete beam which has been commercially made to specification.

One of the unintended consequences of the success of the Constructionarium has been a surge in demand for the MEng Structures and Civil Engineering course, to the detriment of the Environmental and the Maritime MEng courses. All of the Constructionarium projects involve construction of one structure or another. The students enjoy this so much that they then opt to do the Structures MEng course in their 3rd and 4th years. Plans are in hand to redress the balance by introducing Constructionarium projects with more relevance to Environmental and Maritime projects.

The Constructionarium module has been subjected to independent review by the Joint Board of Moderators accrediting the Liverpool degrees and has been highlighted as an example of good practice in learning and teaching.

CONCLUSIONS

The Constructionarium initiative has provided a large number of students with an invaluable active learning experience of construction site techniques and procedures. By working with Contractor and design Consultant professional staff on realistic construction projects, the students gain an appreciation of real life operating procedures. The embedment of Health and Safety into both the preparation and operation for the Constructionarium has prepared the students for safe working practices in their future career and also to maintain a safe working environment for the Constructionarium itself.

The Constructionarium has been operated for three years by the University of Liverpool in conjunction with Contractors Edmund Nuttall and Morrisroe and with design consultants Mott MacDonald without any significant health and safety incidents or accidents. Lessons have been learned from several minor incidents and will be used to improve and enhance future Constructionarium events. It is clear that no amount of training and instruction can be provided to guarantee a 100% safe working environment. Students must be actively engaged in thinking about every action they wish to carry out on a construction site and the potential health and safety implications. Supervisory staff must maintain constant vigilance to reinforce the health and safety training and to maintain the good safety record so far enjoyed from the Constructionarium by all the participating universities. It is vital that Method Statements and Risk Assessments are conscientiously prepared and followed. These procedures are not merely a box-ticking exercise to provide a real contribution to a safe working environment.

ACKNOWLEDGEMENTS

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- Edmund Nuttall
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- Morrisroe

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DWC FLIGHT TEST EDUCATION AT UNDERGRADUATE LEVEL IN REALIZATION OF CDIO INITIATIVES

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ABSTRACT

Most undergraduate aeronautical engineering programs do not contain a significant amount of flight test engineering experience. In line with the CDIO philosophy of engineering education, Daniel Webster College has incorporated flight test education into its Flight Dynamics I (Aircraft Performance) and Flight Dynamics II (Aircraft Stability and Control) courses. Three flight tests plans are designed and executed by students in Flight Dynamics I to investigate and analyze three aircraft performance topics such as pitot-static calibration, saw tooth climb, and turn performance. Also, three flight tests are designed and flown in Flight Dynamics II to investigate three aircraft stability and control topics such as neutral point determination, lateral-directional static stability, roll controllability, phugoid dynamics and Dutch roll dynamics. In the past two years, we have learned several valuable lessons and made a few adjustments. This paper presents our experiences in this area and makes recommendations to other universities that might be interested in establishing flight test engineering in their undergraduate aeronautical/aerospace engineering programs. Highlights of the effectiveness of this experiential learning are presented.

KEYWORDS

Active, experiential, flight, test, stability, control.

1. INTRODUCTION

During the past decade a concerted effort has been made to close the gap between aeronautical engineering education and practice. Major aerospace engineering companies (e.g. Boeing) published lists of desired attributes, and leaders of industry urged a new look at the way students were being educated. Two key reasons account for the lack of convergence between engineering education and engineering practice: an absence of rationale and an absence of necessary experiences.

In surveying the literature, we did not find any papers that address the inclusion of flight tests in undergraduate aeronautical engineering programs. However, Queen's University [1] has presented a module built on problem-based learning in the area of flight handling qualities for senior level aerospace engineering students. This module does not include any flight test experience but is a good reference for schools looking to enhance student learning in the area

of flight stability and control. They provide details of how they incorporated flying qualities into a flight dynamics course. Normally this content is reserved for graduate-level study.

The four-year aeronautical engineering program at Daniel Webster College (DWC) evolved from a long standing two-year associate degree transfer program and was designed and implemented four years ago. DWC joined the CDIO [2, 3] initiative in June 2006. Features of the DWC engineering program include:

- Students will be well-grounded in theoretical bases of engineering;
- Small class size will allow for regular presentations and one-on-one communication;
- Students will get extensive machine shop experience beginning with the first semester;
- Students will have multiple open-ended design experiences beginning with the first semester;
- Students will receive multiple concurrent engineering experiences, taking a product from design and analysis to simulation to manufacturing to assembly and testing; and
- Students will have systems integration experience: sensors, controls, software.

In line with CDIO Standard 8--active learning [4]--that is, "Teaching and learning based on active experiential learning methods," a flight test engineering experience was integrated into the Aeronautical Engineering program.

Junior and senior Aeronautical Engineering students take a two-semester sequence of courses: Flight Dynamics I (Aircraft Performance) followed by Flight Dynamics II (Aircraft Stability and Control). Augmenting the classroom presentation of theory, students develop test plans and perform in-flight experiments using an aircraft equipped with flight test quality instrumentation developed and produced by the Calspan Corporation.

This rest of this paper is organized as follows: Section 2 introduces flight test engineering and its features. In section 3, the role of flight test engineering in undergraduate education at DWC is described. The details of flight test education requirements are examined in Section 4, including instructor qualifications, test pilot requirements, aircraft requirements, and most importantly flight data recording system requirements. Section 5 is devoted to the details of six flight test plans that we conduct in the two courses. Several samples from students' test reports are reviewed in Section 6 to describe the influence of flight tests on student learning experiences. Finally, lessons learned, future plans, and several recommendations to any institution considering adding flight tests to its undergraduate aeronautical/aerospace engineering program are presented in Section 7.

2. FLIGHT TEST

Flight test is a branch of aeronautical/aerospace engineering that develops and gathers flight data during the flight of an aircraft and then analyzes the data to evaluate the flight characteristics of the aircraft and validate its design, performance, flying qualities, and systems operation with emphasis on safety features. The flight test phase accomplishes two major tasks: first, finding and refining aircraft design problems, and second, verification and documentation of the aircraft capabilities for certification or customer acceptance purposes. The flight test phase

can range from the test of a single new subsystem for an existing aircraft to the complete development and certification of a new aircraft. Therefore the duration of a flight test program can vary from a few weeks to several months.

Modern aircraft are complex integrated systems with propulsion, avionics, aerodynamics, and structure blended together to achieve optimum performance, stability, and control and systems operation. The flight testing of such aircraft is an endeavor involving a number of engineering disciplines in addition to the study of the man-machine interface that is referred to as human factors. The human crew, which has both tremendous capabilities and known limitations, must interact with the aircraft and its systems. In addition, the management of a flight test program for a modern aircraft requires management skills that are not often included in most engineering curricula.

The primary purpose of today's flight testing is to determine if the aircraft and its crew can safely accomplish the intended mission. Other purposes may include collection of aerodynamic, power plant, and system data, and research into these or related fields.

The flight test process involves the engineering test pilot, engineering test crew, specialized flight test instrumentation, flight test plan, data acquisition, data analysis, and development of conclusions and recommendations. The flight test process typically involves a planning phase, an execution phase (the actual flying), and a report writing phase (involving data reduction and presentation of conclusions and recommendations).

There are a number of reasons for flight test. One has been the desire of man to push the frontiers of knowledge, i.e., research. Another is for product development and determining the characteristics of the new product. A third and most important reason is to ascertain if the new air vehicle will accomplish its intended mission. The final reason for flight testing is to comply with established requirements and regulations for safety of flight by organizations such as the Federal Aviation Administration (FAA).

Although the flight test is costly compared to flight simulation, the flight test data are very valuable and extremely reliable. On the other hand, flight test is labor intensive and requires a large number of man-hours to conduct. Thus, extreme care must be taken into account if flight planning is going to have necessary and accurate results. For these reasons, any flight test plan must be presented for approval to a panel of experts including operational, technical, and safety officers. Flight test engineers must have relevant communication and briefing skills to satisfy panel members that their plan is adequate, safe, addresses the requirements, and will generate satisfactory results. The panel members usually will ask several questions, and at the end will come up with a list of recommendations to the engineers to update and revise their plan. Approval of the flight test panel is a must in the flight test planning loop and is an important part of flight test engineering. At DWC, we have established a review panel consisting of the Dean of the School of Aviation Sciences, the Chair of the Engineering Division of the School of Engineering and Computer Science, several faculty members from both schools, plus Flight Operations and flight safety personnel.

3. THE ROLE OF FLIGHT TEST ENGINEERING IN UNDERGRADUATE EDUCATION

The area of flight dynamics, namely aircraft performance and stability and control, is the first time that the undergraduate aeronautical engineering student typically deals with the total aircraft. Therefore a flight dynamics laboratory using an actual aircraft provides the student with the opportunity to obtain some hands-on experience while augmenting the classroom theoretical experience. The laboratory portion of the DWC flight dynamics courses are in no way a complete course in flight test engineering. They are, however, a flight test experience that illuminates the theory taught in the classroom and allows the student to design an airborne experiment that follows a typical flight test process (plan, execute, report). The flight test exercises are designed to be simple enough to allow the students to follow the flight test process with some faculty guidance, and they gradually increase in complexity and technical difficulty throughout the two-course sequence.

Adding a flight test engineering experience into an undergraduate aeronautical/aerospace engineering program enriches the quality of the education. The students will be more confident when they discover that flight test will confirm what the equations of motion are predicting. This will directly impact their in-class education by helping them to better comprehend the theory. When students experience a real aircraft and feel its complexity and capability, they will learn the relevant questions to ask in class. Afterward, they have a very real feeling about various aircraft components such as flaps, elevator, stick, pitot-static system, and center of gravity. They comprehend why safety planning is a crucial part of any flight and appreciate why instructors are critical about planning and briefing. Also, the graduates should have a greater range of job opportunities. For example, one of our recent graduates has been hired as a member of a flight test team for one of the advanced aircraft development programs in the U.S. Air Force.

4. FLIGHT TEST EDUCATION REQUIREMENTS

Flight test education requires some resource requirements that are unique in a normal collegiate academic environment. Specialized personnel, equipment (aircraft and instrumentation) and software are needed to enable students to execute a flight test exercise and analyze the results. These include qualified faculty, qualified pilots trained in appropriate flight test techniques, appropriate aircraft, a flight test data acquisition system, and appropriate software for data reduction.

a. Qualified Instructors

The Flight Dynamics courses have two instructors, one professor to teach the theory of flight dynamics in a classroom setting and the other to manage the flight test experience laboratory portion of the course through a classroom recitation and the actual airborne flight experience. The professor who manages the flight test experience portion of the courses must be a pilot, preferably with flight test education and/or expertise.

b. Flight Test Committee

Any flight test plan must be approved by a panel of experts with safety, technical and operational expertise prior to the actual flight test. This step requires students to brief a committee of flight experts and answer their questions. The committee consists of representatives from flight operations, safety, and technical (professors). Every single flight test plan must be presented to this committee and the test plan must be signed by all committee members prior to flight test.

c. Test Pilot

Daniel Webster College was originally formed as the New England Aeronautical Institute and has more than forty years of experience in flight training education in its School of Aviation Sciences. For flight training, Daniel Webster College uses the Cessna 172 for all primary flight training, the Piper Arrow for complex aircraft training, and the Piper Seminole for multi-engine and crew training operations. Aviation Sciences has faculty with engineering and engineering flight test experience who have trained selected flight instructors in the flight test techniques necessary for the support of this program in cooperation with the School of Engineering and Computer Science.

d. Aircraft (Cessna-172)

The Cessna 172 Skyhawk is a four-seat, single-engine, high-wing, fixed-landing gear aircraft. It is probably the most popular flight training aircraft in the world. With a maximum takeoff weight of 2,450 pounds and wingspan of 36 feet, the 172 accommodates one pilot (as flight instructor/test pilot) and has a capacity of up to three passengers. We have selected and equipped one of these aircraft as the test bed for our flight test program. Figure 1 shows our Cessna 172 that is equipped with the Calspan flight test data recorder system.

Figure 1. DWC Cessna-172 N688DW

e. Calspan Miniaturized Flight Data Recording System (MFDRS)

The heart of a flight test is a powerful flight data recorder. While it is possible to obtain usable data in light aircraft by using just a stopwatch and the production flight instruments, one of the learning objectives of these flight test exercises is for students to experience the process of data gathering and reduction using relatively sophisticated flight test instrumentation. DWC

purchased a small but advanced flight test instrumentation system, the Miniaturized Flight Data Recording System (MFDRS), from the Calspan Corporation. We modified the college-owned Cessna 172R Skyhawk, N688DW, with the MFDRS. In addition to the MFDRS this particular aircraft is equipped with the Garmin GNS 430 GPS navigation system and an accelerometer instrument. This aircraft, as instrumented, provides a reasonably sophisticated flight test engineering educational tool for our students.

The MFDRS includes an integral NavCube, Calspan's own highly accurate measuring system that is the core of the measurement system. Figure 2 shows the NavCube with a quarter coin for size comparison. It is a small six degree-of-freedom sensor that measures the three orthogonal axes of acceleration (longitudinal, lateral, and vertical, or Nx, Ny, Nz) and three orthogonal rotation rates (roll, pitch, and yaw, or p, q, and r). Sensing is performed by dual axis accelerometers and single axis gyroscopes on individual boards on five faces of the cube. Calspan developed MFDRS as a low-cost alternative to others found in the industry costing much more and that are much bulkier.

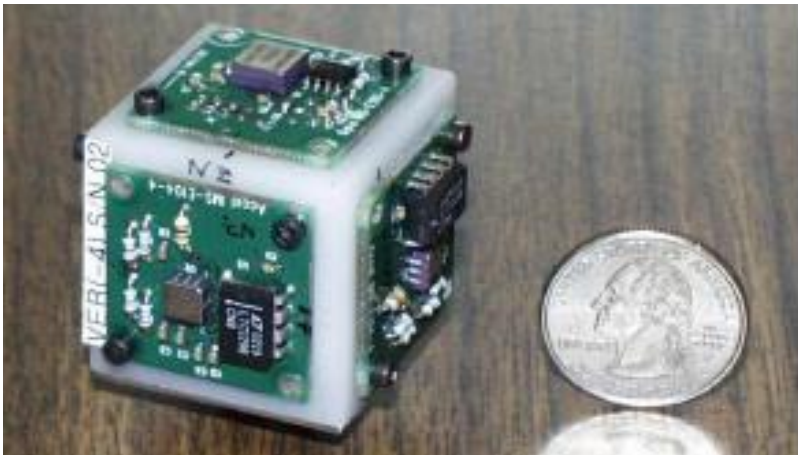

Figure 2. MFDRS--NavCube

The MFDRS primary parameter list includes normal, lateral and longitudinal accelerations: N_z ($\pm$ 10 g), N_x, N_y ($\pm$ 2g), angular speed: pitch, roll and yaw rates: p, q, r (+/-150 or +/-300 deg/s), airspeed, and altitude. In addition, the MFDRS records flight control and surface positions, heading, and GPS parameters from its integral GPS system. The MFDRS has a processor that stores data in a compact Flash Data Storage. Figure 3 shows the complete MFDRS system installed between the front seats of the DWC Cessna 172. Figure 4 shows rudder and elevator transducer and magnetometer (the heading transducer) installation in the DWC Cessna 172.

Data recorded by the MFDRS are stored on an industry standard Compact Flash card for straightforward transfer to a PC or other device. The data are in a conventional DOS binary file format that can be conveniently read by MATLAB, Simulink, Excel, and other analysis tools. Figure 5 illustrates the installation/removal of the flashcard from the MFDRS cockpit unit.

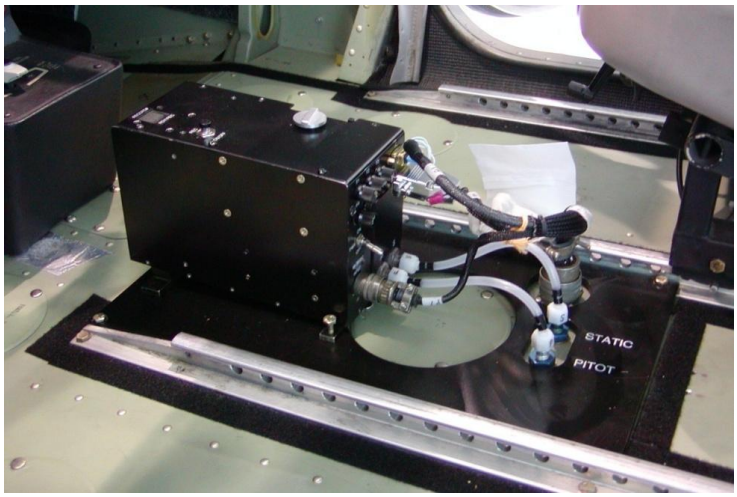

Figure 3. MFDRS Installation on Cessna 172

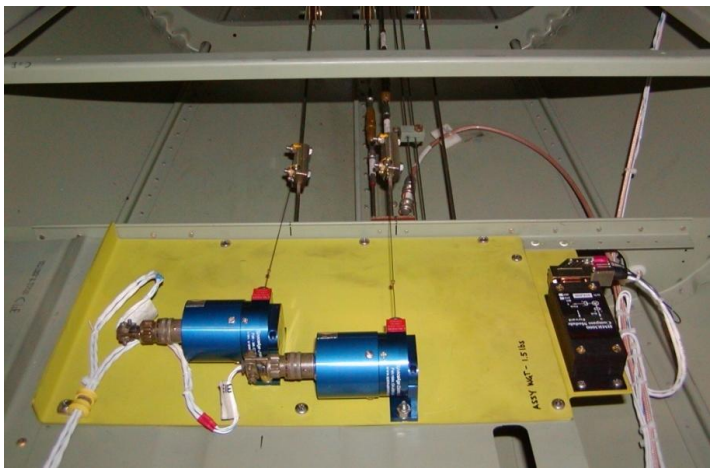

Figure 4. Elevator, Rudder, and Magnetometer Transducer Installation

Figure 5. MFDRS Flashcard Installation and Removal

f. MATLAB software

MATLAB is employed to download the flight test data collected by the data recorder during flight. MATLAB is a numerical computing environment and programming language. Created by The MathWorks, MATLAB allows easy matrix manipulation, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs in other languages. As of 2004, MathWorks has claimed that MATLAB is used by more than one million people across industry and the academic world. All data recoded during the flight are reformatted by a MATLAB program into displays that are easily interpreted by students, who can then manipulate data, plot graphs, analyze results, draw conclusions, and make recommendations. Figure 6 shows a sample of some MFDRS data, a pitch doublet, with the red trace indicating elevator input while the blue and green traces represent output (pitch rate and normal acceleration).

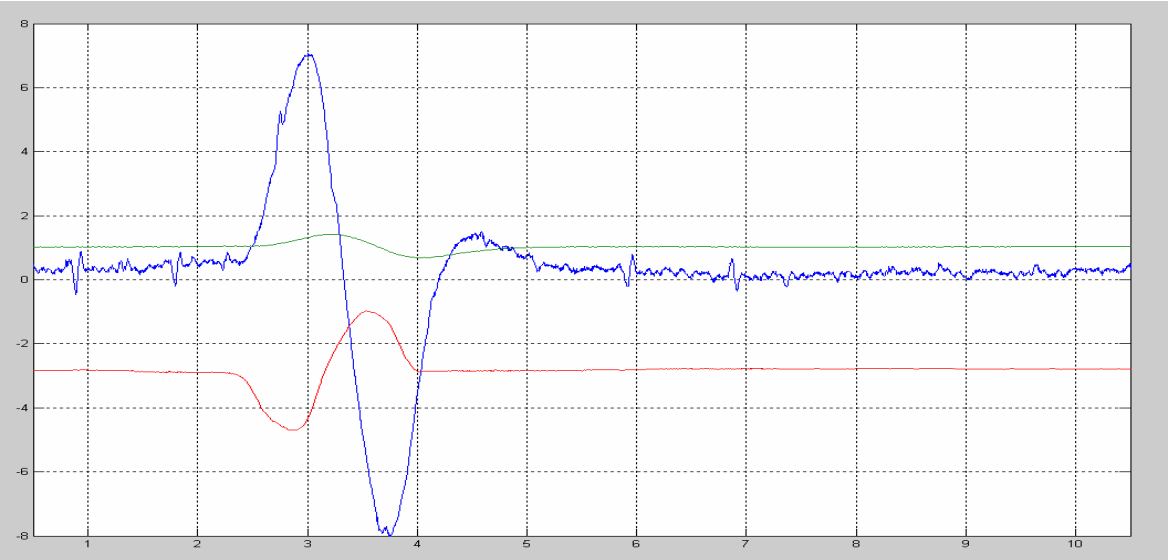

Figure 6. Sample Flight Data: Pitch Doublet

5. DWC FLIGHT TEST PROGRAM

Daniel Webster College has incorporated several flight test experiences into its Flight Dynamics I (Aircraft Performance) and Flight Dynamics II (Aircraft Stability and Control) courses to address CDIO initiatives. Three flight tests are designed and executed in Flight Dynamics I to investigate and analyze the three performance areas of pitot-static, climb performance, and turn performance. An additional three flight tests are designed and flown in Flight Dynamics II to investigate three stability and control topics such as neutral point determination, static stability, dynamic stability, and controllability analysis. Table 1 shows a summary of six flight test experiments that have been conducted in these courses over the past two years.

The Flight Dynamics I and II courses each have two instructors: one to teach the theory of flight dynamics in a classroom setting and the other to manage the flight test experience laboratory portion of the course through a classroom recitation and the actual airborne flight experience. The professor who manages the flight test portion of the courses is a former US Air Force F-4/F-111/F-16 flight test pilot and USAF Test Pilot School instructor. The students are divided into

several groups of two to four members. Each flight test is planned after the relevant section of the theory has been covered. The students write a test plan and obtain approval through a formal oral presentation to a Technical and Safety Review Group of faculty and DWC Flight Operations staff personnel.

Table 1

Summary of Six Flight Test Experiments

No	Flight test	Semester	Course
1	Pitot-static calibration	Spring of Junior year	Flight Dynamics I
2	Climb performance analysis	Spring of Junior year	Flight Dynamics I
3	Turn performance evaluation	Spring of Junior year	Flight Dynamics I
4	Aircraft neutral point determination	Fall of Senior year	Flight Dynamics II
5	Static lateral-directional stability and roll control analysis	Fall of Senior year	Flight Dynamics II
6	Dynamic longitudinal stability analysis	Fall of Senior year	Flight Dynamics II

Following official sign off on their test plans, the students are authorized to schedule and fly the test missions. Each flight test experience for a student group is two flights. Two flights allow the students to collect enough data for reasonable analysis, give them an opportunity to check data collection between flights and make test plan changes if necessary, and keep the flight-hour cost reasonable for the college. It is important to understand that these flights are not a complete flight test of the aircraft or system but an experience to allow the students to attain the learning objectives. Following the flights the students reduce and analyze the data and write a formal technical report documenting their results, conclusions, and recommendations. Each team receives a team grade for each individual flight test experience (e.g., pitot-static) which includes grading of the test plan, oral review presentation, and the final technical report.

DWC has included these flight test experiences in the flight dynamics courses from their first offering, so there are no “before” and “after” data to determine the improvement in performance of the students as a consequence of these flight experiences. Observations of the recitation portion of the course as well as flight debriefings have anecdotally shown the faculty instructors that students tend to more completely understand the material after their flight experience. For instance, after watching the Cessna 172’s climb performance over a range of speeds from near stall to V_{max} they seem to have a better appreciation for the behavior of the power required and power available curve . . . they “get it” better after the flight experience.

There are a number of interesting areas in the Aircraft Performance and Aircraft Stability and Control courses from which to choose flight test experiences. We chose three topics in Aircraft Performance to be most relevant to undergraduate study: pitot-static calibration, climb performance, and turn performance.

In the first flight test, students deepen their understanding of various types of speed such as indicated airspeed, calibrated airspeed, equivalent airspeed, true airspeed, wind speed, and ground speed. They also learn to fundamentally appreciate how a pitot-static system measures the total pressure and static pressure, and where the sources of errors in the speed measurement process are. This experience gives them a better understanding of the theory and operation of a conventional airspeed indicator. Then terms such as position error, lag error, instrument error, and calibration remind them that they are flying in a real world and how errors influence the measurement of aircraft performance data. This flight test is composed of several cruising flights with a constant airspeed and a constant altitude in various headings. More than ten test methods are introduced to students and the pros and cons of each are briefly described.

Flight safety requirements and regulations are reviewed in the first flight test, the students' dealing for the first time with issues such as flight planning, briefing and debriefing, test flight airspace considerations, test proposal, and flight test reporting. This is usually a simple test, but since students are not experienced in the fundamentals of flight test at the beginning of the course they are often faced with problems such as flight planning, teamwork, communication, technical report writing, preflight procedures, safety review, and most importantly, how to answer the unexpected questions that review panel members ask.

The second flight test is devoted to climb performance through the saw tooth flight test technique. In this test, students experience the effect of available power, required and excess power, and plot the available power and required power versus speed. They are also required to analyze various aspects of this plot such as minimum power speed, minimum drag speed, maximum speed, maximum climb angle, and maximum rate of climb. This test consists of several climbs and descents in a limited range of safe altitudes. Students experience the application of the equations of motion as they pertain to climb and compare the flight test results with theoretical predictions. The hard-to-believe truth of "the lift is less than aircraft weight in a climbing flight" is revealed to the students in this test.

The third flight test in Flight Dynamics I is turn performance because it is of primary importance in the evaluation of military fighters. Students enhance their understanding of parameters such as load factor, normal acceleration, turn radius, turn rate, bank angle, level turn, slip and skid. They are required to draw several plots from test data and analyze turn performance of the aircraft, including turn radius versus speed, bank angle versus load factor, and turn rate versus bank angle. This flight test also includes several turning flight data points at various bank angles and speeds.

In Flight Dynamics II three flight tests address aspects of aircraft stability and control: determination of neutral point, static stability and control, and dynamic stability. Compared with the three flight tests in Flight Dynamics I, these are harder to plan and harder to perform and analyze, as might be expected.

In the fourth flight test, students are required to measure an aircraft neutral point through a flight test procedure. Prior to this test they have been introduced to the theoretical methods to identify the location of aircraft neutral point (or aircraft total aerodynamic center) in the longitudinal axis. But this flight helps students understand the practical importance of the location of neutral point.

They learn to appreciate the relationship between the pitching moment coefficient (C_m) versus angle of attack (α) curve, neutral static stability, and the neutral point. This flight test consist of two series of flight tests at two distinct aircraft centers of gravity and with data points collected at different speeds while stabilized longitudinally though the application of elevator deflection. The students determine the location of the neutral point by plotting the variations of the slope of the rate of change of elevator deflection versus aircraft speed. This test is their first experience with the phenomena of static stability and they will thus comprehend why an aircraft must have its center of gravity in front of the neutral point in order to be statically stable in the longitudinal direction.

The fifth flight test deals with the lateral-directional static stability and roll control power. In this test, students experience yaw angle, heading angle, sideslip angle, roll, yaw, relative wind, wind axis, body axis, side force, trim, and coordinated turn. The study of lateral-directional static stability examines the reaction of the aircraft when its flight path deviates from the plane of symmetry. In this flight test the students also experience the coupling between lateral stability and directional stability. The significance of dihedral angle, sweep angle, wing vertical location, and vertical tail in lateral-directional static stability is also presented to students. They analyze lateral-directional static stability and roll control power through several plots such as bank angle versus sideslip angle, aileron deflection, and rudder deflection versus bank angle.

The last flight test addresses dynamic stability. Students identify the features of short period mode and phugoid mode longitudinal motion. With these data they are then able to analyze dynamic stability of the aircraft. The purpose of this flight test is to evaluate dynamic stability of the C-172R in phugoid, Dutch roll, and spiral modes. In theory, dynamic stability occurs when the parameters of interest tend toward finite values as time increases without limit. “Phugoid” describes a longitudinal motion mode with a long period and light damping. During a phugoid, the angle of attack is nearly constant with variations in airspeed and altitude-–which can be thought of as an exchange between potential and kinetic energy. Because the period for a phugoid is typically 45 to 90 seconds, the pilot is usually able to correct for flight path deviations. There is also a short period longitudinal mode oscillation which is not tested because the C-172 typically demonstrates this motion mode in an over damped fashion.

The Dutch roll mode is a second-order lateral-directional motion mode characterized by coupling between yaw and roll. A Dutch roll may occur after a yawing motion that also generates a rolling motion. For a laterally stable and directionally stable aircraft, an opposite yawing moment will be generated, resulting in a Dutch roll to the opposite direction. An important parameter for measuring Dutch roll is the ratio of bank angle to sideslip angle. A low ratio indicates little bank angle during the Dutch roll and is considered more favorable than a high ratio for general aviation aircraft. To analyze spiral mode, a Bank Angle vs. Time plot will be generated using hand collected data. The dynamic stability of the aircraft will be analyzed through upsetting the aircraft using elevator deflection and doublet rudder input and the measurement of aircraft reaction to these inputs.

This section introduced the details of six flight tests in brief. As mentioned before, the test aircraft is a Cessna-172, a subsonic general aviation (GA) aircraft with a piston prop engine.

The aircraft is safe and highly reliable, and aircraft data are available through the manufacturer. The aircraft has sufficiently observable performance, stability, and control characteristics as well as DWC-installed flight test instrumentation to allow students to attain the learning objective of the laboratory portions of Flight Dynamics I and II.

6. SAMPLES FROM STUDENT REPORTS

This section contains two excerpts from student reports (one each from Flight Dynamics I and II). These writings appear to demonstrate the value of flight test education in helping students grasp fundamentals and develop experimental skills. Student interest and motivation in the flight test education are also apparent.

a. *Flight Dynamics I: Turn Performance Test*

The objective of Test Flight 3 was to gather data to plot the V-n diagram and turning radius versus velocity, for the Cessna 172R. The students successfully prepared and presented their test plan to a board of professors overseeing the process. The team flew two sorties and collected data for banked stalls and max power banked flight. The calibrated air speed and the load factor, recorded by the MFDRS, were used to calculate the aerodynamic limit, the power limit and the turning radius at predetermined bank angles. Hand collected data was taken for reference, but MFDRS data was relied on for data reduction. As a result of previous experience, both teams were prepared for flight, and the changes in the procedure adapted from the previous test plan were implemented and resulted in successful flights. For this test flight the data from sortie one was reduced and discussed before sortie two flew. This resulted in better data collection from the second sortie. The test team found it helpful to discuss flight test techniques with other groups. Another important consideration is the minimum weather conditions that permit accurate data collection.

Figure 7 shows some actual student turn performance data applied to a report showing aerodynamic limit (stall) and at the power limit (full throttle). Note that a hypothetical limit load factor of 2 g was imposed to keep the flight within FAA limits for flight without a parachute.

b. *Flight Dynamics II: Dynamics Test*

This flight test VI was performed on June 3rd, 2008 with Sortie 1 comprised of pilot Garrett B. and Benjamin K. acting as flight test engineer. The team flew and analyzed data points used to determine the dynamic stability of the C-172-R in the phugoid, Dutch roll, and Spiral Modes (The roll mode was analyzed in a previous flight test). Graphs were generated to illustrate the dynamic stability of the aircraft. As expected, the aircraft possesses positive dynamic stability. This is favorable for a general aviation aircraft used in flight training for civilian purposes.

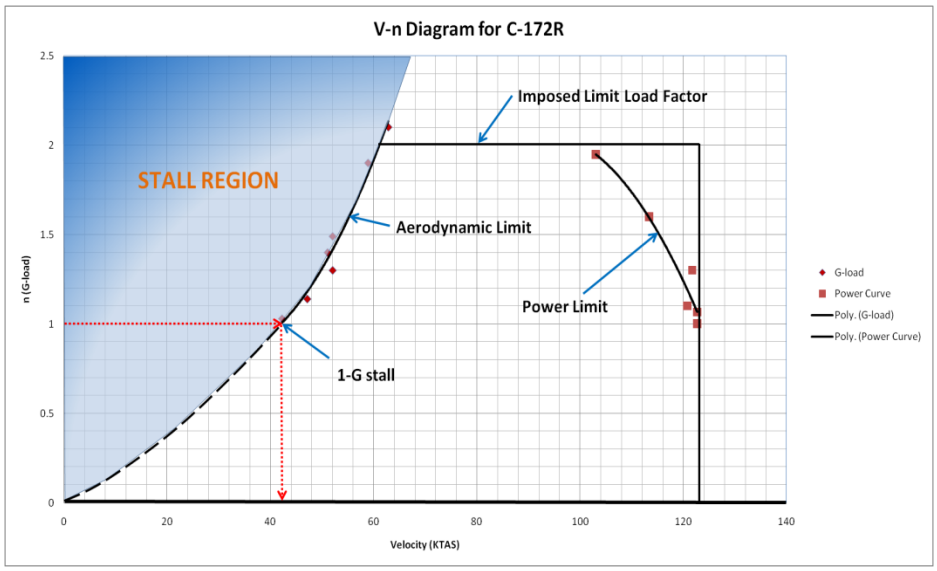

Figure 7. Some Student Data from a Turn Performance Test

Recommendation 1: Develop a better method for analyzing Dutch roll. The intended method was not feasible due to the highly damped response of the aircraft. One possible aid may be to bring a portable inclinometer that can be placed in the aircraft to measure bank angle more accurately than the attitude indicator.

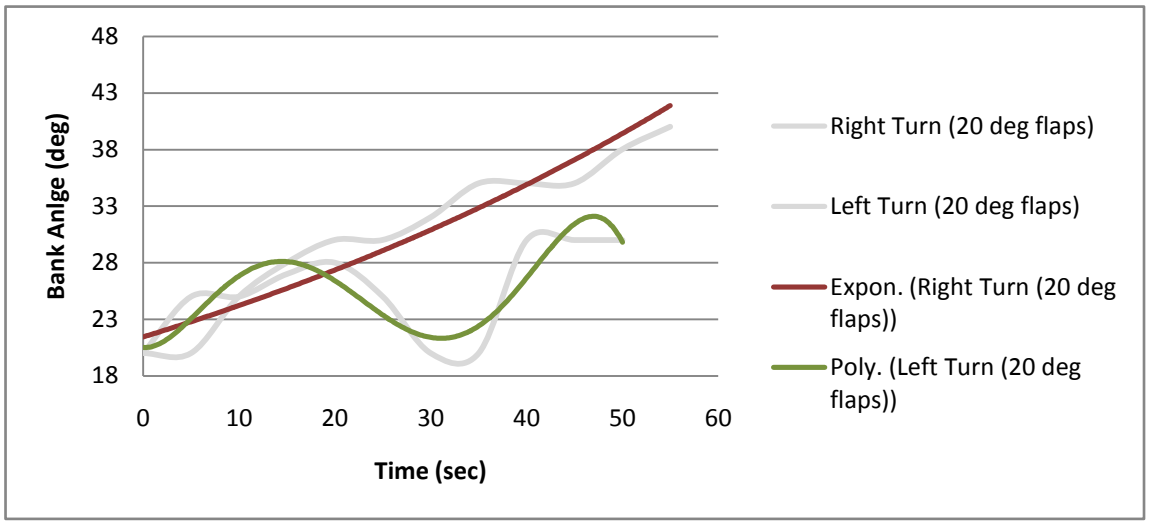

Figure 8. Some Student Data from a Spiral Stability Flight Test

Recommendation 2: Verify that the aircraft will fly straight and level trimmed to ensure that the control surfaces are properly calibrated. The team suspects that the unexpected left bank response during spiral mode may be due to the aircraft's prior mission as a spin aircraft.

Figure 8 shows some student spiral stability data from this dynamics test. The students incorrectly suspected that the left turn response was due to a flight control out of rig condition when it was, in actuality, due to wing fuel imbalance.

The flight test report provides a good indicator of the effectiveness of experiential learning. Through these written reports students demonstrate that they have deepened their understanding of flight dynamics-related topics.

7. EVALUATION OF PROGRAM EFFECTIVENESS AND LESSONS LEARNED

We believe that the root cause for the lack of convergence between flight dynamics education and practical application is the absence of experiential learning. The flight test experience requires students to develop skills such as flight planning and flight test execution, and it reinforces skills in data reduction, analysis, communication, and teamwork. The six flight tests cover a variety of topics so students can identify, formulate, and solve engineering problems at different levels of difficulty. Although each flight test addressed one major topic, the integration of lessons learned in preceding flights was required. In particular, the flight test experience provided motivation for absorbing and integrating the harder topics, such as turn performance and lateral-directional dynamic stability. Students gained a deeper understanding of the flight dynamics context in which aeronautical engineering is practiced. Table 2 summarizes the observations of the instructors with regard to the effectiveness of flight tests as experiential learning in various areas.

Students were also asked to submit comments regarding the effectiveness of "flight test" in their flight dynamics education. Their comments were uniformly enthusiastic and positive. The following quotes were taken from the survey:

1. *I think that flight testing is one of the best parts of the flight dynamics classes. They provide real world hands on experience that is relevant to the topics studied. I think they are very effective and provide experience that employers are looking for.*
2. *I believe they are very effective by reinforcing the topics learned in class.*
3. *I think it greatly aid my learning in this class. It is overall, very well integrated.*
4. *The flight tests are very useful in the course. Despite their extensive time demand, they are very interesting.*
5. *The flight test helped a lot about understanding the differences between speeds (true, equivalent, calibrated,…). More importantly it helped me understand how to account for non-ISA conditions during calculations.*
6. *The flight test was more complex and difficult for me to understand but after working through it, I feel that it helped tremendously with understanding and retaining the information.*
7. *Flight tests allow students to actually evaluate the accuracy of the equations and methods that are learned in flight dynamics.*

8. *The flight tests are crucial to the Flight Dynamics courses. They offer a unique experience to gain real world applications of course material.*
9. *The neutral point flights were very interesting. Loading the plane as far forward and backwards as we could while remaining in the envelope makes one really think about the ramifications of not properly loading a plane.*
10. *I believe they are very effective by reinforcing the topics learned in class. They are also fun, and a great way for engineers to see the pilots point of view. They personally helped me a lot. The pilot let us fly the aircraft during the longitudinal static stability test and you could feel the difference between the C.G. locations.*

Both the observations of the instructors, and student performance and attitudes, attest to the importance and effectiveness of CDIO Standard 8-active learning.

The flight test component has been offered in both Flight Dynamics courses since these courses were introduced two years ago. As such we have no "before flight test" and "after flight test" assessments to compare. However, several lessons have been learned and some recommendations can be made to institutions that would like to introduce this student experience into their programs. They are as follows:

1. Flight Dynamics I and II are both three-credit courses that meet three hours per week. It has been difficult to find sufficient class time for flight test briefings without sacrificing part of the theoretical education. This year, in order to maintain sufficient class time for the theoretical content of the courses, a weekly hour-long recitation was added to each course. Also, because the theoretical content in Flight Dynamics II is particularly challenging it will be changed from a three-credit to a four-credit course in order to gain additional class time.

2. The syllabus calls for three flight tests in Flight Dynamics I and three flight tests in Flight Dynamics II. But in practice it has been hard for students to complete all six flights within two semesters. Each flight test experience is naturally planned right after the topic is covered. The third flight test related topic is covered near the end of the semester, so the students have a very short time to plan and execute that flight test. We suggest planning all three performance tests in the first semester but flying only two. The reason is that there is just not enough time left for flying the third flight prior to final exam week. Since the plan is written and approved, the flight test can be done in the beginning of the second semester. The same problem occurs with the third flight test in Flight Dynamics II (i.e. dynamic stability), since the discussion of dynamic theory comes so late in the semester. Flight Dynamics II has now been moved to the first semester of the senior year. Therefore students can now finish up the final flight test during the second semester of their senior year.

Table 2.

Flight Test Effectiveness/Observations

Course	Topics Enhanced By The Experiential Learning	Effectiveness/Observations
Flight Dynamics I	Ground speed, true airspeed, equivalent airspeed, calibrated airspeed, and indicated airspeed.	Students are used to seeing the ubiquitous "V" in equations without a good understanding of the various airspeeds in aviation. A much better understanding of ground speed, true airspeed, equivalent airspeed, calibrated airspeed, and indicated airspeed is attained by going through an airspeed calibration process in an actual airplane.
	Equations governing rate of climb, climb angle, climb speed, excess thrust, and excess power,	This flight test strengthened understanding of the fundamentals of climbing flight by physically illustrating the airplane's ability to climb at a range of speeds varying from near stall speed to V_{MAX}.
	Bank angle, turn radius, turn rate, load factor, and accelerated stall.	The relationship of bank angle, velocity, and load factor becomes very obvious when performing a series of turns at one g as well as elevated load factors at stall and at full throttle.
Flight Dynamics II	Neutral point, longitudinal static stability	This first flight test experience in the area of aircraft stability and control allowed the students to experience the relation between aircraft center of gravity and neutral point and established the basic foundation for students to solidify their knowledge of static longitudinal stability.
	Lateral-directional static stability, roll control	This flight test experience gave the students an opportunity to observe a static stability case as well as coupling (lateral and directional) in one simple exercise. The roll control exercise was chosen because it is fairly easy to analyze but illuminates visually and with data a controllability case.
	Dynamic stability	Aircraft dynamic motion is often difficult for students to imagine; however, when actually experienced (in this case we look at the phugoid mode and Dutch roll mode) the relation of aircraft motion to the second order equations becomes obvious.
General	Communication	Various communication skills such as writing, graphic presentation, and oral presentation were practiced through six flight test plan written preparations, oral presentations, and written flight test reports. The effectiveness of communication skills was gradually improved.
	Teamwork	Students gained a good understanding of the importance of teamwork. They also had to adapt to rapid changes which demanded flexibility and ultimately increased their self-confidence.
	Analytic ability	Students gained a good understanding of analysis of actual flight test engineering data through use of our instrumentation system and the reduction of the actual data produced.

3. The flight test pilot must be a qualified instructor pilot assigned by the college who is very familiar with the flight test techniques to employ in obtaining the airborne data. A Primary flight test instructor pilot has been identified as a formal policy. Engineering students now have a “go to” person for flying questions if the professor who manages the flight test laboratory is not available. The Primary can also coordinate and discuss flight test techniques with the other instructors. It should be noted that flight testing needs good clear weather with calm winds. This is often a challenge in New England in the winter. With appropriate scheduling, including spreading the flights across three semesters, bad weather can be mitigated.

4. In the course syllabus, we assigned only 15% of the total grade to the flight test portion of the course. Therefore other portions of the course such as homework assignments, midterm exams, final exam and the project assignment are all worth 85%. Our experience, as well as student comments, suggests that the flight test portion should count for about one third of the course grade because the work by the students on the flight test experience is much more than 15% of the total course load.

8. CONCLUSION

Daniel Webster College has incorporated flight test education into its Flight Dynamics I (Aircraft Performance) and Flight Dynamics II (Flight Stability and Control) courses to address CDIO initiatives. Three flight tests are designed and practiced by Aeronautical Engineering undergraduate students in Flight Dynamics I to investigate and analyze three aircraft performance parameters such as airspeed calibration, climb performance, and turn performance. Three additional flight tests are designed and flown in Flight Dynamics II to investigate three flight stability and control parameters such as neutral point, static stability, dynamic stability, and controllability. In the past two years, several valuable lessons have been learned and some adjustments have been made. This paper presents our experiences plus several recommendations to other institutions that might be considering doing the same. The DWC flight test education has given our students a deeper understanding of flight dynamics. Feedback from our graduates has indicated that they found the flight test experience to be important in their transition into the aeronautical engineering profession. Future plans include working with other CDIO partners to continue the development of undergraduate flight test experiences.

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Biographical Information

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Douglas A. Joyce is an Associate Professor of Aviation Sciences at Daniel Webster College and teaches courses in micrometeorology, introductory flight dynamics, and flight safety to aviation majors. He also co-teaches Flight Dynamics I (Performance) and Flight Dynamics II (Stability and Control) to DWC engineering students. Professor Joyce retired from the Air Force in 1994 after assignments as an operational tactical fighter pilot (F-4 and F-111) with two combat tours in Vietnam, experimental test pilot (F-4/ARN-101/GBU-15, F-111F/PAVE TACK/Guided Weapons Integration, EF-111 Prototype), Headquarters USAF Systems Command manager of long range planning for advanced tactical fighter aircraft, Director of Academics at the USAF Test Pilot School, Deputy Flight Test Director of F-16 flight test at Edwards AFB, Director of Programs and Resources for an overseas test and training group, and Flight Test Wing Vice Commander. He completed his BS in 1967 and MS in 1968, both in aeronautical and astronautical engineering from Purdue University. He is a Senior Member of the American Institute of Aeronautics and Astronautics, a former Chair of the New England Section of AIAA, and is currently serving as a Director of the New England Section of AIAA. Professor Joyce holds Airline Transport Pilot and Flight Instructor certificates and is type rated in the Beechliner 1900. He has over 5000 hours of flight time in 56 aircraft types.

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Nicholas Bertozzi is a Professor of Engineering at Daniel Webster College and chair of the Engineering Division. He received his BSME in 1977 and his MSME in 1982 from Northeastern University. Since 1982 he has taught courses in physics, differential equations, engineering design, thermodynamics, fluid mechanics, aerodynamics, statics, dynamics, and strength of materials. His major interest over the past ten years has been the concurrent engineering design process. Professor Bertozzi has a particular interest in helping engineering students develop good communications skills and over the past few years has mentored four undergraduate student teams who have co-authored and presented papers and posters at EDGD and other ASEE and American Institute of Aeronautics and Astronautics (AIAA) meetings as well.

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Engineering education and concept of 'Bildung'

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ABSTRACT

Since a couple of decades many engineering education programs focus on engineering capabilities and on how knowledge will be used rather than on engineering knowledge per se. Communication, leadership and ethics are among these capabilities. Bildung the ability to integrate humanistic aspects and points of view is not. The Royal Institute of Technology is now considering the introduction of Bildung into the engineering education. What is Bildung and what is it expected to bring to bring to engineering education? This paper uses a pragmatic method and tries to define Bildung by giving examples from situations where Bildung comes into expression. Some of its implications are discussed. One conclusion is that knowledge building in humanities adds new and pregnant perspectives to technical knowledge. Students who are able to apply wide general knowledge ('Bildung') to engineering problems and situations are able to bring new aspects to their critical thinking. One argument is that engineering students should be exposed to Bildung in order to strengthen their integrity, independent thinking and responsibility.

KEYWORDS

Bildung, critical thinking, internalization, communication.

1. BACKGROUND

The Royal Institute of Technology, (KTH) Stockholm, Sweden has initiated a study in 2008 of a project designed to deepen understanding around a few key engineering capabilities. The proposal is that these capabilities would be demonstrated by all students graduating from KTH. Six areas where capabilities must be shown have been identified: Innovation and entrepreneurship, Sustainable development, Internationalization, Cooperation with society, Communication and Bildung in engineering.

Five of the above mentioned capabilities are more or less included in the CDIO-syllabus which has been adopted by many engineering programs. The fifth one Bildung in engineering science is not yet. It is this capability and the need for its inclusion in the list of graduate capabilities which is the focus of discussion in this paper.

Some questions may be reasonable to ask. (i) What is 'Bildung' and what is it expected to bring to engineering education? (ii) In what situations in the professional life of engineers will competencies drawing upon 'Bildung'-type decision making come into expression? (iii) How can 'Bildung' be taught and assessed?

2. METHOD

The method used in the current paper is pragmatic i. e. to give concrete examples before discussing the general concepts they represent. Concepts in the natural language have different meanings in different situations and for different people. [1] It is therefore necessary

to give an example to narrow the interpretation of the concept and make the communication more efficient and reliable. Thus, I will try to identify some situations in engineering practice, where the capability of Bildung is involved and discuss its implications.

3. WHAT IS BILDUNG AND WHAT IS IT EXPECTED TO BRING TO ENGINEERING EDUCATION?

3.1. WHAT IS BILDUNG?

The concept of Bildung is not easily defined. Among others things it has to do with the capability to include many perspectives in one's decision, be aware of the limits of the knowledge one represents and the preconceptions one harbours. None the less we can say a lot about Bildung, many times by giving examples when such capability comes into expression in real life.

As a broad understanding Bildung can be seen as the capability of an individual to think by him or herself and to make well grounded judgments on a lot of human related endeavours. As such Bildung can be seen as a capability that adds new layers to technical rationality. If technical rationality is about what can be modelled and computed Bildung is about what is complex and doesn't lend itself to this kind of information processing just because it belongs to a complex domain that should be dealt with holistically. Many phenomena in this domain are not deterministic nor can they be reduced. In the complex domain knowledge, capabilities as well as emotions have to be considered to meet the demands of a specific situation before making decisions. [2]

3.2. CRITICAL THINKING

It goes without saying that the capability of assessing knowledge and performance in any domain requires a mastery of that very domain whether it is technology or art. It is only the one who masters the knowledge or skill domains that is able to tell what is lacking a performance to improve its quality. This kind of critique may be perceived as a critique from inside a paradigm.

Most engineering problems on the other hand are of practical nature. They are about acting in the world, about defining and solving technical systems. Attention is most of the time concentrated on *What* the problem is and *How* it should be solved. Sometimes it is however necessary to ask *Why, for whom* and *what* are the consequences of the solutions proposed. This kind of critical thinking may be characterized as from outside the paradigm and some times even be seen as controversial. None the less this is the kind of questions that many engineers have to deal with each time they apply for a new position in industry or undertake a project.

Another aspect of critical thinking has to do with a critical attitude towards the view implicit in ones own education, how problems are defined and solved and with what methods. Even Science and technology have their limits. [3] Intuition for instance plays a major role in creating hypothesis, designing systems as well as communicating results to others.

3.3. INTERNATIONALIZATION

The work market for engineers has in the last few decades become more and more global. But what new challenges does this new situation demand from young engineers?

In international situations where cultures come together the problem of interpretation and common understanding is even more acute. It may be at home with foreign professionals or abroad where one is foreign to the culture and where communication's patterns are different

from what we are used to. To be aware of one's preconceptions is at least to partly dominate them and act to minimize their negative effects on our behaviour. It is however in reflection together with others that you may develop these capabilities.

It is hardly feasible to learn about all the cultures in the world. What is realistic is reflect and learn from a few examples to become aware of one's own culture and the preconceptions inherent in it to be able to handle intercultural situations properly.

3.4. COMMUNICATION

In engineering education communication is often seen as a number of methods and instruments engineers can use to communicate efficiently. In this model it is presupposed that the information is given and the only existing problem is how to convey efficiently to a specific audience. In some cases this may also be true.

In new situations in the complex knowledge domain like; sustainable development, internationalization and cooperation with the society experts from different domains are engaged. When economists, politicians, scientists, psychologists are involves to reach a common decision in a project, communication may be quite different. The ability to carefully listen to others points of view is crucial. To act like there is only one solution to the problem at hand may sometimes be rather contra-productive and may give rise to unforeseeable conflicts. A dialogical approach to the truth and a sense of compromise is much more suitable for reaching sustainable solutions.

Many of the concepts used especially in the complex domain are contested. [4] Experts from different domains have different views on them which complicate every consensus attempt. What are the causes of the global warming and what should be done to prevent it and save the world are no easy questions to answer. Even expert in the same domain may disagree on causes and effects of different phenomena.

3.4.1. Interpretation: The only way of making sense?

Recently a teacher participating in reflective seminars declared that apparently easy concept that he almost uses daily in ship design courses like the ship should have "satisfying properties and performance" have become quite difficult to deal with. Each time he re-examined a concept somewhat closely he became aware how elusive the concept is and each definition makes even more difficult to understand. [5]

Another professor responsible for the doctoral students declared that the written rules regulating postgraduate studies were clear to him when he was appointed head of doctoral studies ten year ago. With the experience he has acquired it is not the case any longer.

Cases likes these are most of the time around us and can only be seen if we give enough attention to what experience demands from our judgment. When we have experienced many situations that may be categorized under a same rule we realize that the real world is much more complicated than what can be caught in formal rules. The Anglo-Saxon case-law system is an ample example of this phenomenon. In this system rules are created at the same time the court is dealing with specific cases. [4] It is, most of the time, with variation in experience and in contact with concrete and different situations that we learn to detect patterns and develop our judgment.

What these examples suggest is that even apparently easy everyday concepts become complicated when they meet experience and reflection. [6] The same goes for other with other concepts central to engineering activities like ethical behaviour, responsibility and risk assessment for example.

3.5. THE THEORY OF KNOWLEDGE

In mathematics it is easy for a knowledgeable person to establish if a reasoning in true or false. Sciences reduce nature to very small phenomena possible to test in experiences for example pendulum, drop of water on a surface or reflection of the light. This kind of phenomena may be characterized as belonging to a *simple* domain of knowledge. Rules emanating from such experiments are universal and have a predictive power.

Based of this fundamental rules the engineer has to integrate imagination, technology and entrepreneurship to create technical systems to define and solve the needs of individuals, groups and society, cell-phones, power plants, airplanes, bridges etc are created and developed. This knowledge domain is based on science but has many times to count on uncertainties, trial and error, and testing. Unlike science technical systems are not always easy to classify as true or false and there is not only one right answer. More or less efficient systems are maybe better categories to classify them. This knowledge domain may be called a *complicated* knowledge domain.

In big projects like global warming, sustainable development, traffic planning and the like engineers have to work with other professionals i. e. economists, scientists, psychologist, politicians and others to reach durable solutions. Decisions in this domain are of course based on the scientific facts available but even if we are lucking knowledge and there is a lot of uncertainties we have to act sometime based not only on scientific knowledge but also on proven experience. This domain may thus be called a *complex* knowledge domain.

Both in the complicated and the complex knowledge domains engineers act in the world. Systems are created by people for people, operated by people and if broken people may as well suffer from they failures. Technical failures of airplanes, nuclear power plants and space shuttles talk for themselves.

The ability to use the adequate knowledge building perspective in each domain may help avoid more than one misconception. Responsibility, integrity, flexibility, involvement and ethical behaviour are hardly of the kind of abilities that could be developed by methods for experimental or by mathematical modelling.

Decisions in the complex domain require most of the time dialogical skills i.e. to be able to both listen carefully and make sure you interpret your collaborators correctly. It has to do with the ability to perform dialogical skills to avoid conflicts and misunderstanding. It is also to let oneself be convinced of others perspective when found sound. This has to do with the capability to think critically, recognize the limits of one's own knowledge and learn to discern ethical dilemmas in one's practice. The real world in its complexity is not always easy to categorize in objective-subjective dichotomies it may prove necessary to open up for intersubjective decisions i.e. consensus decisions. To reach this kind of decisions is to show the "capability" of Bildung.

Scientific knowledge can most of the time be taught in lectures and recitals and assessed by written exams. This presupposes however that answers are given. Theses forms of acquiring knowledge are not always possible with skills or judgment. Here you have no other way of learning that practicing in real situations and getting feedback on your performance.

4. CONCLUSIONS

The situations that the engineer meets in his or her working life can thus be classified into two broad categories requiring knowledge from two different realms: the realm of science and the realm of interpersonal capabilities and values. These two realms require two different

approaches of teaching and assessment. Science is what can objectively be proven and has a predictive power. Interpersonal capabilities and values are what the individual is able of performing and adheres to. Capabilities can be acquired by practice and feedback. Values by identifying dilemmas in engineering practice, discussing their implications, considering the consequences for those involved taking inclusive positions that can ethically be motivated in a social context.
The situations that the engineer meets in his or her working life can thus be classified into two broad categories requiring knowledge from two different realms. The realm of *Having* and the realm of *Being*.

- To *have* the knowledge of mathematics, science and technology and the capability to integrate them to create technical systems
- *Being* involved, responsible, ethical and flexible.

In the simple domain, knowledge and abilities the engineer has, are most of the time enough to cope with the challenges at hand. In most complicated domain and in the complex domain the qualities of *Being* come more to the fore. It is when these two categories are developed and interact in a balanced way with each other that the necessary holistic way of professionalism that may be called Bildung is reached.

Bildung has to with individuals and *how* they use their scientific and technical knowledge. It brings a holistic perspective to engineering makes the engineers able to act in a diverse world in an inclusive, responsible and ethical way. It also guides engineers to help humanity satisfy its needs without denying future generations the possibility to satisfy theirs.

Bildung has thus to be a different perspective that counterbalances technical rationality in order to bring a new holistic perspective of how knowledge and abilities of the engineer should be used. With the increasing challenges in the complex domain, Bildung will be more required to handle engineers' collaboration with other professionals and cultures to reach sustainable solutions.

Bildung can not be taught the same way science is, for there are few universal rules to convey. It has also to do with the ability to develop one's own judgment, ethical behaviour, involvement, responsibility, critical thinking and the like when bringing general rules to specific situations. In a seminar form students are afforded opportunities to reflect about dilemmas in engineering practice to train their integrative capacities and develop the judgment together with others. Motivated, independent and inter-subjective decisions are fundamental aspects of Bildung.

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Biographical information

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Enhancing the Educational Development of Individuals in Group Projects

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ABSTRACT

Group Design Built Test (DBT) projects are well established as an effective means of integrating a number of the engineering science elements of the curriculum in the context of the practical realization of the solution to a design problem. In professional practice these activities are typically carried out in teams. In order to prepare students for what they will be expected to do in industry many accrediting bodies, such as the Institution of Mechanical Engineers (IMechE), require that degree programs contain at least one group DBT project.
At Queen's University Belfast these projects typically involve students identifying a customer need and then developing a viable innovative solution to the point of a working prototype, and also developing an associated business plan for the product introduction. As such these projects provide an opportunity for personal development in all of the CDIO phases.
With the introduction of a new degree in Product Design and Development (PDD) in 2004, based on the CDIO standards and syllabus, a decision was made to introduce such group DBT projects from first year and to repeat these throughout years 2 and 3 with projects of increasing complexity and duration. What has become evident is that the learning strategies of first and third year students differ considerably and that the learning environment needs be controlled differently for the younger students in order to facilitate their educational development across a full range of skills and attributes to produce balanced learners who are able to contribute to all phases of a new product development process.
The objective of a professional group of designers is to maximize the output of the team by getting each member to concentrate on what they do best. In the educational environment such an approach does not help students develop the areas in which they are weakest. They tend to avoid tasks in favor of someone in the group who is more competent in a particular area and as a result individuals build on their inherent strengths and fail to develop their weaknesses. It is therefore important to construct a regime, particularly in first year, which enables development and focuses less on rewarding the final output and more on encouraging participation in all aspects of a project.
The paper discusses observations of running DBT projects in Stages 1, 2 and 3 over the first 4 years of the PDD degree and provides an analysis of the effectiveness of policies and procedures introduced to enhance the educational development of individuals within group DBT projects. Results and conclusions will be drawn from ongoing monitoring, questionnaires and student feedback which has been carried out as part of the evaluation of the new PDD pathway.

KEYWORDS

Design Built Test (DBT) projects, Skills development, Cognitive development, Personal Development Planning (PDP), Assessment, Curriculum planning

INTRODUCTION

The capstone project is a well established element of the final year of many engineering undergraduate programs. It typically aims to provide an opportunity for students to demonstrate the application of disciplinary knowledge in a realistic design, build and test (DBT) activity. These objectives are well aligned with the objective of a CDIO structured program, to prepare graduates for professional practice, but if the capstone is the first such experience of a group project then students are likely to be ill prepared for this major task. If in addition to this all assessment is terminal and summative then opportunities for development can easily be missed.

Many such as Perry [1] have suggested that cognitive development is a multi stage process. Perry contends that growth happens in major steps and as a response to challenges set just above their current level of ability. He also determined that stagnation in development can occur if the challenge represents too big a step. Culver et al [2] described freshman students as “immature novices with limited knowledge of the physical world” and in their study focussed on the mechanisms available to develop these students for professional practice by the time of graduation and in line with the ABET EC2000 requirements. As part of their assessment of student development they also emphasised the importance of timely formative assessment as part of an educational system which gets the students engaged with their own learning.

The psychologist Csikszentmihalyi [3] describes flow as a state of consciousness in which people are more engaged with and get greater satisfaction from the activities in which they are involved. In an educational context this relates to deep learning rather than surface learning and assists the individual in their ability to progress through the stages of cognitive development. Csikszentmihalyi also contends that this state can be controlled by ordering the information that enters the consciousness. Often referred to as the “+1 principle”
this requires setting tasks of appropriate level, challenging but achievable and related to prior knowledge and skill levels. Often described as being between boredom, where no new learning occurs, and panic where survival strategies rather than deep learning dominate.

In their description of the CDIO approach to the development of student skills and attributes Armstrong and Niewoehner [4] recommended that the CDIO standard 5 requirement for an introductory course that incorporates design-build experiences followed by at least one further design-build exercise of a more advanced and demanding nature should be extended to include a project based course in every year of the program. They also suggested that projects should progressively include more lifecycle stages in each year and build towards a capstone that would cover conception, design, implementation and operation phases.

Bloom’s taxonomy of learning domains [5] categorises learning behaviour into 6 levels and provides descriptors and key words to assist in the design and assessment of the learning process. The taxonomy can be used as a guideline for defining tasks and assessment methods. The different levels can be used to indicate the expected performance level to the student at different stages in their program and also as a means of measuring the current level of assessed work.

Table 1: Bloom's Taxonomy of Learning Domains

Level	category or 'Level'	Behaviour Descriptions	'key words' (verbs which describe the activity to be measured at each level)
1	Knowledge	recall or recognise information	arrange, define, describe, label, list, memorise, recognise, relate, reproduce, select, state
2	Comprehension	understand meaning, re-state data in one's own words, interpret, extrapolate, translate	explain, reiterate, reword, critique, classify, summarise, illustrate, translate, review, report, discuss, re-write, estimate, interpret, theorise, paraphrase, reference, example
3	Application	use or apply knowledge, put theory into practice, use knowledge in response to real circumstances	use, apply, discover, manage, execute, solve, produce, implement, construct, change, prepare, conduct, perform, react, respond, role-play
4	Analysis	interpret elements, organizational principles, structure, construction, internal relationships; quality, reliability of individual components	analyse, break down, catalogue, compare, quantify, measure, test, examine, experiment, relate, graph, diagram, plot, extrapolate, value, divide
5	Synthesis (create/build)	develop new unique structures, systems, models, approaches, ideas; creative thinking, operations	develop, plan, build, create, design, organise, revise, formulate, propose, establish, assemble, integrate, re-arrange, modify
6	Evaluation	assess effectiveness of whole concepts, in relation to values, outputs, efficacy, viability; critical thinking, strategic comparison and review; judgement relating to external criteria	review, justify, assess, present a case for, defend, report on, investigate, direct, appraise, argue, project-manage

In the UK a set of specific learning outcomes for undergraduate programmes is defined in the UK-SPEC published by the Engineering Council UK, a royal chartered educational charity responsible for the UK register of Chartered Engineers. The Institution of Mechanical Engineers (IMechE) use this set of outcomes when examining a course for accreditation. There are 27 learning outcomes specified across 5 categories which cover both disciplinary knowledge and professional skills and attributes. Part of the IMechE accreditation process focuses on identifying where these learning outcomes are delivered in the modules of a degree program. A matrix is produced for all modules over all years of the degree to help identify any gaps or imbalances that occur. This approach can also be used as a tool for designing a new degree, as well as auditing existing programs, ensuring that the relevant learning outcomes of the CDIO syllabus, ABET or UK-SPEC are met.

DBT GROUP PROJECTS IN STAGES 1, 2 & 3

Running in parallel with the School of Mechanical and Aerospace Engineering's CDIO implementation plan at QUB, focused on adapting the existing Mechanical and Aerospace degrees to the CDIO principles and standards, has been the introduction of the new PDD program which accepted its first students in 2004. Designed from the outset to be CDIO compliant this program is structured to have an integrated curriculum with group DBT projects in each of the first 3 years. The learning outcomes from the associated module

handbooks are shown in Table 2. These illustrate a progression in level with key words in the learning outcomes being drawn from Bloom's taxonomy.

The level of cognitive ability required in each project in the sequence increases over the 3 years and facilitates the development of the students by building on their knowledge, skills and experience while setting a task at each stage sufficient to challenge them, in line with the "+1 principle".

Table 2: Summary of Learning Outcomes of DBT Project Modules in Stages 1, 2 & 3 of the QUB PDD Undergraduate Program

Stage 1 - MEE1025 – Design Project1 (1 group project, 12 weeks duration)
• Use creative and lateral thinking tools and techniques in the creation of ideas and concepts for an innovative new product. • Perform market analysis to compare products of competitors. • Conduct product dissection to analyze existing products. • Apply critical thinking and problem solving techniques in the development of a new design. • Use sketching, rendering and CAD skills to illustrate design concepts. • Produce a technical report and presentation, referencing relevant sources. • Develop time management, project management and team working skills
Stage 2 - MEE2026 – Design and Prototyping Projects 2 (3 group projects, 8 weeks each)
• Develop design briefs into viable physical prototypes involving a number of assembled components. • Use a range of Rapid Prototyping and virtual prototyping hardware and software tools along with physical testing to iteratively revise design concepts to establish an optimal solution. • Utilize a number of tools and techniques introduced in the Stage 1 "Product Design Methods & Practice" module, further developing the skills required of professional product designers. • Plan and organize a project. • Run effective formal design review meetings. • Develop problem solving and effective decision making skills. • Refine time management and team working skills.
Stage 3 - MEE3052 – Project 3P (1 group project, 24 weeks duration)
To provide students with experience of working within a team on a realistic major project developing a product from the identification of a problem / customer need through concept development, product design specification, detailed design, prototyping and testing and finally to a plan for manufacture. To enable students to gain further appreciation of the potential applications and practical limitations of the technical knowledge they have acquired throughout their degree program. After successfully completing this module students should be able to: • Identify an unfulfilled customer need and assess the potential for a viable new product in the market. • Apply knowledge and understanding of a specialist subject and related elements of professional product design practice. • Collate information, analyze and solve a technical problem. • Design or develop a system, component or process and recognize opportunities for improvements in a design through review. • Utilize appropriate laboratory equipment, computer software and instrumentation, in order to accomplish the objectives of a project. • Communicate effectively the results of a project in oral presentations and written reports. • Design and plan a project and manage the time involved to complete all tasks to the respective deadlines. • Work and learn independently. • Work and communicate effectively as a member of a project team. • Critically review all aspects of the completed design build and test project

In stage 1 the project is typically well constrained and looks only to produce an updated or improved version of an existing design. The students are given the theme of the project and are asked to benchmark and critically analyse against competitor products. Sample products are provided for dissection and analysis. The assessment regime provides opportunities for the development of skills taught in other modules, such as sketching and CAD, to be evaluated. New designs with unique selling points are developed and first prototypes required to demonstrate functionality only are made, often from recycled materials or prototyping foam. Several milestones (submissions) are indicated from the outset and students follow a structured product development process schedule supplied by the tutor.

In stage 2 the projects are often more open ended and challenge the students to produce an innovative concept and analyse its viability as a commercial product. Examples design briefs have included devices to make bananas bought in a supermarket last longer at home before becoming over ripe and devices to cleanly remove the top of a boiled egg. There may not be a perfect solution to these problems but the process of conceiving, designing and implementing a solution remains valid. Students are assessed in large part on how they carry out this process. Working prototypes are required to be produced (often using rapid prototyping) and tested, the results analyzed and conclusions drawn. Students are given less instruction regarding milestones and have to organise their own project plan and the division of labour within the group. Formal design review meetings are scheduled and chaired by the course tutor for the first project but subsequently this becomes the responsibility of the group. Computer Aided analysis tools are introduced by demonstration only and self paced learning materials supplied to the groups to encourage independent learning.

In stage 3 students are required to identify a customer need for which there is currently no effective solution on the market and develop a viable design for this need. In addition they develop in parallel a business plan for the product and determine the most effective route to market. Designs are developed with full manufacturing considerations and prototypes produced in the School's engineering workshop. Testing is also required to be carried out in a more comprehensive manner. While the themes of the project usually overlap with areas in which they have received formal instruction the nature of these projects often requires an amount of self learning in order to fully understand the issues related to a viable solution in the particular field. Groups must organise themselves and call and run the formal design review meetings at which the supervisors attend as regular members under the chairmanship of an elected group leader.

Figure 1 shows the author's assessment of the target level of skills and attributes that can be developed by students successfully completing the DBT projects in the first 3 years of the PDD program. It is important to recognise that while these are objectives they do not necessarily relate to the levels attained by all students on the program. The vertical axis indicates the level of learning in relation to Bloom's taxonomy as defined in Table 1. Conception is lower in stage 1, for example, since the theme of the project is provided and the students only seek to develop incremental improvements to something which already exists (level 3 – application) while a much higher level of conception (level 6 – evaluation) is targeted in stage 3 where original and unique solutions to problems are sought. In all phases (C, D, I & O) a stepped development is mapped out from which learning outcomes are defined and from which tasks and assessment regimes are subsequently devised to deliver these outcomes. This approach is consistent with the constructive alignment model defined by Biggs [6] and provides clarity to the student between the tasks set and the assessment requirements. These DBT modules are the core of the integrated PDD curriculum and provide an opportunity for students to immediately apply the engineering science content of other modules in a design context.

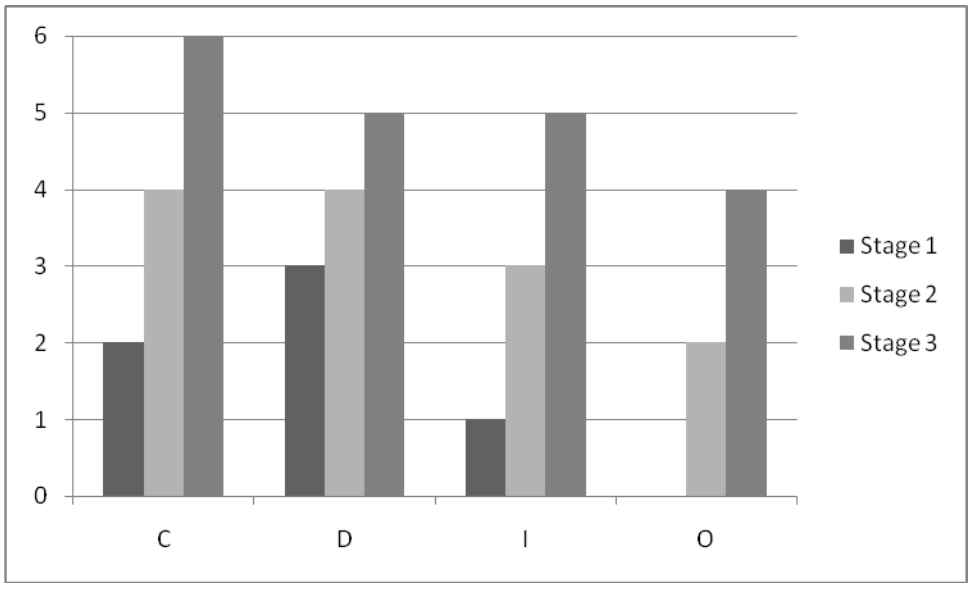

Figure 1 – Stepped Development Objectives of CDIO Skills and Attributes in PDD DBT Projects at QUB in Levels Defined by Bloom's Taxonomy of Learning Domains

ASSESSING THE INDIVIDUAL IN A GROUP

Most QUB engineering students arrive at university with limited or no experience of working or studying in a group. It is important to have a working system which first year students can see rewards those in a group who contribute more than average and also assigns lower grades to those who try to "take a free ride". From the outset it was decided that individual grades should be awarded rather than all members receive the same grade. While giving everyone in the group the same mark is certainly easier in terms of the effort required by the tutor it does not help build trust between the students and faculty. The alternative of having a rigorous, transparent and demonstrably fair marking scheme is not easily achieved but in the author's opinion if worth pursuing. Over the last 5 years the model for group marking has been revised taking into account feedback from students through module reviews, reflective critiques and questionnaires relating to the project organisation and assessment methods.

In all projects a combination of group and individual submissions are required with some variation between projects. In all cases a group technical report is produced using a standard template with Summary, Introduction, Theory, Market Analysis, Design Development, Testing, Results, Discussion, Conclusion, References and Bibliography sections. Group submissions would also typically include a presentation and associated prototype. Individual submissions may include project log books and reflective critiques as well as oral interviews.

Peer Assessment spreadsheets are used in all projects and are a mandatory requirement. The confidential peer assessment works on a zero mean basis with each student scoring themselves and all other members of the group in each of fifteen categories, which are aligned with the deliverables and learning outcomes of the particular project. Each row must add to zero and justifying comments must be entered in the right hand column for any rows with a non-zero value in any cell. Statements are provided describing the range of values between -2 and +2 which students can enter in each cell.

	Alan	Bertie	Clive	Darren	Eddie		
Technical Contributions	**Alda**	**Bassett**	**Clarke**	**Day**	**Edwards**	**TOTAL**	**Comments / Evidence**
Ability to apply technical knowledge (ergonomics, manufacturing processes, injection mould design)	0.5	0.0	0.5	-1.5	0.5	0.0	Darren did not apply any technical knowledge to the project. Alan, Clive and myself did most of the work.
Consideration of design requirements and constraints	0.0	0.0	0.0	0.0	0.0	0.0	
Sourcing of relevant technical information	0.5	0.0	-0.5	-0.5	0.5	0.0	I carried out all the research for the theory and the suitablity for injection mouldng. Alan researched on CES. Bertie used the resources of the library.
Contributed alternative design concepts	0.0	0.0	0.0	0.0	0.0	0.0	
Effectively troubleshoots problems and finds answers	0.0	0.0	0.0	0.0	0.0	0.0	
SUB TOTAL	**1.0**	**0.0**	**0.0**	**-2.0**	**1.0**	**0.0**	
Contributions to Deliverables	**Alda**	**Bassett**	**Clarke**	**Day**	**Edwards**		
Sketching, rendering and model making	0.0	0.0	0.0	0.0	0.0	0.0	
Geomagic	-0.5	-0.5	1.0	-0.5	0.5	0.0	Clive and I spent most time trying to figure out how to use geomagic. Clive used the geomagic on the final model we received.
Solidworks CAD	0.5	0.0	1.0	-2.0	0.5	0.0	darren did not do any of the CAD. Clive spent most time on the CAD. Bertie did try some of the CAD but it had to be edited.
CES & Moldflow	0.5	-1.0	0.5	-1.0	1.0	0.0	Alan and myself were the only people who looked at CES. Me and Clive spent most time looking at MoldFlow.
group report & user manual	1.0	-1.5	1.0	-1.5	1.0	0.0	Alan collated the report. Clive and I created the user manual.
SUB TOTAL	**1.5**	**-3.0**	**3.5**	**-5.0**	**3.0**	**0.0**	
Teamworking	**Alda**	**Bassett**	**Clarke**	**Day**	**Edwards**		
Effectively takes charge of tasks assigned	1.0	-0.5	-0.5	-1.0	1.0	0.0	I felt Alan and I had to organise most of the project, assigning tasks and checking what had and had not been done. Darren did not make any effort to move the project along.
Produces work on time	0.5	-0.5	0.0	-0.5	0.5	0.0	Darren and Bertie were the worst with handing work in on time. Clive did not do tasks for the dates he was supposed to.
Willing to take on fresh challenges	0.0	0.0	0.0	0.0	0.0	0.0	
Acted as a mentor to other group members and helped their skills development	0.0	0.0	0.0	0.0	0.0	0.0	
Communicates clearly with other members of the team	0.5	0.5	0.5	-2.0	0.5	0.0	Darren was poor at responding to emails or replying to comments on the forum.
SUB TOTAL	**2.0**	**-0.5**	**0.0**	**-3.5**	**2.0**	**0.0**	
GRAND TOTAL	**4.5**	**-3.5**	**3.5**	**-10.5**	**6.0**	**0.0**	
	Alda	**Bassett**	**Clarke**	**Day**	**Edwards**		

Figure 2 – Sample DBT Project Peer Assessment Spreadsheet

The spreadsheet values are not typically used in isolation to alter marks for individuals in group submissions but rather in combination with the supervisor's observations of individual contributions. The supervisors rate each individual in absolute terms on a weekly basis according to a metric which considers quality of contributions as well as quantity. The expected quantity of contributions is determined by the module size of the project. The observation scores come from performance at the formal design review meetings, conduct during timetabled classes and contribution to an online blog. To gain higher marks the contributions must clearly be of value to the project. The online blog also provides the opportunity for instant feedback by the supervisors which reassures students that the continual assessment is in fact being carried out continuously. The blog is archived automatically each day and also provides an audit trail should it be required at a later date to review individual contributions.

Students are advised at the start of a project that individual marks for group elements may be adjusted by as much at ± 25% about the group mean. Experience has shown that it is more likely for an individual to have their mark adjusted down by the full range due to lack of engagement than for an individual to have a significant adjustment upwards. In general it has been noted that less adjustment is required in stage 3 by which time the students are more fully engaged in the learning process.

PERSONAL DEVELOPMENT PLANNING

While the scope and progressive challenge of the DBT projects combined with the constructive alignment of the assessment regime provide a basis for each individual student to develop it cannot be assumed that this will occur in all cases. In order to develop to the higher levels in Bloom's taxonomy students will need to take responsibility for their own learning. The objective of the PDD degree is to produce balanced learners capable of making a significant contribution at all phases of a new product development. Entry surveys of learning style preferences over the last 5 years have shown however that many of the PDD students have a dominant preference and a minority have avoidance tendencies for particular types of task or activity. In group situations this typically results in the person who is most competent or comfortable at a particular task volunteering or being assigned to their area of perceived expertise. As a result individuals build on their inherent strengths and fail to develop their weaknesses, applying a strategic approach to completing the project.

A skills audit questionnaire linked to the Personal Development Planning (PDP) process within the School is used to highlight areas of strength and weakness. Students self assess their skills and abilities across a broad range of categories and record evidence to support their claims. They then meet with their personal tutor and after discussion come to an agreed rating for each item, usually lower than the student's first assessment. An action plan is then devised with the tutor who highlights opportunities associated with tasks and assignments where the required skills can be developed. Emphasis is placed on improving weak areas and in developing an attitude of continual professional development. The intention is that this process continues throughout their academic studies with diminishing input from the personal tutor as the student takes more responsibility for their own learning.

In support of this process the assessed tasks for the DBT projects are adjusted to provide ample opportunity for development in the areas where the cohort of students is weakest. To date the profile of each PDD year group has been characteristic and consistent with a dominant "hands on", practical preference and less enthusiasm for technical report writing, which consequently is an ever present part of the assessed elements of these modules. In order to encourage peer learning students are rewarded for mentoring team members in areas where they are more able. This is reinforced by having such "management skills" appear as items in the peer assessment spreadsheets. In the earlier stages the division of marks among the different tasks is also weighted towards the process of designing rather than concentrating on the final output. This is done to encourage individuals to develop the "softer" skills such as team working and project management.

FEEDBACK

Race [7] has identified 5 qualities and attributes which should be considered when seeking to provide effective feedback:

- **Timely** – early and often.
- **Intimate and individual** – it means more to the student if it is personalized.
- **Empowering –** need to take care when providing critical feedback not to demoralize.
- **Open doors not close them** - words such as 'weak' or 'poor' can cause an irretrievable breakdown in communication between tutor and student.
- **Manageable** - providing feedback to students can take up all your the time and energy

The structured series of DBT projects on the PDD degree seeks to meet all of these feedback standards. Among the methods employed are; anonymous peer comments from interim presentations, interim private peer assessment feedback, draft report comments and interim individual meetings to discuss supervisor's continual assessment grading. In these

cases the feedback is formative and timely. In stage 2 when 3 projects run nose to tail in the same module there is also an opportunity for a full project debriefing to groups and individuals with an immediate opportunity to apply the lessons learned. In stage 3 the individual peer assessment feedback sessions concentrate on areas where contributions are significantly above or below the group average so that students can address the imbalance in the remaining weeks of the project. In all stages the project blog helps the supervisor identify who has contributed to the different tasks in the project and so the feedback can be personalised to assist with individual development. Before the introduction of the blog such individual and timely feedback could not be provided.

Throughout the development of the degree student opinions of the assessment and feedback regimes have been sought. Initially peer assessment was not linked directly to grades but student opinion was overwhelmingly in favour of changing the marking scheme so that their assessments were included. This change has been implemented but the module co-ordinator compares the supervisor and peer assessment grades to ensure that these are consistent and that no attempt has been made to “play the system”. If a significant mismatch occurs a second marker can be asked to examine the archive transcript and compare this to the supervisor’s weekly notes.

Table 3 shows the number of responses for a sample of questions from a larger questionnaire for the MEE3052 (Project 3P) module. From this it can be seen that peer assessment is viewed as a valuable process by the students and that it has a motivating and reflective influence on their learning.

Table 3: 0809 QUB Stage 3 PDD Attitudes of Peer Assessment

	STRONGLY AGREE	AGREE	NEUTRAL	DISAGREE	STRONGLY DISAGREE
Peer assessment is a valuable practice which helps me reflect on my own performance	7	11	2	2	0
I feel uncomfortable criticising the efforts of my peers, even anonymously	0	4	11	6	1
I would prefer that my individual marks and comments are made known and not just a group summary fed back to individuals	5	7	4	4	2
I am motivated to work harder knowing that my peers will be rating my contribution	3	10	8	0	1

Student feedback from module questionnaires suggests that the series of DBT projects have been well received with many positive comments identifying these projects as the place where the core skills required of the profession are developed, as was intended.

Teams from the first two cohorts through the PDD degree have had considerable success in external competitions. In 2007 a group of 4 students were one of 10 shortlisted finalists in the Enterprise Belfast 25k awards. In 2008 a group of 5 were runners up in the All Ireland Student Enterprise Awards. Of particular note is that the PDD students concerned were in

stage 3 which is a year earlier than the other teams from the School who have previously been successful in these same competitions.

CONCLUSIONS

- Including group DBT projects in all stages of an engineering degree program can provide a staged development process for the skills and attributes required for professional practice.
- Bloom's taxonomy of learning domains can be used to define appropriate learning outcomes for the projects at each stage of such a staged development process.
- Including students' peer assessment in the marking scheme can help build confidence among the student body that individual's marks accurately reflect their contribution to the group.
- Timely formative feedback combined with a formal PDP process can be used to assist students in taking responsibility for their own learning.

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EVALUATING THE IMPLEMENTATION OF CDIO PROGRAMS AT SINGAPORE POLYTECHNIC: THE FIRST YEAR

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ABSTRACT

This paper describes the evaluation of the large scale implementation of the CDIO initiative in engineering programs in 4 schools in Singapore Polytechnic. Changes were made to the syllabuses to incorporate the CDIO skills to develop the students' personal and professional skills and attributes; interpersonal skills of teamwork and communication; and system and product building skills. Existing courses were reorganised and linked and an "Introduction to Engineering" course aimed at stimulating students' interest in, and strengthening their motivation for, the field of engineering was introduced.

This longitudinal study of the implementation of CDIO focused on the impact of the curriculum changes on students' learning and acquisition of CDIO skills. The research questions were:

1. Were the learning outcomes, learning activities and assessments aligned
2. Were the learning of the courses integrated in the Introduction to Engineering Module?
3. How has the integration of the CDIO skills into the syllabuses impacted the students?
4. What were the lecturers' perception of the curriculum changes and their impact on students' competence in the selected CDIO skills and interest in subject?

Data for the evaluation was collected through document checks, student co-participant blogs, student surveys, and focus group interviews with students and lecturers. The paper will report on the findings of the first year of implementation and conclusions of the evaluation. It will discuss the support provided and make recommendations on improvements that can be made to the implementation

KEYWORDS

Program evaluation, personal skills and attributes, communication skills, teamwork skills, Introduction to Engineering, integration of skills,

INTRODUCTION

In October 2006, work began on revising and restructuring 13 engineering programmes from the Schools of Architecture and Built Environment, Chemical and Life Sciences, Electrical and Electronic Engineering, and Mechanical and Manufacturing according to the CDIO framework. Some of the revisions made include the integration of the CDIO skills of personal and professional skills and attributes; interpersonal skills of teamwork and communication; and basic system and product building skills into the syllabuses. In all programmes, an Introduction to Engineering module was instituted to provide students' with the opportunity to develop the selected skills; link and integrate knowledge across the courses; and stimulate interest in, and strengthen students' motivation for, the field of engineering through real world

design build activities. Existing assessment schemes were also reviewed and revised accordingly to include the assessment of the skills. The revised programmes were implemented in April 2008.

The CDIO evaluation was initiated to provide a structured research driven approach to monitor and review the implementation of the CDIO Framework at Singapore Polytechnic. The purpose and approach of the evaluation is consistent with that identified by Kemmis (1989):

> Evaluation is the process of delineating, obtaining and providing information useful for making decisions and judgements about educational programmes and curriculum. (p.117)

The evaluation activities were designed to address three broad research questions central to understanding the impact of key aspects of the CDIO implementation:

1. Are the learning outcomes, learning activities and assessments aligned?
2. How has the changes in the curriculum, learning activities and assessments impacted the students?
3. What are the lecturers' perception of the curriculum changes and their impact on students' competence in the selected CDIO skills (thinking, teamwork and communication) and interest in the subject?

These three broad research questions were subsequently broken down to more specific questions within each area (Table 1):

Table 1: The broad and specific research questions

Broad Research Questions	Specific Research Questions
1. Are the learning outcomes, learning activities and assessments aligned?	• Are the CDIO skills sufficiently incorporated in the learning outcomes, learning activities and assessments? • Are the learning designs appropriate? • Are the assessments appropriate and valid?
2. How has the changes in the curriculum, learning activities and assessments impacted the students?	• Are the students showing competence in the CDIO skills? • Are the students more engaged and interested? • Do students find the lessons more meaningful?
3. What are the lecturers' perception of the curriculum changes and their impact on students' competence in the selected CDIO skills and interest in the subject?	• In what ways, do the activities help develop the selected CDIO skills? • In what ways do the activities encourage interest and learning? • What are the difficulties and areas for improvement?

METHODOLOGY

The methodology is eclectic, utilizing the strengths of the methods chosen for their potential to provide useful data and insights. Most were identified and systematically planned prior to the data collection activities. However, certain modifications were made in response to emergent data. As Cronbach (1988) points out:

> Designing an evaluation is a continuing process, what variables deserve close attention will be discovered as the fieldwork proceeds. (p.7)

Where appropriate, triangulation of data is employed to generate multiple framing and the possibility of enhancing validity in relation to some questions. However, as Hammersley & Atkinson (2008) caution:

> One should not adopt a naively 'optimistic' view that the aggregation of data from different sources will unproblematically add up to produce a more complete picture. (p.199)

Table 2 below summarizes the data collection methods and evidence sources utilized. For the qualitative data sources, a broad grounded theory approach (Glasser & Strauss, 1976; Straus & Corbin, 1990) is employed in that theory generated will be emergent from the data rather than researcher determined constructs. In the case of the student focus groups, a more phenomenographic approach was adopted after the initial round of interviews. This was in response to recognizing the potential of the research situation to explore more rigorously how student experienced certain key skills of the CDIO curriculum (e.g., thinking) and their perception of how these were being taught.

Table 2: Data collection methods

Broad Research Questions	Data collection Methods (evidence sources)
1. Are the learning outcomes learning activities and assessments aligned?	• Examination (in collaboration with participating faculty) of a range of curriculum materials (e.g., course documents, module documents, learning plans, schemes of assessment, assessment items)
2. How has the changes in the curriculum, learning activities and assessments impacted the students?	• Student questionnaire for all students in the sample • Student Blog • Focus group interviews with a sample of students
3. What are the lecturers' perception of the curriculum changes and their impact on students' competence in the selected CDIO skills and interest in the subject?	• Focus group interviews with lecturers teaching on CDIO programmes • Observation of selected lessons (e.g., those incorporating activities related to selected CDIO skills)

The data collection methods employed, their rationale in context and how they were used in practice are outlined below.

Examination of a range of curriculum materials

As identified in Table 2, this involved the examination of a range of related curriculum materials (e.g., course documents, module documents, learning plans, schemes of assessment, assessment items). The aim was to ensure that the curriculum materials met the conditions of an aligned curriculum (e.g., Biggs, 1999) and were consistent with relevant CDIO standards (Crawley et al, 2007).

In practice, this involved ongoing collaborative work with lecturers (who are the subject specialists) and Educational Development staff (who provided the pedagogic guidance) in producing the necessary materials and to the standard required.

Student Questionnaire

This was administered to all the students online at the end of each semester (Sept 08 & Feb 09).The response rate was approximately 45% of the total population cohort.

The student questionnaire provided quantitative data relating to a number of the research questions across the full student sample. Care was taken in the design of the questionnaire items to ensure clarity, appropriate focus and efficiency, as well as incorporating the wider principles of good questionnaire design and implementation identified in the literature (e.g., Oppenheim, 2000).

It is to be noted that there are some key differences in the questions posed between the two administrations (e.g., Sept 08 and Feb 09) as well as between schools. For example, for year long courses, there was interest in identifying the extent to which student were aware of the infusion of the selected CDIO skills in the first questionnaire. In the second questionnaire, the focus was more on establishing the extent of application of the skills in the module context.

(See Appendix 1 for examples of the student questionnaires used)

Student co-participants and Blog

It was decided to engage students as "co-participants" (a terms used by Lincoln (1990, p.78), to blog their experiences of the lessons taught. Forty-seven student co-participants were involved semester 1 and 55 for semester 2, with representation across schools. The selected students were given a full briefing on the research purpose and their role and responsibilities. It was made very clear to the potential student groups that they should only participate if they felt that they could meet the responsibilities in an authentic and conscientious manner. They were specifically required to:

- Chat to classmates and identify some broad experiences relating to learning the selected CDIO skills and the teaching approaches used
- Make personal notes and/or blog their experiences in relation to both structured and open questions in the designated student blog
- Meet with the researchers at least once a semester for group sharing

A student blog, incorporated into the Blackboard learning management system, was employed as a means of providing regular, ongoing communication and feedback with the student co-participants. Students were typically presented with specific questions relating to their experience of lessons taught, and asked to provide their responses with examples to illustrate where possible.

They were also at liberty to post comments at any time if they felt this information would enhance our understanding of their learning experience in the classroom context. Apart from the collection of data per se, the use of the blog was seen as a useful and novel way to help build rapport with the students, encouraging more authentic and open communication – hence increasing the possibility of more valid situated data.

(See Appendix 2 for examples of the blog questions used.)

Focus Groups

The use of focus groups was employed for the following main reasons:

- Enables the collection of data relatively quickly from a larger number (as compared to individual interviews) of research participants

- Provides a more naturalistic context than the individual interview in that it is closer to the everyday conversations that people typically participate in

- As a synergistic effect in that it allows participants to react to and build upon the responses of other group members, producing richer accounts of the experience being investigated

The focus group interview typically lasted from between 1-2 hours for both lecturers and students, depending on situated factors (e.g., the number of participants involved and time commitments, etc). In practice the process worked well and it was felt that sufficient time was available to encourage a wide range of participation and achieve a sufficient depth of exploration of key areas (e.g., attain "theoretical saturation", Glaser and Strauss, 1976; Strauss and Corbin, 1990).

The lecturer participants in the focus groups comprised those teaching courses in which selected CDIO skills were infused. Twenty-one lecturers, representing all schools, participated in 4 focus group sessions. In the interview sessions, an opening scenario of 3 main areas was presented to lecturers to offer their experiences and reflections on:

- What have you been involved in doing, in terms of CDIO implementation?
- What have you specifically done and how?
- What is your perception of its impact on student learning, based on your experience with student groups?

Where necessary points of clarification are offered, and lecturers encouraged to ask their own questions to each other and to participate in the kind of dialogue arrangements that they feel comfortable with. The advice of Douglas, 1984, who argues for more 'creative interviewing' in which the interviewer must establish a climate for *mutual* disclosure, is interesting in this context:

> Creative interviewing…involves the use of many strategies and tactics of interaction, largely based on an understanding of friendly feelings and intimacy, to optimize cooperative, mutual disclosure and a creative search for mutual understanding. (p.24)

The interviews were facilitated by two members of EDU staff, one acting as main facilitator and the other doing the summary recording of key responses.

In the case of the student focus group interviews, questions were asked specifically focusing on their subjective experience relating to aspects of CDIO. It was made clear to the students that we were not looking for 'right' or 'better' answers, only the best representation of their experience as they could recall it. The typical interview process for each area of interest involved:

- A standard opening scenario is presented to the students (e.g. have you experienced your lecturer explicitly teaching thinking in any of the classes; what does thinking mean to you; how have you responded to this learning experience; why did you experience it in this way?)

- No new features are introduced – only encouragement to students to explain and provide examples

- Clarification of meaning and checking understanding where appropriate

Observation of Lessons

The purpose of observing selected lessons taught by lecturers involved in the CDIO implementation is to obtain a more ethnographic insight into what is actually occurring in the

situated context of the classroom and what might be useful for enhancing understanding of how students experience learning activities related to the selected CDIO skills. Such insights might prove important in deciding what is of most value in this curriculum and how it is best negotiated in a range of learning contexts.

The process for conducting this part of the evaluation is as follows:

- The classes to be observed are mutually agreed by lecturers and EDU staff
- The lesson must incorporate a significant component relating to the teaching/assessment of a CDIO skill area
- There is opportunity to ask student questions (at the end of the observation) pertaining to their experience of the particular learning activity and CDIO skill areas

Eight lessons were observed. This process is likely to continue in the next semester and modifications (e.g., duration, form or focus, etc) will be made as appropriate.

DATA ANALYSIS & FINDINGS

Data analysis techniques were selected on the basis of appropriateness to the data types generated from the various collection methods. Table 3 summarizes the approaches taken.

Table 3: Data analysis approaches

Data Type	Data Analysis Approach
Curriculum Materials	Analysis of curriculum documents and materials (e.g., module documents, learning activities, learning designs, assessment schemes, assessment items and scoring systems) Recording of the numbers of appropriately completed (and non-completed) document/material types
Student Blog	Quantitative tabulation and analysis of responses to questions Qualitative data analysis (e.g., categorization and generation of themes)
Student Questionnaire	Quantitative tabulation and analysis of responses to questions
Focus Groups	Qualitative data analysis (e.g., categorization and generation of themes)
Observation of Lessons	Qualitative data analysis using designated recording categories (e.g., tasks relating to thinking, teamwork and communication)

The analysis of the qualitative data components provided the greater challenges in terms of collation and analysis. As Marshall & Rossman (1989) point out:

> Data analysis is the process of bringing order, structure and meaning to the mass of collected data. It is a messy, ambiguous, time consuming, creative, and fascinating. Qualitative data analysis is a search for general statements about relationships among categories of data; it builds grounded theory. (p.112)

The following headings summarize the main findings from the various data sources obtained in the evaluation to date.

1. Are the learning outcomes learning activities and assessments aligned?

Analysis of curriculum documents and material

This part of the evaluation was a valuable learning experience, both for lecturers and EDU staff. It readily becomes apparent, through the collaborative activity, that some courses needed significant revision in terms of the writing of learning outcomes generally (e.g., rationalization, performance focus, clarity of intent, etc). Hence, the initial challenge was to both revise and rewrite existing learning outcomes and appropriately infuse selected CDIO skills.

Once this was achieved, a similar process of review and revision was made to key learning tasks and assessment activities (including the scoring systems). This process of collaborative work continued until the module curriculum was fully aligned and the various components appropriately designed (e.g., learning outcomes, learning designs, assessments). This whole collaborative process led to much rapport building and sharing between lecturers and EDU staff.

2. How has the changes in the curriculum, learning activities and assessments impacted the students?

Student Questionnaire

The Student Questionnaires were designed to gather feedback from students at the end of the semester. Due to differences in implementation across schools and across semesters, different variants of the questionnaire were used. Students were required to submit their responses to the questions on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

Table 4 shows the frequency distribution (with percentages in parenthesis), mean and standard deviation (SD) of students' responses by module for Semester 1. Nearly 50% agreed and 25% strongly agreed, in favour of the implementation of CDIO. The mean scores ranged from 3.73 to 4.03, with an overall mean of 3.90 (SD = 0.90). The Cronbach alphas were 0.93, 0.96, 0.96, 0.94, 0.96, and 0.94, respectively, showing high internal consistency in student responses.

Table 4: Frequencies, percentages (in parenthesis), means and SD of students' responses for the six courses in Semester 1

Module	1	2	3	4	5	Mean	SD
BE710Y	1 (0.3)	12 (3.2)	80 (21.1)	195 (51.3)	92 (24.2)	3.91	0.73
BE715Y	19 (3.3)	73 (12.6)	103 (17.8)	235 (40.5)	150 (25.9)	3.73	1.07
CP5009	12 (1.4)	31 (3.7)	168 (20.2)	413 (49.6)	208 (25)	3.93	0.83
CP5045	15 (1.3)	38 (3.3)	162 (14)	624 (54)	316 (27.4)	4.03	0.78
ET101Y_SP0302	121 (3.2)	244 (6.4)	731 (19)	1652 (43)	1092 (28.4)	3.87	0.98
MM1028	13 (0.8)	56 (3.6)	289 (18.7)	790 (51.1)	397 (25.7)	3.97	0.79
Overall	181 (2.2)	454 (5.4)	1533 (18.4)	3909 (46.9)	2255 (27.1)	3.90	0.90

Similarly, Table 5 shows students' responses for Semester 2. Although slightly lower values than those in Semester 1, nearly 50% agreed and 25% strongly agreed, in favour of the implementation of CDIO. The mean scores ranged from 3.74 to 4.10 i.e. agree, with an

overall mean of 3.85 (SD = 0.93). The Cronbach alphas were 0.97, 0.97, 0.94, 0.94, 0.96, and 0.96, respectively, showing high internal consistency in student responses.

Table 5: Frequencies, percentages (in parenthesis), means and SD of students' responses for the six courses in Semester 2

Module	1	2	3	4	5	Mean	SD
BE710Y	12 (1.6)	28 (3.7)	104 (13.8)	378 (50.0)	234 (31.0)	4.05	0.87
BE751Y	26 (1.1)	98 (4.0)	457 (18.8)	1194 (49.1)	655 (27.0)	3.97	0.87
CP5008	1 (0.3)	18 (6.1)	46 (15.5)	116 (39.1)	116 (39.1)	4.10	0.86
CP5009	3 (0.4)	12 (1.5)	171 (21.4)	474 (59.3)	140 (17.5)	3.92	0.67
ET101Y_SP0302	231 (3.7)	474 (7.5)	1512 (23.9)	2557 (40.5)	1546 (24.5)	3.74	1.00
MM1028	50 (3.4)	71 (4.9)	343 (23.4)	631 (43.1)	368 (25.2)	3.82	0.96
Overall	324 (2.7)	703 (5.8)	2636 (21.4)	5354 (44.3)	3064 (25.4)	3.85	0.93

Student Blog

The data from the student blog over the two semesters were collated and analysed. The following are the more generic findings:

- The great majority of students who blogged, perceived the importance of the CDIO skills as a valuable part of the curriculum. The explicit teaching of the selected skills seems to vary from module to module and across lecturers. The overall data indicates that the majority are not consistently teaching the skills explicitly. A number of responses are consistent with the response from one student who blogged, "Teacher never teaches what is good thinking". However, there is evidence that some lecturers, while not teaching the skills explicitly, are creating authentic learning opportunities for such skills to be fostered. The following response is not untypical, "The teacher give us the problem for us to do the thinking and produce a good idea to get the answer".

- The responses to specific real world tasks introduced to students in the courses, strongly suggests that such tasks link theory to practice, make the learning experience more meaningful and interesting. It is evident that such tasks, when well designed and managed, are effective in both the teaching of CDIO skills as well as consistent with good pedagogic practice generally. One student captured the essence of many when he/she blogged, "We finally made use of what we learnt in class. It is an experience that is different because what we learnt came alive".

Student Focus Groups

The generic findings from the student focus group interviews are:

- All students who participated in the focus groups felt that the selected CDIO skills (e.g., thinking, communication and teamwork) were relevant and important to learn. The experience of learning these skills seems to be significantly mediated by the particular practices of individual lecturers. For example, in some cases, students are clearly experiencing these skills being taught in an explicit manner ("…lecturer poses questions during the practical to probe our thinking. It is on a regular basis"; Mr X challenges us all the time, he wants us to present our thoughts and answers."). In particular, students who

had completed the Teamwork and Communication module were able to articulate what constitutes good teamwork and communication.

- While some lecturers were teaching the skills explicitly, this did not seem to be the majority practice in most classrooms. In many cases students were provided with learning activities that involved the skills, but were expected to learn experientially without sufficient guidance and scaffolding ("We are told to think well but since we are not guided, we just thinking in the way we want")

3. What are the lecturers' perception of the curriculum changes and their impact on students' competence in the selected CDIO skills and interest in the subject?

Lecturer Focus Groups
The responses to the questions and issues raised are diverse across schools and individual lecturers. The following represent some of the more salient and general findings across the data:

- Lecturers saw the relevance of the CDIO framework (e.g., need to make engineering more practical and interesting). Some have experienced positive impact of the changes made to the curriculum on student attention and interest, especially when doing hands-on activities (e.g., building and racing a car).

- The lecturers also observed that while the more motivated students coped better with the more challenging integrated learning tasks, the less competent students required more help and time.

- There was a range of practices concerning the explicit teaching of the selected CDIO skills. Some lecturers were explicitly teaching the skills and following up with relevant performance-based activities. However, in other situations, skills were not being taught explicitly.

- Lecturers were universally agreed that CDIO implementation has resulted in an increase in workload, resulting from the preparation and assessment involved, especially when cohort size is large and there are a number of assessment components. There was concern that teaching creativity and other CDIO skills was beyond the existing capability of some lecturers.

Observation of Lessons
The main findings from the classroom observations are:

- Some learning tasks provided opportunities for the development of types of thinking, teamworking and communication skills.
- Students were generally positive about the learning activities, some needing more support than others.
- The actual skills and what were involved in developing them were not seen to be taught explicitly in most observations. The relative lack of the explicit teaching of these skills is supported by the data obtained from the student focus group interviews.

RECOMMENDATIONS

As Kemmis (1989) once argued:

> The quality of the evaluation may be judged by the quality of its contribution to informing and improving the critical debate about the programme. (p.120)

The following summary statements and recommendations are those deemed most pertinent in relation to the research questions, and other significant learning derived from the evaluation experience to date:

1. Are the learning outcomes, learning activities and assessments aligned?
The collaborative work between schools in evaluating the present curriculum materials (e.g., course documents, module documents, learning activities and assessments) has led to significant improvement in these areas. This is likely to continue as more courses are revised to incorporate the CDIO standards.

2. How has the changes in the curriculum, learning activities and assessments impacted the students?
The data from all the evaluation activities suggest that there is extensive acceptance of the relevance of the infused CDIO skills into the engineering content curriculum. This has been consistently articulated in the focus groups and from the blog responses in particular. The wider quantitative data further verifies this across the wider student sample.

In terms of student engagement, interest and perceived meaning, it seems to be the case that many of the introduced real-world projects and tasks support a positive frame in this context. Many students have communicated that these tasks have made the learning more meaningful, supporting the development of understanding and competence. However, it is also apparent that some students have found the tasks difficult and feel that not enough time is available to fulfill the requirements adequately. This was corroborated through dialogue with lecturers in their focus groups. It is recommended, therefore, that lecturers consider ways to make such tasks more differentiated in terms of requirements.

3. What are the lecturers' perception of the curriculum changes and their impact on students' competence in the selected CDIO skills and interest in the subject?
Lecturers across schools see the relevance of the underlying purpose and practices of the CDIO Framework. Generally, the data from the various evaluation components supports the view that engineering education should focus more on practical applications and incorporate generic skills such as thinking, teamwork and communications.

There is general agreement that many of the tasks introduced have led to greater student interest and engagement, though again recognizing that students cope to varying degrees with the demands set. Furthermore some lecturers have expressed concern about their own competence in teaching these skills, especially creativity. It is recommended, therefore, that module teams consider carefully who is best able to teach specific areas of the curriculum and try not to put lecturers in situations that challenge their existing skill set, where possible. It is further recommended that specific training and online support materials are made available to support lecturers in the most effective and efficient ways possible.

CONCLUSION

Firstly, the eclectic methodology employed in the evaluation has provided a range of insights into aspects of teaching and learning relating to both CDIO implementation and the student experience of teaching and learning in SP. For example, the qualitative data, made possible through the ongoing blog activity and focus group meetings with co-participants, clearly highlights the importance of the lecturer as the active agent in curriculum implementation. The experiences of the curriculum changes that have been initiated are significantly mediated by the way individual lecturers conduct their practices. As a consequence, a major consideration in the success of CDIO implementation will be to ensure the necessary

competence of the lecturers involved. It is recommended that training and support in good pedagogic practices and instructional methods use (e.g., facilitation skills, student project design and management, etc) are made readily available and delivered flexibly.

It is certainly now established that the selected CDIO skills implemented so far have been sufficiently well received by both students and lecturers. The next focus is likely to be more on verifying and extending the range of pedagogic and assessment practices necessary for effectively meeting the range of CDIO standards.

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APPENDIX 1
EXAMPLE OF STUDENT QUESTIONNAIRE
CDIO Evaluation Survey (ET101Y/Z Introduction to Engineering)

Dear Students,
Over the past semester, your lecturers have been attempting to teach you teamwork, communication and thinking skills that would be relevant to you as a technologist. The following questions are to gather feedback for your experiences in learning these skills. In order to improve the teaching of these skills, we would appreciate your most honest feedback. These questions present some statements relating to learning in your courses. Please think about these statements and consider how they relate personally to you, with 5 being Strongly Agree, and 1 being Strongly Disagree.
(SD = Strongly Disagree, D = Disagree, N = Neutral, A = Agree, SA = Strongly Agree)

		SD		N		SA
1	I am aware that the following skills are being practised in my lessons.	1	2	3	4	5
	a) thinking	o	o	o	o	o
	b) teamwork	o	o	o	o	o
	c) communication	o	o	o	o	o
2	I understand the usefulness of the following skills in my learning and development as a technologist.					
	a) thinking	o	o	o	o	o
	b) teamwork	o	o	o	o	o
	c) communication	o	o	o	o	o
3	The activities in my Introduction to Engineering lessons make my learning more interesting and motivate me to learn more about my course.	o	o	o	o	o
4	I am participating more actively during my Introduction to Engineering lessons.	o	o	o	o	o
5	As a result of the activities in the Introduction to Engineering lessons, I am able to think more creatively and generate ideas.	o	o	o	o	o
6	As a result of the activities in the Introduction to Engineering lessons, I am able to use a range of critical thinking skills more effectively in problem-solving (e.g. analyse, compare & contrast, evaluate).	o	o	o	o	o
7	As a result of the activities in the Introduction to Engineering lessons, I am able to manage my learning more effectively (e.g. keep to deadlines, organise notes and prioritise learning activities).	o	o	o	o	o
8	In doing the project/s in the Introduction to Engineering module, I understand the importance of having initiative and the willingness to take thoughtful risks.	o	o	o	o	o
9	The activities in the Introduction to Engineering module gave me a greater understanding of the importance of team roles and their impact on team performance.	o	o	o	o	o
10	As a result of the activities in the Teamwork and Communication Skills module, I am able to design and deliver more effective oral presentations in my IDEA/IE courses	o	o	o	o	o
11	I am able to connect and see the relevance of the concepts in PEEE and DE to the IE module contexts.	o	o	o	o	o
12	I am able to connect and see the relevance of the concepts in TCS to the IE module contexts.	o	o	o	o	o

APPENDIX 2
EXAMPLES OF BLOG QUESTIONS

Week 7

1. Did the Voltage Level Detector project help you understand the core fundamental courses (PEEE & DE) better and/or deeper? Please elaborate.

2. Did the Voltage Level Detector project help you to understand and practice the Core CDIO skills of Teamwork, Communication Skills and Thinking? Please elaborate.

3. What changes do you think could be made to the Voltage Level Detector project to make it a better learning experience? Please elaborate. You may choose to highlight more than one point.

4. Is the lab layout, seating arrangement, equipment & component level etc conducive for IE/IDEA discussions and project work? Please elaborate.

Week 14

1. Having been introduced to engineering, are you aware of what it means to be an engineer? What do you think is the purpose and goal of an engineer?

2. What skills and attributes do you think is required of engineers in this 21st century?

3. Do you feel that the module, Introduction to Engineering give you the opportunity to develop the skills which you have mentioned in Question 2. Briefly explain.

Week 15

1. The semester will be ending in a few weeks. List down the skills which you think you have developed through the Introduction to Engineering module in this semester. (E.g.: ability to troubleshoot problems, teamwork, etc)

2. What do you think are some of the ethical issues facing engineers in your field of engineering? Were these issues discussed in the lessons?

3. Is there anything else which you like to improve regarding the lessons (lecture, tutorial & workshops/labs)?

4. Having gone through 2 semesters, how would you rate (1-5) your interest in your field of engineering? (1 being Not Interested and 5 being Very Interested) Briefly explain your rating.

EVALUATING THE STUDENT EXPERIENCE OF SPECIFIC CDIO SKILLS FROM A PHENOMENOGRAPHIC APPROACH USING STUDENTS AS CO-PARTICIPANTS

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ABSTRACT

This paper outlines the evaluation approach presently adopted at Singapore Polytechnic to identify the impact of CDIO implementation on student learning. It specifically focuses on how selectively infused CDIO skills are being experienced by students in terms of their perceived relevance, the learning approaches adopted, and motivation.

To achieve an understanding of the student learning experience a phenomenographic approach is being adopted as part of the overall evaluation strategy. This seeks to explore how students perceive the infusing of CDIO skills and the responses they are making in terms of learning orientation. We are specifically interested in their approach to learning these skills (e.g., Deep or Surface and the variation involved) as well as their perception of relevance and motivation.

The research approach also includes a sample of students who are “co-participants” (a term borrowed from Lincoln, 1990, p.78) in that they are interested in the research and what it might produce. These co-participants provide regular feedback on their and fellow students experiences through a designated blog and semi-structured focus group interviews.

The research is longitudinal and will provide us with the opportunity to employ a grounded theory approach (Glaser & Straus, 1967) in which we can validate emerging theory with student co-participants.

While, at the time of writing, the research is in its earlier stages, it will provide useful insights into how evaluation of CDIO might be formulated in terms of direct exploration of the student learning experience, and what we might learn in terms of improved implementation and specific teaching practices.

INTRODUCTION

This paper documents a key component of an evaluation of a curriculum innovation based on the CDIO approach in engineering education (Crawley et al, 1) at Singapore Polytechnic. The evaluation was initiated in 2008 to provide a structured research driven approach to monitor and review the implementation of the CDIO Engineering Educational Framework at SP. The purpose and approach of the evaluation is consistent with that identified by Kemmis (2):

> Evaluation is the process of delineating, obtaining and providing information useful for making decisions and judgements about educational programmes and curriculum. (p.117)

The wider evaluation activities are presently addressing three broad research questions central to understanding the impact of key aspects of the CDIO implementation:

1. Are the learning outcomes, learning activities and assessments aligned?
2. How has the changes in the curriculum, learning activities and assessments impacted the students?
3. What are the lecturers' perception of the curriculum changes and their impact on students' competence in the selected CDIO skills and interest in the subject?

This specific research focus of this paper is on understanding the student experience of selected CDIO skills in terms of the actual learning occurring, learning approaches adopted, and relationship to teaching practices. It firstly outlines the theoretical framework, its underlying premises and rationale. Secondly, the methodology is detailed and explained in terms of the research purpose. Thirdly, it identifies emerging data trends from the initial interviews, and how the evaluation is likely to progress over time.

FRAMING LEARNING FROM THE STUDENT EXPERIENCE

The late Lawrence Stenhouse (3) once wrote:

> …the central problem of curriculum study is the gap between our ideals and our attempts to operationalize them (p.3)

It is one thing to have clearly defined educational aims, but translating them into effective educational arrangements and practices which actually results in the attainment of these aims is, to use an old English metaphor, "another kettle of fish". Furthermore, in the practical context, as Prosser (4) points out:

> …it is not the way we teach and design our courses that relate to the student learning experience and outcomes, but the way students perceive the teaching and the courses. (p.39)

This is not to say that many teachers are using unsound pedagogies in the way they construct courses, design teaching strategies and organize learning environments. Indeed, we have come a long way in terms of understanding human learning and its implications for learning design and teaching approaches. For example, Marzano (5) argued that:

> …over the past 3 decades, we have amassed enough research and theory about learning to derive a truly research based-model of instruction. (p.2)

More recently, Darling-Hammond & Bransford (6), from surveying the research findings, concluded that:

> There are systematic and principled aspects of effective teaching, and there is a base of verifiable evidence of knowledge that supports that work in the sense that it is like engineering or medicine. (p.12)

However, while there are certain universal core principles of learning that underpin sound pedagogy, they are always mediated by the dynamics of the situated context in which learning occurs. Apart from a whole range of structural features (e.g. physical environment, resource availability, time of day, etc), there are the more ubiquitous processes of human personality, motivation and individual competences of the learners themselves. In most basic terms, while we can talk about the learning context in general terms, at the individual level it is essentially the subjective experience of each individual that is most important in learning. Hence in any classroom context, the experience of teaching will be mediated by each individual's beliefs, motivations and situated perceptions. As Prosser et al (7) suggest:

> Experience is seen, not as a stable entity in cognitive structure, but as a dynamic entity relating the individual to the context in which he or she is situated. (p.51)

Csikszentmihaly's (8)framing of the human mind is an interesting one in this context:

> Contrary to what we tend to assume, the normal state of the mind is chaos (p.119).

Such a view of human consciousness is also shared by Pinker (9) who asserts that:

> Behavior…comes from an internal struggle among mental modules with differing agendas and goals (p.40).

In that students are making individually situated meaning out of the learning contexts in which they find themselves in, the outcomes of this process are highly significant for what teachers are trying to achieve. Glasser (10) illustrates this in stark terms when he argues that:

> No teacher will successfully teach anyone who does not have a picture of learning and those who try are doomed to failure (p.41)

If students do not find personal meaning or relevance to what is occurring in a particular learning context, they simply may not pay attention or the attention will be sporadic and poorly focused. The consequences are as Sylwester (11) identifies:

> It's biologically impossible to learn anything that you're not paying attention to; the attentional mechanism drives the whole learning and memory process" (p.6)

METHODOLOGICAL APPROACH

The methodological approach used in this research is within a broad qualitative paradigm, emphasizing the following key characteristics of qualitative research in that:

- The focus is on the description, understanding and interpretation of human experience in situated contexts (e.g., in this case, student's experience of teachers teaching specific skills)

- Those who are studied are to speak for themselves, to provide their perspectives through personal stories in their own words.

Within this broad paradigm, phenomenography was the main research approach employed. Phenomenography is concerned with describing qualitatively different ways (and the variation involved in these different way) in which people experience, understand and make sense of the kinds of phenomena in the world around them. While people make sense of the world based on prior experience and selective perception, etc, our common human apparatus and need orientation typically results in shared ways of experiencing the world. Indeed, without this commonality, the inter-subjectivity of everyday life would be even more problematic than it is already. Marton (12) argues that:

> …we have repeatedly found that phenomena, aspects of reality, are experienced (or conceptualized) in a relatively limited number of qualitatively different ways. (p.181)

In the context of this research, the purpose was to describe, understand and interpret the ways in which students experienced the teaching of selected CDIO skills and how they went about their personal learning of them. Within the wider evaluation context, this was to identify the impact of specific curricula changes brought about by the redesign and their potential worth in terms of enhancing the quality of student learning.

Data was obtained by means of focus group interviews, drawing from a sample of 55 students. The use of a focus group was employed for the following main reasons:

- Enables the collection of data relatively quickly from a larger number (as compared to individual interviews) of research participants
- Provides a more naturalistic context than the individual interview in that it is closer to the everyday conversations that people typically participate in
- As a synergistic effect in that it allows participants to react to and build upon the responses of other group members, producing richer accounts of the experience being investigated.

The typical focused group interviews lasted around 1 hour, using the following broad structure:

- A standard opening scenario is presented to the students (e.g. have you experienced x; what does x mean to you; how have you responded to x; why did you respond to x in this way?)
- No new features are introduced – only encouragement to students to explain and provide examples
- Clarification of meaning and checking understanding where appropriate.

The data analysis involves careful reading and reflection on the original transcripts from the focus group interviews with the aim of finding stable generic categories of description (note these are formed out of an aggregate of similar perceptions, not any one perception as such). As Green (13) notes:

> ...the meticulous construction of categories can be framed as a particular kind of collective reflection, a particular way in which shared meaning is created (p.58)

Modifications to the typical phenomenographic approach were employed to enhance method use where appropriate. Firstly, some students (e.g., those who volunteered) took on the role of "co-participants", a term borrowed from Lincoln (14), as they were interested in the research and what it might produce (e.g., improve their and subsequent students learning experience). I felt that this might add motivation to participate in the research activity as well as encourage openness in response behavior over time through rapport building. As the evaluation is longitudinal and may continue over the next 2-3 years, this was felt to add richness and depth to the evaluation. Secondly, certain data analysis principles were incorporated from the grounded theory approach of Glaser and Strauss (15). Most significant was the checking of conceptual understanding with co-participants to ensure that the categories of description were accurate representations of their experiences.

EMERGING CATEGORIES

At present, 4 focus group interview sessions have been conducted, involving 33 of the total 55 co-participants. All co-participants initially provide their individual experiences relating to learning the CDIO skills, until 'theoretical saturation' is attained (at least in that situated context). Once this has been completed, students are invited to share other experiences relating to their learning that they feel may lead to improving student learning generally in the wider polytechnic context.

In the context of this research so far, the following findings are most pertinent.

1. Variation and similarities in constructs of good thinking

The student response to the question, what is 'good thinking', suggests significant variation in constructs relating to what thinking is and what is good thinking. The following examples of student responses illustrate this variation:

> "conscious mind, a good amount of reasoning"
>
> "using the mind like a freight train with a checklist
>
> "logically, systematically and creatively to solve problems"
>
> "thinking in positive and optimistic ways

However, through more detailed exploration, two findings are becoming apparent:

- Student prior learning (including the impact of the explicit teaching of thinking) plays a significant role in their present framing of what is good thinking. For example, from the wider evaluation evidence, it is clearly the case that some staff explicitly teach the components of good thinking (e.g., specific types of thinking, dispositions relating to good thinking, etc). It may well be that this is resulting in some students using these models and incorporating the 'language of thinking' into their descriptions. In contrast many staff do not teach thinking explicitly. This may be related to less formalized and tidy constructs of what is good thinking.

- While there is variation in the ways students express their perceptions and experiences relating to thinking, their responses, when asked to illustrate, reveal typical and universal aspects of the way the mind works in relation to solving problems and living in the world.

For example, certain key dimensions are emerging that are consistent with the vast range of literature in the field:

- There are different broad, though related, types of thinking (e.g., critical and creative)
- There are a range of more specific types of thinking (e.g., analysis, comparison and contrast, inference and interpretation, evaluation, generating possibilities, etc)
- Thinking is affected by other human attributes (e.g., perseverance, optimism, etc)
- Thinking has internal organization (e.g., conscious self-directed activity is important in good thinking – whether it be systematic, or 'thinking out of the box')
- Thinking involves making connections with knowledge.

2. The impact of teaching on shaping the subjective experience of learning

A major finding from the interviews confirms the powerful impact that individual lecturers make on the ways in which students experience their learning in classrooms, irrespective of subject context. While, there is agreement among students that some subjects are "drier" than others, how the lecturer teaches (the types of strategies used, human conduct, etc) significantly impact attention, subsequent forms of engagement and learning, and the learning approaches adopted. While many factors influence student learning orientation (e.g., prior experiences, motivations, etc) there is much in the situation that can impact what is learnt and how, and most importantly, teachers are the most significant agents in the construction of these individual student experiences. This is consistent with an increasing body of research, which highlights the high level of effect that individual teachers have on student learning and attainment. For example, Izumi & Evers (16) point out

> …nothing is as important to learning as the quality of a student's teacher. The difference between a good teacher and a bad teacher is so great that fifth-grade students who have poor teachers in grades three to five score roughly 50 *percentile points* below similar groups of students who are fortunate enough to have effective teachers (ix)

Similarly, Rivers & Sanders (17), document:

> The effect of the teacher far overshadows classroom variables, such as previous achievement level of students, class size…heterogeneity of students, and the ethnic and socio-economic makeup of the classroom. (p.17)

IMPLICATIONS FOR TEACHING & LEARNING

The importance of understanding how students are experiencing aspects of our courses and teaching has significant implications for the enhancement of practice and the possibility of helping students to be better learners. As in any human performance activity, there are better and worse ways of doing things – some ways are even dysfunctional to the performance. This applies equally to the process of learning. As Prosser and Trigwell (18) point out:

> …there are better and worse ways for students to approach their learning – a deep approach being better than a surface approach (p.7)

Given that student approaches to learning are based on the prior experiences and perceptions of their situation in a learning context, the challenge for teachers is to create learning experiences that encourage – even demand – better approaches to learning. This is certainly possible as Prosser and Trigwell (18) argue:

> …approaches to learning are not stable characteristics of students. Students *approaches* to learning do change with changes in perception of their learning situation and their perception of it can be changed by…teachers. (p.83)

While we can never design learning experiences that are going to get desired results with all students, we are in a position to inform practices based on a better understanding of our students experiences and the meaning they are making of their time in our classrooms. In terms of a broader approach to pedagogic practices, we can move to a position where we can draw both upon an increasingly empirical base of knowledge about human learning, as well as the situated realities of the student we teach, in improving the quality of student learning outcomes. As Marton (19) suggests:

> It is only when we have a fair understanding of what learners are expected to learn, what they actually learn in those situations and why they learn something in one situation but not in another that pedagogy becomes a reasonably rational set of human activities. (p.22)

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EXPERIENCES FROM A MULTI-CULTURAL DESIGN, BUILD, TEST PROJECT

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ABSTRACT

To train students and prepare them for industrial projects, where two key elements are communication and planning, we expected a Design, Build, and Test (DBT) project would use available staff efficiently and at the same time give the students a multi-disciplinary view on embedded system development, which is difficult to give in our normal curriculums.

The students taking part in the project have varied cultural background. The project has been given two times and we report our experiences from running the project and trying to adapt it based on experiences from the first time.

Identified key experiences are: it is difficult to motivate the students to work independently in the project, it is difficult to communicate what is a successful project (i.e., the focus should be on how the group is working and not on technical solutions), and model-based development.

KEYWORDS

DBT project, fellow student assessment, multi-cultural project

INTRODUCTION

At School of Engineering, Jönköping University, Sweden, a 2 year Master's programme in Embedded Systems is given. The programme is designed based on the CDIO Syllabus (1). Admitted students should have an undergraduate degree in electrical engineering that corresponds to a Bachelor degree. The admitted students have varied educational background, as well as varied cultural background. The students come from north Africa, middle East, east Asia, Europe, and north America.

As part of the programme is a linked project (2) where the course work of two concurrent courses are joined and merged into a Design, Built, and Test (DBT) project. The two courses are Mechatronics and Software Engineering. Mechatronics and Software Engineering constitute two key competencies that are needed in many industrial projects in the embedded systems area.

Designing a project around the development phases design, build, test is not uncommon, and experiences of such activities have been reported elsewhere (3) (4). In this paper, we

discuss our experiences with executing such a project with students from many different backgrounds.

By using a linked project of the two courses, we feel that the following from the CDIO Standards (3) are addressed: Standard 3 Integrated Curriculum, Standard 5 Design-Build Experiences, Standard 6 CDIO Workspaces, Standard 7 Integrated Learning Experiences, Standard 8 Active Learning, Standard 11 CDIO Skills Assessment.

In the DBT project work, the students were grouped by the supervisors and then the groups worked independently with product development. The supervisors gave the groups written requirements of two products, where the groups should develop the software for these products.

The DBT project has now been given two times. Based on our experiences from the first round, we made adaptations to the DBT project. Some of the adaptations addressed issues that we believe originates in different learning cultures of the students. We report our first time experiences and the experiences from the second round in the paper.

The conclusions of the paper are that (i) it is hard to make some of the students work independently and creatively with a problem (this may be due to educational culture in their undergraduate studies), (ii) the question 'when is a DBT project successful?' must be well communicated with the students before and during the project, and (iii) working with model-based development of controllers requires a physical system where it is possible to determine control parameters within a short time frame (the project is run during 10 weeks).

The outline of the paper is as follows. The setup of the DBT project is given in Section PROJECT DESCRIPTION. The experiences from round one is described in Section EXPERIENCES ROUND ONE. Section ADAPTATIONS FOR SECOND ROUND discusses the changes that were made for the second time the project was given. The Section EXPERIENCES FROM SECOND ROUND discusses our experiences from applying the adaptations. The paper is concluded in the Sections DISCUSSION and CONCLUSIONS.

PROJECT DESCRIPTION

Project Setup

As described in Biggs' 3P model (4), it is important to reason about teaching and learning before and during such activities, but also what is the learning product of the activities. Biggs also describes two student types; the Susans that are highly motivated deep learners and the Roberts that are less motivated surface learners. The teacher can be on three 'maturity' levels (i) blaming the student, (ii) what the teacher does, and (iii) what the student does.

We strongly believe that taking an approach of continuous development of courses and choosing a teaching approach that suites the subject best, helps making less motivated surface learners more motivated, and hopefully deep learners. The DBT project being discussed in this paper constitutes the practical course work of the two courses Mechatronics and Software Engineering. A project work is well suited for Software Engineering as this course teaches development processes, and Mechatronics touches upon many problem areas that are relevant for a programme in embedded systems.

Our goal with the DBT project is for students to (i) familiarize themselves with a product lifecycle and a systematic approach to working with (software) development, (ii) reason about their own performance in a bigger context, and (iii) understand the need to plan the work and the benefits to reason early about architecture and design. The systematic development approach should also contain a model-based approach to development.

Thus, we should consider the DBT project to be successful if the students have been able to work according to a systematic development process and reflect upon the successes and failures of the group's performance.

The project task is for each student group to develop and deliver two products:

1. A software for a control equipment that can control a pendulum system such that the pendulum is balanced in a hanging down or inverted position.
2. A software that shows the real-time position of the pendulum system. The software should also be able to log pendulum positions to a file and later play these back.

The courses are taught concurrently during one segment of 10 weeks. The courses constitute 400 effective hours together and 40% of the time should be allotted to the practical course work, i.e., 160 hours. Thus, each student is expected to put in approximately 160 hours of work in the project.

As the curriculums are formulated, each course is supposed to have an individual grading, which usually is based on a written examination. The practical course points of each course have only the grades pass or fail. However, we feel the project so important for the learning of the students, that we wanted each student's performance be reflected in the course grades. We achieved this by fellow student assessments and grading of each group's performance based on each artefact they delivered. The grading is discussed further below.

The students were randomly grouped into project groups of 5-9 students by the supervisors. The reason such a grouping method was used was to simulate that you seldom, in industrial projects, have the possibility to select your own colleagues.

The theoretical knowledge necessary for carrying out the project work was given in the theoretical parts of the courses. The Mechatronics course teaches

- Control theory
- Sensors
- Actuators

Software Engineering course teaches

- Software development processes
- Roles
- Risk management
- Software requirements elicitation
- Software architecture and design
- Software testing

The supervisors prepared written requirements of two products that each group should deliver at the end of the project. The supervisors also required deliverables in the form of documents and presentations during and at the end of the project. Documents were (i) artefacts of the project work and (ii) individual documents concerning the learning outcomes. Examples of the first kind are software requirements specification and software test report. Examples of the second kind are self reflection and fellow student assessment.

Each submitted document and given presentation was graded by the supervisors. The first few artefacts could be resubmitted if the group wanted to address comments and get a higher grade.

Two pendulum systems with electronics hardware enhancements were available at project start. The enhancement is an FPGA that converts angle and position sensor signals to a form readable by a National Instruments I/O card. Furthermore, the FPGA can also communicate the sensor readings to an LPC 2294 board using SPI. The following sample code was given at project start:

- C code implementing real-time operating system with tasks reading sensors using SPI. The sensor readings are also transmitted to a PC using RS232.
- Simulink project reading sensor data from National Instruments I/O card.

The project groups choose a development process and they defined different roles that were allocated to different group members. Moreover, each group also created and maintained a project management document including time plan and risk management.

Grading

Each group's performance was derived by taking a weighted average of all graded artefacts they delivered. Since quite a few documents and presentations were prepared and given, each student has been involved in at least one document and presentation. Thus, we believe that the average quite well matches the overall performance of the group.

Each student was also requested to do a fellow student assessment, where they graded all students in their group. The average grade of a student's assessment should be 60 on a 0 to 100 scale.

EXPERIENCES ROUND ONE

Specifics of project setup

The first time the DBT project was given was January to March 2008. 16 students followed the Master's programme in embedded systems. 6 students were exchange students only taking the Software Engineering course, and the groups with these students were instructed to allocate half the workload to these students. In total three groups were formed of 6-9 members each.

The following deliverables were required from each group:

- Project management document (2 submissions)
- Software requirements specification (2 submissions)
- Software architecture for embedded control software
- Software design for embedded control software
- Software test specification for embedded control software
- Software test report for embedded control software
- Software architecture for GUI
- Software design for GUI
- Software test specification for GUI
- Software test report for GUI
- Software requirements tracing document
- Hand-over documentation describing how someone could setup development environments
- Presentation of project management
- Presentation of architecture
- Presentation of products

The groups split the work by defining several roles, typically project manager, architect, designer, implementer etc., and constructed a time plan outlining the work of the group. Each group was supposed to have one meeting every week where its assigned supervisor attended.

The groups were supposed to use model-based development by first modelling the pendulum system using Matlab/Simulink followed by a design of a controller. This controller should then be transformed to the embedded control software and implemented in C code.

Experiences

Several problems occurred during the project as described below.

- The students have significant differences in both cultural background but also learning background. Some students where high performers (deep learners) with a high level of independence and creativity, while others seemed most accustomed to follow instructions (surface learners) and did not have a high level of independence and creativity. We believe a DBT project can suite both 'learning styles' and the high performers excel and train the others in being more independent and creative. However, it must be enforced that the high performers do not do the work of the others.
- Connected to the above bullet, we also observed that there is a large difference in students' preconception about embedded system development in general and specifically software development. All aspects of software development cannot be covered in detail in the Software Engineering course, which means that the students must be motivated to try to do some read up on their allocated role's tasks by themselves. Moreover, the students may also need to read up on technical details by themselves. This is a good opportunity for them to get experience in such activities as they are expected to be able to work independently in industry and in their master's thesis.
- All groups were unable to construct a model of the pendulum system that was usable for constructing a controller that could work with Simulink in continuous time with the National Instruments I/O card. The students understand the concepts behind constructing a plant model and connecting a controller to it, but problems seem to be related to difficulties in determining plant parameters.
- All groups were significantly delayed with implementation of the embedded control software. This is because the groups focused on deriving a correct model before looking at and trying to use the embedded software development environments. Therefore the deadline for product delivery was extended by one month.
- Related to the above bullets is that everyone expects a person having a master of science degree to be able to understand the context of a problem, divide it into subproblems, and work on the identified subproblems until the problem is solved. Our experience is that students, even though studying on a master's programme, are unable to perform a systematic way of solving a larger problem. Students' learning background has thus been lacking in giving them experiences in understanding a larger context and identifying subproblems. The DBT project as such, is a way to mitigate this, but as the project is given in a limited amount of time, a certain degree of independence at project start is needed. Perhaps the students need to be prepared better in courses given before the project.
- The vast amount of documents each group was supposed to prepare also seems to have delayed the work on the solutions. This, however, is not a problem per se, as the purpose of the project is to work in a systematic way with product development.

- The documents, all with a deadline, forced the students into working in a waterfall like process since the documents should be delivered in the order specifications, architecture and design, test specification, and test report.
- The question 'when is a DBT project successful?' is important and it happened that both some supervisors and the students felt the DBT project was partially a failure. The students found the project a failure because they were not able to deliver a working implementation. However, course evaluations show that the students liked the idea of working systematically in a setting simulating an industrial project. Some supervisors found the project a failure because they felt there was a too big focus on imposing a certain workflow on the students (waterfall process model including the documentation).
- Some students seemed uncomfortable in assessing each other's performance and being assessed. We believe this is due to a cultural background where they are not used to being assessed by fellow students.

As can be understood from the list above, many of the supervisors' perceived problems stem from students' motivation and learning style (deep or surface).

ADAPTATIONS FOR SECOND ROUND

Based on the experiences acquired during the first round of the DBT project, several changes were made to the project setup. The changes are described in the bullets below:

- Independence and motivation: based on our experiences from the first time the project was given, we are concerned that students may not be working with their allocated tasks for the following reasons (i) they are not accustomed to working independently, and/or (ii) they have other motivations than studies to move to Sweden and have therefore less motivation to spend the necessary time to work in a project, and/or (iii) they do not have the background to work with the task and they are not trained in independently finding information and read up on the subject using the found information. The problem of motivating students is thoroughly discussed by Biggs (4). Since the supervisors have relatively little insight how the work is actually performed by the group, we choose to address this by simulating industry where each group had to set up a time reporting process and each member had a limited number of hours to put into the project. Furthermore, each group must include the risk 'student is not doing allocated tasks' in the group's risk management. The idea being that the students would motivate each other to do their allocated work.
- When is a DBT project successful?: as stated in the section above, some supervisors did not feel the DBT project was successful due to the focus on documents and the development process the delivery of the documents enforced on the groups. Thus, the amount of documents that needed to be handed in was reduced. Also, some new deliverables have been introduced: presentations of working subsystems. Our idea is that a smaller number of documents may give students a bit more time to focus on solving the problems and the focusing on delivering working subsystems would enforce an iterative development process. Modern software development processes, e.g., agile methods, are iterative.
- Model-based development: by showing the students, and motivating them to use, Matlab/Simulink for plant modelling and control algorithm construction, we hoped the students would get an idea how model-based development works in practice. As we reported in the section above, this was a failure since the students never succeeded in deriving control algorithms that worked. We therefore reformulated the problem to reducing the oscillations of a disturbed free hanging pendulum. It should be easier to find parameters of a free hanging pendulum than the inverted pendulum, since the system is more 'forgiving'.

We have not adapted the grading scheme as we felt it worked well the first round.

EXPERIENCES FROM SECOND ROUND

Project Setup

The second round started in January 2009 and ended in March 2009. The supervisors prepared a new set of documents with the requirements of the products and the subsystems that should be presented during the project.

The deliverables requested from each group during second round are listed below:

- Project management document (2 submissions)
- Software requirements specification (2 submissions)
- Software test report for GUI and embedded control software
- Hand-over documentation describing how someone could setup development environments
- Presentation of project management
- Presentation of model of free hanging pendulum and of software for control of free hanging pendulum
- Presentation of products

There are 18 students and they have been divided into three groups of 6 members each by the supervisors. When the courses start, the groups are supposed to decide on a development process, define roles, assign roles to group members, start planning the work in a time plan, and also start the risk management.

The project groups were supposed to be working in the same way as in round one where a model should be developed for the plant and then a controller should be constructed and simulated.

The presentations were scheduled to be given 3 and 5 weeks into the project, and at the end of the courses. We hoped that these subsystems that should be ready would help the groups to focus on smaller parts of the problem so that they would not be as delayed as in the previous round.

Experiences

First we discuss what problems occurred during the second round and then we relate them to the adaptations that were introduced.

- The independence issue arose again. The problem seems to be accentuated during the second time the project was given.
- The groups were again unable to derive working controllers even though the free hanging pendulum should be more ‘forgiving’ when it comes to parameters of the controller.
- The groups were unable to stick to their time plans, which was expected. However, as in round one, the groups were very focused on getting a working plant model and controller, which hindered their progress in other activities even though they had planned independent activities. We do not know if this behaviour boils down to pure stubbornness or due to learning background, but since it has happened twice now, we start to believe it is learning background related. This means that the students are lacking in experiences in dividing a problem into subproblems and working on these independently.

- It seems, paradoxically, that the reduction of documents made it a bit harder for the students to clearly see the benefits of a systematic development approach. A systematic development approach would 'reduce' the effects of cultural and learning background differences.

The adaptations for the second round were in the areas independence and motivation, 'when is a DBT project successful?', and model-based development. Below we discuss how the adaptations worked out.

- Independence and motivation: the supervisors feel a higher percentage of the students are not serious about the project during the second time compared to the first time the project was given. The groups should include the risk 'student is not doing allocated task' and use a time reporting process. The following were observed during the project.
    - The groups misunderstood the formulation and never monitored the work of the project members. If the group allocated a task to two or more group members, all of them should try and contribute equally and not rely on one of them to deliver, since the project is given in the context of a learning activity. The supervisors observed that it occurred during the project that if two members were supposed to do a certain task, only one of them did the work.
    - On direct questions to the project leaders how the members were doing with respect to worked hours, the answer was always that the members worked according to allocated hours. This is very unlikely, as some tasks must have taken longer or shorter amount of hours. Our interpretation is that the group members covered for each other, and that it was accepted that some members worked less than others. We believe that some of the students were working part time and prioritized the paid work over the project work. In the fellow student assessment some students got low assessments, which we think reflected the fact that some students did not do their allocated work. We also noted that for some students it was very difficult to confess that they could not do a specific task or did not put in the number of hours requested. We believe this is partly culturally affected, since in some cultures one cannot lose face.
- When is a DBT project successful?: since there were few deadlines during the project for documents to be submitted, no particular development process was enforced upon the groups. However, the presentations the groups were supposed to give gave a small focus on iterative and incremental development. It seems the students realized this. Removing some documents ended up in that some parts were not documented at all; removing the software architecture document gave the effect that no formal software architecture was developed before the software started to be implemented. There is thus a trade off how much documentation should be part of a course like this.
- Model-based development: as mentioned above, the groups were unable to construct working controllers also the second time the project was given. In order to have meaningful tasks for all roles, most notably the testers, the supervisors prepared a fuzzy logic controller implemented in C code that almost worked in the inverted pendulum case. This code was distributed to all groups and they could manipulate it for the free hanging pendulum case and the inverted case.

DISCUSSION

The DBT project has enabled the students to reason about embedded system development, working in teams, and project management.

For the Software Engineering course lectures, the experiences the students acquire in the project during the project are valuable and can be used as a common shared understanding where new concepts can be introduced. However, this means that some lectures inevitably need to be prepared solely for each time the project is given since the preconditions, e.g., encountered problems by project groups, may be different from time to time.

The anticipated, by the supervisors, main problems in giving the DBT project as a learning activity are

- Give the students the conditions to execute the project as a learning activity, because the students have so different cultural and learning backgrounds, and many of them do not have the background skills in designing computer programs and implementing them.
- Motivate the students to work independently with allocated tasks since, as it seems, some of the students have other motivations to move to another country than to study. Many of the students need to work to finance their studies, which may have a negative effect on the involvement in a time consuming project.

CONCLUSIONS

Before starting the project the second time, several changes were made to the project setup. One change worked out for the better, namely, reducing some documents the project groups have to submit as this reduces the effect of a specific process (the waterfall process) on the project group's work.

The main problem, which has not been solved by our adaptations, is motivating the students to work hard in the project and independently on their allocated tasks.

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EXPERIENCES OF AND IMPROVEMENT OF WRITING SKILLS IN A LECTURE BASED COURSE IN POLYMERIC MATERIALS

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ABSTRACT

This paper aims to describe the development work done regarding the project Topic to Study (TTS) which intends to enforce written communication skills while simultaneously improving student working knowledge. TTS is a part of an ordinary lecture based master level polymer course assessed by a written exam; points earned from TTS are added to exam points and typically constitute 10% of total. It is a learning experience where, early in the course, participants are offered a range of topics to choose from. These are slightly more specialized than the course content and the students are expected to find the relevant information by the use of scientific literature and write a very short academic report. The improvement was made on the basis of faculty experience, course evaluations 2001-2008, programme goals, best practice from within the CDIO initiative as well as pedagogical research. Firstly, new ***outcomes*** for the project were stated. Secondly, ***assessment criteria*** were formulated and handed out to students to be brought to bear on the report. The criteria contain aspects of the technical content as well as aspects of academic writing and oral presentation. Thirdly, ***actions regarding teaching approach*** necessary for faculty to take on were identified concerning clarity and transparency in assessment and feed-back, specifically in order to strengthen the outcomes regarding critical thinking and judgement. Finally, the experiences from the development were written in a more generic manner and gathered in a ***guide***, to be used by any faculty member, within the master programme or outside, wanting to perform a writing project in a traditional lecture based "knowledge transfer" course.

KEYWORDS

CDIO, development, written communication skills, write to learn, best practice

BACKGROUND

The reasons for students to perform a writing project in an engineering course are manifold. Basically there are two main aspects. Firstly, the students can be ***writing to learn***, using the process of writing to achieve a deeper working knowledge. The result is often positive even if it is claimed that the actual cognitive process is complex; even though since long studied,

more knowledge is probably needed to fully understand the these processes [1]. Secondly, it can be claimed that the students are ***learning to write***, learning the skill of writing in the disciplinary context. The CDIO-concept stresses the importance of integration, as pointed out in CDIO standard seven; Integrated learning. This means that communication skills are to be trained in the engineering context, which is clearly stated to be of pedagogical benefit [2,3]. The possible benefits are more; Brew [4], for instance, claims the importance of bringing the students into the research paradigm. She suggests a new model of relationship between teaching and research which replaces the concept of scientific discipline by academic communities of practice where teaching is student-focused, concentrating on conceptual change within a learning milieu intertwined with the research milieu. The students can be regarded as apprentices.

Even though there are many benefits with writing projects there are some issues to regard. As with all learning experiences it is important to be aware of the intended learning outcomes, design an appropriate support to facilitate learning and make sure that assessment is constructively aligned [5]. It is not uncommon that students experience writing tasks in engineering education set up without support or formative feedback or with intentions and assessment unclearly described. It is clear that support to faculty on integrating generic engineering skills, like communication skills, have the potential to improve learning further. According to the number nine and ten of the twelve CDIO standards, possibilities for faculty to develop their competencies is something that is important in a CDIO-inspired environment [2]. As a part of the continuous competence development, faculty could also actively share their experiences and practices with each other.

This paper aims to describe the development work done regarding a writing project performed within an advanced level polymer course. More specifically the remainder of the paper is structured as follows:

- The TTS project, prior to development, is described in more detail
- The process of change is described starting with a chapter on analysis regarding teaching, learning, course evaluations 2001-2008 as well as TTS outcomes in relation to the CDIO-based programme goals. This is followed by a presentation of the new changes to improve the learning.
- A short evaluation is made of the first year of implementation of the reformed project
- A more generic teaching aid package developed on the basis of this specific project is presented

THE PROJECT "TOPIC TO STUDY" (TTS)

The project TTS is performed in a course aimed at polymer education: *Engineering polymers (MPM080)* at Chalmers University of Technology. The course was previously given within a 1½ year international master's programme. Since 2007 and the change to the 3+2 (BSc + MSc) Bologna system, it is set within the master's programme Advanced engineering materials (MPAEM). This programme is international but also forms the last two years of the 5 year Swedish "civilingenjör"-degree. The "Civilingenjör" (MScEng) programme of mechanical engineering, which hosts the MPAEM, has undergone a complete process of change during 2000-08 into a CDIO-based programme, and the MPAEM programme started in the spirit of CDIO as described elsewhere [6]. However, the students are enrolled with their BSc degree from mechanical or chemical engineering, engineering physics, technical design, materials science, metallurgical or polymer engineering and have thus varying background in terms of CDIO-competencies.

The TTS project is part of a traditional lecture based course concluded by a written exam; points earned from TTS are added to exam points and typically constitute 10% of the total

amount of point needed to pass the exam. The module has been running since 2000 and is a learning experience, where early in the course; participants are offered a range of topics to choose from. These are slightly more specialized than the course content and the students are expected to find the relevant information by the use of scientific literature. The topics could be defined as:

- modern topics/trends in polymers research and/or industry e.g. “Polylactic acid - a polymer from renewable resources” or “Polymers containing nanotubes - a new generation of composites”
- fast lane advanced polymers e.g. “High-modulus polyethylene - a poor man´s Ferrari?”
- actual theories and characterizations e.g. “Free volume/PALS - what is the importance for polymers?”

The assignment is performed in groups of 3-4 students and the teachers supply coaching and feedback when asked for. The assessment is written and oral; the resultant literature survey is presented by means of a very short written report (700-1000 words) and a short oral presentation of only 5 min to the class at a mini-conference organized at the end of the course. The intention of having the report very brief is to give the students an opportunity to train on finding the essential knowledge, the most important out of a larger supply of information, and create short written and oral presentations common in an industrial engineering context. The limitations to the learning experience are set as follows:

- TTS is a polymer science and engineering exercise and not any other one. e.g., it is not a mechanics of materials exercise
- TTS can have various forms: e.g. compilation of existing knowledge
- TTS can include ethical/societal/environmental issues
- TTS shall report and briefly discuss
- TTS is not meant to be in-depth mini-publication
- TTS is not a report with innovative ambitions towards new business

The purpose of TTS from the beginning was to provide a learning experience that would give the students a possibility to view the core engineering subject from a new perspective. The students shall be able to go more into depth into the polymer discipline and deal with a selected research or engineering specific topic extending the course material though broadly connected. The project will provide motivation, variation in forms of teaching and professionally relevant outcomes of the teaching & learning process. For many of the students the project is a final, ‘crown’ activity in polymers education. As a result students will understand that the course is a ‘scientifically living platform’ a field where world-wide research takes place at cutting-edges. Particularly important intended learning outcomes identified from the beginning was individual research thinking, introduction to scientific papers and more reading, building up on scientific platforms, witnessing that scientific progress is achieved with ‘tools’ discussed in course as well as presentation and listening, critique and feedback.

EVALUATION OF THE TTS PROJECT

Over the years faculty experience has been that the TTS project works out, the students do their writing at the expected level of proficiency and there are no complaints. However, as all learning activities often have a potential for development, it was supposed that a thorough examination concerning alignment of learning outcomes, assessment and activity would improve the project.

From the students' point of view the learning experience was found to be satisfactory but the course evaluations showed that students over the years grade TTS to be slightly less rewarding compared to the course on the whole and not fully reaching the intended learning outcome "to bring the students further into the world of polymers", see table 1. It has to be noted though, that the questionnaire item on TTS is not strictly asking for evaluation of the activity. In addition, TTS was subjected to remarkably few comments. While students often had various comments on the course, they did not comment on TTS (the only comment ever made was that more time (>7 min) should be allocated for presentation of TTS. It is still not clear why this project work raised so few comments. It is a demanding experience in terms of time spent and the scientific literature is different from the usual text books.

Table 1
Results from course evaluations 2001-2009 regarding TTS and the course on the whole

Year	Question: *Has TTS brought you further into the world of polymers? (% of all replies)*			Question: *Would you recommend the course to other students? (% of all replies)*		
	Yes	Hesitant	No	Yes	Hesitant	No
2001-2002	46	46	8	63	31	6
2002-2003	62	34	4	76	24	--
2003-2004	43	43	14	43	43	14
2004-2005	57	21	22	62	38	--
2005-2006	55	45	--	100	--	--
2006-2007	78	5	17	83	13	4
2007-2008	73	20	6	80	6	13
Afterwards						
2008-2009	70	20	10	90	10	---

From the point of view of programme curriculum and goals, the TTS experience addresses several of the important generic skills pointed out in the CDIO syllabus. During the design and implementation of the MPAEM curriculum 2006, specific emphasis was placed on considering CDIO-based programme goals, formulating course learning outcomes and ensuring integration of personal and interpersonal skills [6]. The resultant programme goals are shown in appendix A. As part of the continuous curriculum development it was also seen as important to investigate whether it was possible to improve the TTS project.

Evaluation of the TTS in context of the above programme goals showed that specifically five were addressed to some extent by the TTS namely, 2.4, 2.5, 2.8, 3.1 and 3.3:

1. create, analyse and critically evaluate different technical solutions
2. critically and systematically integrate knowledge and predict and evaluate material behaviour and events, also with limited or incomplete information
3. communicate, in a dialogue, their conclusions and the rationale underpinning these, to both specialists and non-specialists, nationally and internationally, based on fundamental concepts, results from material characterisations or theoretical predictions
4. formulate judgement concerning selections of materials or development of new materials that include reflecting on scientific, social and ethical responsibilities and to demonstrate awareness of ethical aspects on research and development work
5. draw conclusions showing insight into the possibilities and limitations of materials science, its role in society and the responsibility of humans for its use, applying social, environmental and ethical considerations

The first two goals concern the technical aspects of TTS; it might involve analysis of technical solutions or techniques used in materials science or predict or evaluate materials behaviour in a specific setting. The third concerns the actual communication part, technical writing and oral dialogue, with an audience of peers from an international community. The fourth and fifth goals are both not purely technical but intertwined with societal and sustainable aspects e.g. judgements, societal or ethical considerations

DEVELOPMENT OF THE TTS PROJECT

After evaluation different aspects of the TTS experience was improved; outcomes, teaching approach and transparency in assessment criteria. Based on the evaluation in context of the programme goals above, the following further limitations or requirements were formulated for the TTS:

- TTS report and presentation is an exercise to integrate the knowledge in the topic field
- TTS report should be based on published scientific results, may include ethical aspects, and students should comment on the importance of such research for the society
- TTS report and presentation should be constructed from fundamental concepts, results from material characterisation, theoretical predictions and the like
- If and when material judgement is involved then, generally, a reflection/awareness of scientific, social and ethical responsibilities is important. Particularly, such judgement would seem compulsory for novel materials in TTS. However, due to the shortness of the projects as well as likely inexperience in this matter, the team could include this discussion, but this is not a strict requirement.

Even though the programme goals mentioned above are met to a larger extent after the reform, it has to be noted that the outcomes for the experience are yet to be explicitly outlined as “the student should be able to..”.

In addition to clarify which learning outcomes that are addressed and the accompanying requirements of the project, considerate attention was placed on analysis of how the experience could become more appreciated and to a higher degree help to reach intended learning outcomes. In a previous CDIO-project students were interviewed regarding their learning approach and the results compared to pedagogic literature on surface and deep approaches to learning. The resultant “list of 10 requests from students” conveys a compact list of good ideas whereof “Make sure students know exactly what is expected of them. Produce explicit criteria for assessment” is one [7]. Foundation for Critical Thinking has developed guidelines for engineers to critically evaluate their own writing [8], and pedagogic research point in a direction that supports the idea of transparency in assessment would facilitate learning [9]. For TTS, clearer criteria for the students to follow were thus one of actions chosen. ***Assessment criteria*** were brought to bear on the TTS written report and oral presentation, where both activities were necessarily evaluated per team and not per individual student. The criteria contain both aspects of the technical content as well as aspects of technical writing. The following list was handed out to the students:

- is the material ‘on track’, clearly organized/structured and within limits? (number of words)
- is there an attempt made to integrate the knowledge in the topic field?
- is the work dealing with the topic using polymer science and engineering methods/platform?
- is the coverage of the topic field comprehensive and complete?

- has the group shown (some) knowledge of relevant literature and judged well in choosing the references? (titles of references must be given)
- do students comment on the importance of such research for the society?
- are conclusions included, and what is their quality in the report and presentation?
- are the authors rights to figures observed in the report?
- what was the graphical impact of the report and presentation?

In addition to the new outcomes and the criteria handed out to the students, several ***actions regarding teaching approach*** were taken in order to facilitate reaching the intended learning outcomes by the students. The basis for the actions taken was mainly experience from the previous eight years, where explicitly it was found important that the task should be set early in the course, as it was found to be of importance for students to finish the project in due time before the exam. In addition students need to know what they should expect, not expect, and experience partnership. The changes were again related to clarity and transparency regarding assessment and feed-back and specifically actions taken in order to strengthen the intended outcomes regarding critical thinking and judgement. The actions were gathered in a Guide, to be used in a more generic teaching aid package as described below.

DEVELOPMENT OF A MORE GENERIC TEACHING-AID

As a result of the work with TTS it was possible to develop an adaptable teaching-aid package, to be used by any faculty member, within the master programme or outside, wanting to include a writing assignment in a traditional lecture based "knowledge transfer" course.

As a way of improvement suggestions are proposed regarding (i) a change of course time plan, (ii) guidelines for teachers (*Guide)*, (iii) criteria for students (*Criteria)* and (iv) implementation/realization (*Outcomes)*. The main suggestions are as follows:

(i) to set the activity ***early*** in the course

(ii) Be inspired by the proposed teaching approach ***Guide in table 2***. Students need to know what they should expect, not expect, and experience partnership feeling among themselves and with lecturer. The guide contains advice to set clear expectations about the student´s writing and presentation, explicit guide on what you can or hope to provide for the supervisee as well as what is not provided. In addition some suggestions are given on how to improve partnership.

(iii) ***Assessment criteria*** are helpful to be brought to bear on the written report and oral presentation where both activities will be evaluated per team and not per individual student. We suggest to hand out the assessment criteria, also incorporating students' ability of critical thinking, to the students,.

(iv) The intended learning ***outcomes*** should include generic skills, derived from programme goals.

EVALUATION AFTER RUNNING THE REFORMED TTS 2008-2009

Faculty experience was positive, especially it was noticed that the general level of proficiency was greatly increased regarding both oral and written presentations. This was also noted by other faculty members in a parallel course.

Table 2
Proposed guide for faculty to use in implementation of writing assignments

GUIDE

Students need to know what they should expect, not expect, and experience partnership:

1. Set clear expectations about the student´s writing and presentation:

- number of pages/words
- when written work is expected
- date for oral presentation
- clarify that every member of project team will be presenting
- set date when feedback on written report and presentation will be ready
- clarify whether students should keep back-up copies
- inform if you plan to keep supervisory record (from the course of *TTS*, from presentation, from written report, from perhaps questions and discussions)

2. Be as explicit as you can what you hope to provide for the supervisee:

- methodological help
- structuring the report
- advice on the literature search
- theoretical ideas
- help with computing
- visits (if fieldwork is involved)
- hand-on help with equipment
- practical tips

3. Be as explicit as you can what you cannot or will not provide:

- *e.g.,* email supervision
- *e.g.*, language correction, stylistics and spelling

4. Elements of partnership:

- encourage training of judgement: *e.g.*, read each other's work
- ask for their critical opinion: *e.g.,* on the references they used
- reflect to students that likely they will face the need to 'sieve off' some omnipresent and ubiquitous 'noise knowledge' and this will help sharpening and making the report and oral presentation attractively terse
- more partnership, e.g., ask for a couple of suggestions towards next year topics

The course evaluation, see table 1, was somewhat disappointing, not showing any difference, but the overall evaluation of the course seemed to have slightly increased. The statistics of the course evaluation is uncertain though, since the ratio of students answering this year was much lower than usual owing to a change from paper to a computerized system. A positive sign was that 100% of the respondents graded the Assessment criteria as very useful. An

improvement for next year will be to formulate the intended learning outcomes more explicitly and in an active manner.

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We would like to express our gratitude to IMPACT at Chalmers, which sponsored this work.

CONCLUDING REMARKS

This paper describes the development work done regarding a writing project performed within an advanced level polymer course. Specifically

- It was found useful to express the limitations or requisites of the assignment and analyse from the aspect of programme goals in order to include appropriate generic skills in the intended learning outcomes. The evaluation after implementation seems to be positive.
- Assessment criteria were formulated and made transparent, handed out to students to be brought to bear on the report. The criteria contain aspects of the technical content as well as aspects of writing.
- Actions regarding teaching approach were identified. Explicitly it was found important that the task should be set early in the course, students need to know what they should expect, not expect, and experience partnership.
- A guide was proposed, gathering the experiences in a manner useful to faculty members

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Appendix A Programme goals; those met in the TTS project are marked in bold

Graduates should be able to independently and professionally participate in and manage projects concerning aspects of materials in conceiving, designing, implementing and operating products, processes and systems. They should also be able to independently and professionally participate in and lead industrial or academic materials research.

1. **KNOWLEDGE AND UNDERSTANDING:** Graduated students should be able to:
   - 1.1. attain a basis of deep disciplinary knowledge to be able to recognise and describe properties for metals and explain how these are coupled to the structure at an atomic as well as microscopic scale
   - 1.2. attain a basis of deep disciplinary knowledge to be able to recognise and describe properties for polymers and explain how these are coupled to the structure at an atomic as well as microscopic scale
   - 1.3. attain a basis of deep disciplinary knowledge to be able to recognise and describe properties for ceramics and explain how these are coupled to the structure at an atomic as well as microscopic scale
   - 1.4. evaluate and draw conclusions concerning different materials' fields of application based on knowledge of material properties
   - 1.5. explain how different processing methods can influence the structure of a material and whereby its properties
   - 1.6. describe and draw conclusions based upon the scientific foundation and proven experience of materials science as well as show insight into current research and development work
   - 1.7. demonstrate knowledge and understanding that is founded upon and extends the learning objectives for materials science, mathematics, applied mechanics, manufacturing technology and thermodynamics associated with bachelor's level
   - 1.8. *For Engineering Materials:* apply fundamental concepts concerning materials' behaviour at the microstructural scale in improving mechanical properties of the material, joints between materials or a resultant product
   - 1.9. *For Functional Material:* describe and discuss concepts concerning materials' electronic, optical and magnetic properties on nano- and microscale in applications where these properties are of primary interest
   - 1.10. *For Materials and Manufacturing:* describe and choose methods for machining and joining for different materials and discuss influence of different manufacturing parameters on materials' resultant behaviour on both micro- and macroscale
   - 1.11. *For Materials and Applied Mechanics:* compute and dimension for safety, perform simple simulations using constitutive models being aware of the differences in material behaviour, ageing, and failure on a mesoscopic and a macroscopic scale
2. **SKILLS AND ABILITIES:** Graduated students should be able to:
   - 2.1. critically, independently and creatively conceive, design, implement and operate products, processes and systems such as design of materials, materials selection, failure analysis and prediction of properties.
   - 2.2. describe, address applicability of characterisation methods and within given constraints plan and carry out qualified tests using e.g. hardness measurements, tensile testing, optical, scanning electron and transmission electron microscopy or X-ray, Auger or ESCA analysis
   - 2.3. participate in research and development to create new knowledge and develop originality in ideas.
   - ***2.4. create, analyse and critically evaluate different technical solutions***
   - ***2.5. critically and systematically integrate knowledge and predict and evaluate material behaviour and events, also with limited or incomplete information***
   - 2.6. consider relevant scientific, societal and ethical aspects fulfilling human needs and the society's goals for sustainable development in the context of materials science
   - 2.7. work with projects in a group, solving open problems while being aware of different stages in project work and group dynamics
   - ***2.8. communicate, in a dialogue, their conclusions and the rationale underpinning these, to both specialists and non-specialists, nationally and internationally, based on fundamental concepts, results from material characterisations or theoretical predictions***
3. **FORMULATION OF JUDGEMENT AND ATTITUDES:** Graduated students should be able to:
   - ***3.1. formulate judgement concerning selections of materials or development of new materials that include reflecting on scientific, social and ethical responsibilities and to demonstrate awareness of ethical aspects on research and development work***
   - 3.2. demonstrate insight concerning consequences for manufacturing, product behaviour and environmental load during the full life cycle
   - ***3.3. draw conclusions showing insight into the possibilities and limitations of materials science, its role in society and the responsibility of humans for its use, applying social, environmental and ethical considerations***
   - 3.4. identify their need for more knowledge, and to continuously develop their competence

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EXPLORING DIFFERENT FACULTY DEVELOPMENT MODELS THAT SUPPORT CDIO IMPLEMENTATION

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ABSTRACT

This paper describes different models of faculty development in engineering from five higher education institutions that support CDIO implementation. It is interesting to see that although geographically dispersed, these institutions express a strong consensus that it is necessary for faculty to be trained in educational methods. The five models encompass many similar characteristics that are in line with a fundamentally sound faculty training programme. They all share the basic activities one expects to find within a faculty development facility. That said, each model has built its unique functioning structure which sets it apart, particularly in the nature of the programme, and the format delivery takes place. These differences are most likely related to national policies and legislations, as well as to cultural or historical reasons. The paper also discusses the pedagogical training and support given to faculty implementing CDIO.

KEYWORDS

Faculty development models, pedagogical support, teaching skills

INTRODUCTION

Many engineering programmes worldwide realise the importance for quality teaching and therefore allocate resources for training and support in pedagogy for their faculty members. This is usually done through the Faculty Development Centers (FDC) whose main activities consist of training new faculty members, supporting existing faculty, programmes or departments wishing to implement innovative pedagogies, and helping in the teaching evaluation process. Their goal is to prepare faculty by developing their teaching skills; mainly in course design and planning, teaching methods, use of information technology, student assessment, and evaluation of teaching.

Despite these common threads, we do come across some variations in these activities amongst institutions. Moreover, there are a variety of faculty development models, particularly in the format the delivery takes place. For instance, the most frequent differences

in the programmes are related to their nature (compulsory or elective), their structure (length, schedule), their format (individual meetings or group sessions), and their assessment requirements.

Because teaching effectiveness stands at the heart of student achievement and learning outcomes, it appears crucial to support initiatives aimed at developing useful academic skills. The spirit of this paper is to share information, ideas, and experiences that foster sound faculty development models, while addressing genuine concerns and challenges related to faculty development efforts. Hence, the aim of this paper is to help higher education institutions set up or improve activities of existing FDCs, by describing five faculty development models destined to promote excellence in teaching and learning, to support an assortment of programmes, and activities in order to enhance professional teaching skills.

All of the five faculty development models support CDIO implementation efforts. They come from distinct institutions: 1) Singapore Polytechnic (Singapore); 2) École Polytechnique Montreal (Canada); Queen's University of Belfast (Ireland); 4) Royal Institute of Technology Stockholm (Sweden); and 5) Massachusetts Institute of Technology (USA). Table 1 summarizes the commonalities and differences between the various models.

Table 1
Comparison of the various faculty development models

Institution	Established	Nature/level	Structure	Format	Assessment requirements
SP	1982	Compulsory	12 month period in 3 parts	Group	Teaching portfolio
EPM	1977	Compulsory. Institution level	12 month period, one hour-long sessions every 2 weeks	Individual	None
QUB	1997	Compulsory for new staff only. Institution level	12 month period with 2 week long modules Full and half day sessions.	Group (about 70 people)	Written assignments, graded as a piece of Masters level work on a pass / fail basis only
KTH	2003	Requirement for eligibility as Senior Lecturer. State and institution level	10 weeks full time, divided in modules. The first module is scheduled over a semester with 14 half-day meetings about once a week.	Group (about 35 people)	Compulsory attendance in meetings, three assessment tasks required to pass the first course module.
MIT	1997	Elective	Workshops	Group	None

The first model describes the professional development support that the Educational Development Department provides to faculty in Singapore Polytechnic (SP). The professional development programmes in SP is guided by a learning roadmap that defines the teaching competencies that faculty need to develop to pursue a teaching career. New faculty, for example, attend a rigorous one year programme that focuses on the core competencies and essential underlying knowledge bases of teaching, and the personal dispositions related to highly effective teaching and training. Sharing of good practices by invited guests and innovative faculty is conducted at platforms like the monthly Educational Roundtable and Excellence in Education and Training Convention.

The second model describes the Faculty development center in École Polytechnique Montreal (EPM). Established in 1977, the center engages in a range of activities related to the support of teaching. Since 1984, EPM introduced a compulsory pedagogical training programme for all new faculty members. Therefore they must attend individual meetings with a pedagogical consultant that assists them in enhancing their teaching skills, improving courses, and resolving instructional problems. The Faculty development center also assists faculty with the preparation of promotion and tenure materials. For this purpose, EPM has adopted an integrated approach for instructor evaluation by implementing a campus policy.

The third model describes Queen's University of Belfast (QUB) Postgraduate Certificate in Higher Education Teaching (PGCHET). In this model, new faculty sign up for a course that leads to a postgraduate certificate in higher education teaching and is accredited by the UK Higher Education Academy. At QUB only new staff is required to pass the PGCHET. The objective is to enhance the quality of teaching provision across the university by helping faculty adopt best practices and become effective teachers and facilitators of learning.

The fourth model describes the package of courses offered by the Royal's Institute of Technology (KTH) Learning Lab. This package corresponds to the national requirement for newly appointed staff that must be trained in teaching and learning in higher education in order to be eligible for a position as Senior Lecturer. Several principles guide the TLHE courses.

The fifth model describes the Faculty Development efforts at the Massachusetts Institute of Technology (MIT). Various offices and initiatives have formed a widely spread network, providing a full range of services to the MIT community. There are Institute-level offices with the function of services, support and collaborations in the campus, and educational specialists on department-level who can provide specific disciplinary and pedagogical consultation. There is also other on-campus resource that the faculty can access and get support.

The following sections describe in more detail each of these five models. We then discuss possible implications for faculty development in engineering

1) PROFESSIONAL DEVELOPMENT AT SINGAPORE POLYTECHNIQUE

> "It could well be that faculty members of the twenty-first century university will find it necessary to set aside their roles as teachers and instead become designers of learning experiences, processes and environments. … Faculty members will be less concerned with identifying and then transmitting intellectual content and more focused on inspiring, motivating, and managing an active learning process by students." James J. Duderstadt. "A University for the 21st Century", 2000 [1].

The professional development of faculty at Singapore Polytechnic (SP) is led by the Department of Educational Development (EDU). The department's mission is to enhance the quality of teaching and learning in SP. It provides expertise for the professional development of faculty and assists academic schools and departments in developing strategies to enhance the quality of teaching and learning.

The department's key functions include encouraging and leading educational innovations and initiatives, providing consultancy in the areas of curriculum, teaching, learning and assessment, applying educational research to enhance teaching and learning, promoting pedagogically sound applications of educational technology to teaching and learning, and providing services to support audio/video production and e-learning content creation.

Professional Development Programmes

The professional development programmes in the institution is guided by a Learning Roadmap. The Learning Roadmap (Appendix 1) describes the competencies faculty need to develop to pursue a teaching career at SP. It guides faculty in developing their annual Staff Development Plan (SDP) of which at least 20 hours would consist of learning- and teaching-related programmes. It has 2 main learning dimensions – Professional Knowledge and Practice, and Core and Leadership Competence. The Professional Knowledge and Practice dimension covers continued professional development in one's discipline as well as in teaching.

It has been clearly established that highly effective teachers not only have technical competencies in planning, delivering and assessing learning, but also excellent interpersonal skills and display behaviours that communicate genuine interest and concern for learning and learners. As it is impossible to cover all competences for teaching and learning, the Learning Roadmap focuses on the key competences that every lecturer needs to play the dual role of content matter expert and facilitator of knowledge.

The department offers a range of professional development workshops in the areas defined in the learning roadmap. These could be half day workshops or 45 min lunch time sessions and are offered throughout the year. Customised workshops are also conducted on request. The resources used in all workshops are available online for faculty to browse and use.

Professional Development for New Academic Staff

The Certificate in Teaching (Higher Education) Course is specially designed to provide quality training for faculty who are new to teaching. The programme focuses on the core competencies of teaching, the essential underlying knowledge bases and the personal dispositions related to highly effective teaching and training. It is aligned to SP's Learning Roadmap that faculty use to plan their professional development.
There are 4 core competences in the Certificate in Teaching (Higher Education) programme. They are Learning Design and Management, Assessment, Student Management, and Reflective Practice. The course extends over a 12 month period and consists of 3 parts and a teaching portfolio:

Part 1 – Induction Programme

New faculty, when they are first appointed, have to attend a one week induction programme which equips them with some pedagogic skills like creative teaching, classroom management and facilitation skills before they begin teaching.

Part 2 – Learning Design Project

For part 2 of the CT course, faculty use a set of core principles of learning to design meaningful learning experiences that incorporate notebook activities. We suggest that the core principles that underpin good learning design in the face-to-face learning context are equally applicable to designing and managing learning in the online environment. Learning online does not change the way the human brain functions or the basic processes of learning. Clarke and Lyons (2005) [2] illustrate this fundamental point when they argue that:

> The most robust instructional principles are those based on a model of human psychological learning processes….Any given instructional method will be effective or ineffective depending on the extent to which it supports or disrupts basic-learning psychological processes regardless of the delivery media. (p.594)

This perspective is reinforced in this one week project based programme where faculty are introduced to good practices of e-learning and a range of e-tools, and are tasked to design lessons with meaningful laptop activities based on the core principles of learning.

Part 3 – Specialised Workshops

Part 3 comprises of specialised workshops that help hone the competency of faculty in the 4 areas like active learning techniques, writing learning outcomes and designing open and closed assessments. Half a day every week is set aside for faculty to attend these workshops.

Teaching Portfolio

Faculties are also expected to apply their learning and work on a range of assignments which are submitted in a teaching portfolio. These assignments include producing lesson plans, learning resources, assessments, conducting an action research, observing an experienced faculty and a teaching practicum. The portfolio hence documents their journey on the course and their attainment of the competences spelt out in programme objectives.

The merits of the new structure, apart from those documented above, are the important motivational and rapport building between faculty developers and the new faculty. Common comments from faculty who have completed the course include “the course provided me with more ideas and also helped to make getting started on teaching easier” and “I realise that this is a new programme and I would like to say that it is a great idea to have such a programme right at the start of our teaching stint at SP”.

Professional Development for New Initiatives

- *CDIO Implementation*

A special series of workshops for faculty implementing CDIO were also developed. In these workshops, an overview of CDIO, the CDIO syllabus, and the underpinning knowledge of CDIO skills like teamwork, communication skills, thinking and managing learning are shared. Faculty conduct a gap analysis, integrate selected CDIO skills into the curriculum, and design active learning activities and assessments for these skills.

In addition to these workshops, the EDU team also meet with a cross disciplinary CDIO implementation team once a week to discuss the curriculum and pedagogical approaches to adopt. A customised CDIO syllabus for SP was drawn up by the team which defined the learning outcomes for the CDIO skills appropriate for students at the polytechnic (Table 2).

The EDU team work closely with the CDIO implementers to revise or develop new syllabuses and to develop suitable assessments for the activities and skills integrated into the curriculum.

Table 2
Example of learning outcomes for personal skills and attitudes

Personal skills and attitudes	Learning outcomes
Apply the thinking process	• Use a range of critical thinking skills (e.g., analysis, comparison and contrast, inference and interpretation, and evaluation). • Identify the creative thinking process (e.g. Generating possibilities, incubation, illumination, etc.). • Use a range of creative thinking tools and techniques (e.g., brainstorming, mindmapping, triz). • Identify contradictory perspectives and underlying assumptions. • Reframe and take a range of different perspectives. • Use metacognition in monitoring the quality of personal thinking.
Analyze factors that affect thinking	• Identify barriers to effective thinking (e.g., traits, dispositions, working memory, perception, lack of information, etc. • Evaluate ways to reduce barriers to effective thinking. • Identify factors that promote effective thinking (motivation, openness, risk taking, exposure to varied knowledge bases and ideas, etc.).
Manage learning	• Identify one's own learning approach. • Identify approaches for self-improvement (e.g., lifelong learning, creating positive beliefs and psychological states, etc.). • Display key dispositions e.g., (initiative, perseverance, flexibility) in work projects). • Use a range of learning strategies and skills (e.g., goal setting, learning plans, organizing/summarizing information, receiving feedback, etc.). • Manage time and resources.

Besides the syllabus, starter kits for Introduction to Engineering and Design Build were developed. These kits contain information on activities, processes and techniques that can be adopted. A website was also set up for sharing of resources developed.

A longitudinal programme evaluation is currently being carried out to study the impact of the changes made to the curriculum on students' learning, skills development and interest in engineering. The evaluation design includes blogs by a group of student co-participants, student questionnaires and focus group interviews with students and faculty.

- *Elearning Initiative*

SP's e-learning strategy is to embed e-learning into teaching and learning. It is intended that e-learning be developed as an integral part of learning and teaching while leveraging on the BlackBoard Learning Management System (LMS) and the notebook PC. It is about using technology within a campus-based course in ways that add value to the learning experience as well as support new modes of learning and teaching.

In 2008, an eLearning Project was initiated by EDU which aimed to put in place the following provisions:

1. Course websites that provide course-specific information such as syllabus, schedules, assessment criteria, etc, to assist students in completing the course and in understanding its objectives and procedures
2. Lessons designed with active learning activities using the notebook PC.
3. Recorded lectures to be made available for the students via Blackboard**.**

Pedagogical support was provided to course co-ordinators on a one-to-one basis. EDU staff helped faculty to integrate useful technological tools into their lesson designs, restructure the delivery of their programmes through course maps and provided useful resources that faculty can use to enhance the learning experience for their students. Sharing of appropriate e-tools to help deliver their content like wikis, blogs, Cmaps and voicethread were also conducted.

Platforms for Sharing of Best Practices

Best practices and new directions in education are shared at three platforms organised by the Educational Development Department. New and innovative ideas in the area of teaching and learning as well as interesting pedagogy are shared by invited guests or by the SP faculty themselves. These platforms also allow faculty to network with their counterparts from different schools and to build rapport with faculty developers.

- *A monthly Educational Roundtable*

The Educational Roundtable (ERT) is a popular lunch time talk that brings together experts from the educational field to share their thoughts on popular educational topics for faculty in SP. Held once a month, invited speakers have shared on a wide range of topics ranging from innovation in education to competency based education. Faculties get to identify and evaluate recent developments in professional practice and it usually concludes with lively discussion and debate.

- *A community of practice gathering held every semester*

To continue to build a sense of professional identity amongst the new faculty, they are invited to attend the Communities of Practice (COP) meeting which is held every semester. This is a platform where past and present CT participants gather to share teaching and learning ideas as well as listen to speakers from the field of education. Set in an informal environment, faculty share with each other teaching nuggets that their peers can then try and adopt in their own classrooms. More importantly, the COP allows EDU to continue to build professional relationships with the faculty who have graduated from the CT programme.

- *An annual in-house Excellence in Education and Training Convention (EETC).*

The EETC is a gathering of all academic faculty in the polytechnic to keep them abreast with developments in higher education. The theme of the convention is usually focused on an area that the polytechnic has selected as a strategic goal to be achieved. The convention also a platform to publicly honour the polytechnic's faculty who have excelled in their teaching and to provide faculty with the opportunity to showcase their innovations and research in teaching and learning.

It is essential that opportunities for professional development training and activities are provided to faculty to ensure the quality of the programmes and graduates from the polytechnic. However, while this need for upgrading of competencies and skills is regarded as important, there are often competing demands on faculty's time and priorities. Ensuring the professional knowledge and skills of faculty developers themselves to meet the changing demands of education is another challenge. In the area of engineering education, a collective

effort by the CDIO collaborators to share innovative ideas and approaches in teaching and learning amongst teaching faculty and faculty developers across institutions has certainly helped to engage and motivate faculty in SP to review and improve their curriculum and instructional practices.

2) ÉCOLE POLYTECHNIQUE MONTREAL – FACULTY DEVELOPMENT CENTER

Background

École Polytechnique of Montreal (EPM) is the biggest French speaking engineering school in Canada. Founded in 1873, it has an enrolment of over 6000 students, 230 full-time faculty members, and more than 400 part-time instructors. Located on the same campus as the University of Montreal, EPM remains a completely autonomous institution, and offers 13 undergraduate four-year programmes, and 15 disciplines in graduate programmes, all exclusively in the field of engineering.

EPM is committed to providing quality teaching, and has recently launched an institution-wide initiative to renew all of its undergraduate programmes. The goal was to adapt the curriculum to the needs of the society and the labour market, and to introduce sound modern pedagogies that are more appealing to today's students. In 2004, each programme mobilized a team of faculty members whose responsibility was thinking and planning the entire process. Guidelines were somewhat loose, but each programme had to make room in their curriculum for at least one project-based course per year, and get every student to do an internship in industry during the third or fourth year of their programme. One year earlier, the department of mechanical engineering decided to undergo a similar reform by joining the CDIO initiative. Both these initiatives are driven by the same vision which is giving a more active role to students, and engaging them in the development of technical knowledge and reasoning as well as personal and professional skills and attributes. EPM, who was one of the first higher education institutions in Canada to establish a Faculty development center (FDC), didn't hesitate to call on its staff to support faculty in implementing these pedagogical initiatives.

The Faculty Development Center (*Bureau d'appui pédagogique*) in EPM was established in 1977, with an original goal of improving classrooms, supporting faculty in their mass production of overheads, offering individual consultations, and running workshops on various pedagogical aspects. Its mission has evolved over the years, and has now a more integrated approach to promoting faculty development. The FDC has a staff of five, the director (a specialist in evaluation and assessment), two specialists in integration of information and communication technologies (ICT), one specialist in higher education pedagogy, and one secretary. The FDC is seen as a service center dedicated to faculty, to departments, or to any other academic authority. With different fields of expertise, the educational consultants often collaborate to give the best possible service to faculty.

Compulsory training programme for new faculty

In Canada, although there are no State requirements for faculty members to have any formal training in pedagogy, most institutions offer optional support to faculty in their work as teachers. However, what is particular to EPM is that in 1984 it introduced a compulsory pedagogical training programme for all new faculty members. They receive individualized and confidential consultations on a variety of instructional issues, including course design, classroom performance, students' learning assessment, and reflection upon their practice. This individually tailored pedagogical programme runs one-hour-long face-to-face meetings; during the first year new faculties are hired. The meetings take usually place once every two weeks, but scheduling is convenient and very flexible, hence taking into consideration busier

than normal periods of the year for faculty (e.g. grant requests, midterms and end of semesters).

Faculty members are encouraged to engage in continuous improvement of teaching. Discussion topics include the teaching and learning process, classroom presentation skills and methods to enhance teaching and learning, interactions with students, providing and receiving student feedback, how to utilize effectively the latest developments in ICT to enrich course content, presentation and enhancing the student's educational experience, and other matters related to teaching.

Reasons why the programme is appreciated

New faculty members are usually very grateful for the opportunity they are given to develop their teaching skills in a participant-friendly environment. They also appreciate the hands-on approach which gives them the chance to work directly on their courses, and not just having to listen about pedagogy in a theoretical or philosophical manner. The intent is to share as many ready-to-implement ideas and activities, and to provide useful real examples taken from other faculty members. For example, when covering student assessment, faculty like to see what a grading rubric looks like, or how others have written their course objectives when presenting Bloom's taxonomy of educational objectives of the cognitive domain. The examples are updated regularly to reflect actual practices.

Another important reason new faculty members appreciate the programme is related to the fact that tenure is obtained after a four year probation period. During this period, every course they give must be evaluated. The course evaluation process at EPM is based on a questionnaire of student opinion. The twenty-two question evaluation form gives students the chance to comment anonymously about the course and how it was taught. The statements are grouped in four categories: course organization and communication, instructional skill, student outcomes, assignment, exams, and grading. There is also an open-ended comments and suggestions section. The results of the evaluation are not given to the instructor until final student grades have been submitted. Quantitative results are only given to the instructor and his or her dean. Written comments are seen only by the instructor. Because of the high-stakes nature of the final summative evaluation for new faculty members on probation, instructor evaluation is always associated to a feedback process. Every semester, results of course evaluation are transmitted to new faculty by the pedagogical consultants who write a brief comment, while inviting faculty with weaknesses to a meeting in order to analyse the situation and look for solutions for improvement. The consultant also helps to put the evaluation results in perspective and to present a comprehensive portrait of the new faculty member by exposing his or her strengths and emphasizing growth and improvement. This will also help the head of the department to make final decisions concerning instructor retention. In Canada, the possibility to obtain feedback is quite rare in universities. Generally, departments only send faculty their evaluation results, and hope teaching will automatically improve.

Policy for faculty evaluation

EPM has adopted an integrated approach for instructor evaluation by implementing a campus policy. The first policy was introduced in 1986 and its purpose was to establish common grounds for evaluation across the departments by building a standardised questionnaire. The policy was written in collaboration with the FDC's pedagogical consultants. The policy applies to the final summative evaluation process for new faculty members who have yet to obtain tenure, as well as for the promotion of tenured faculty.

Ten years after the adoption of the first policy of evaluation, a committee was asked to revise it and widen its scope. In 1997, the second policy is introduced and does not only cover

course evaluation, but also looks to promote quality teaching, and seeks to foster an environment where teaching is rewarded and recognized. The second policy allows EPM to emphasise the integrated approach of faculty evaluation and to set some conditions. This set of conditions are multiple and diverse, but essential to help carry forward its mission to promote the value of teaching. Therefore, before thinking of evaluating faculty, it is important to support faculty in professional development in teaching. It is also important to make sure the process of evaluation is valid, and feedback mechanisms as well as adequate help are available. Tangible actions for the recognition and an increase in the value of teaching are necessary in order to engage faculty members in continuous improvement of teaching. Appropriate examples of such actions can be providing resources like teaching grants, and awarding promotions that value teaching as well as research.

Furthermore, genuine support from university administrators is an essential condition to the success of any policy concerning excellence in teaching. The FDC must be able to count on the support of the establishment's leaders, and on a constant institutional will in the successive administrations. Indeed, if a president or a vice-chancellor is needed to give the initial impulse, his or hers successors must also be convinced of the need for continuing the work. Evidently, the constant commitment of faculty is another crucial condition for success. Faculty must recognize the importance of teaching, and get actively involved in its promotion.

Finally, all actions must be structured, and decent policies should guide the actions. It is also necessary to envisage a certain time to set up the components of the system, in EPM's case the process has taken 30 years. That can appear long, but it is necessary to respect the rhythm of the establishment in its capacity for change, and the process of acceptance and implementation of the proposed measures. It is also necessary to take into account the people, the faculty and the students, who work on the various committees. In addition, a major crisis, like the global financial crisis happening now for example, can occur and slow down any initiatives or developments.

3) QUEEN'S UNIVERSITY OF BELFAST – POSTGRADUATE CERTIFICATE IN HIGHER EDUCATION TEACHING (PGCHET)

Established in 1997, and coinciding with the publication of the Dearing Report [3] which recommended the introduction of formal qualifications for all teaching staff in UK universities, the Queen's University Belfast (QUB) PGCHET course leads to a postgraduate certificate in higher education teaching and is accredited by the UK Higher Education Academy. At QUB it is jointly delivered by the School of Education and the Centre for Educational Development, part of the university's Academic & Student Affairs Directorate which works with staff, students and employers to enhance learning, teaching and assessment within the University. Academic staff on probation are given priority for places on the course. Successful completion of the PGCHET is a condition for passing out of the probationary period for new academics. While Dearing recommended such qualifications for all staff it is not as yet a mandatory requirement in the UK and each university currently set their own policy in this regard. At QUB only new staff are required to pass the PGCHET.

The PGCHET has been designed primarily for recently appointed lecturers and teaching fellows with limited experience of teaching in higher education. It aims to help participants develop their knowledge and skills in teaching and learning and to encourage them to reflect on their professional practice. The course runs over a 12 month period with 2 week long modules scheduled outside teaching weeks supplemented by several full and half day sessions throughout the year. The course is generic in content and each cohort comprises up to 70 students drawn from various Schools of the university. The objective is to enhance the quality of teaching provision across the university by helping staff adopt best practice and become effective teachers and facilitators of learning.

Assessment is by a number of written assignments with a strong focus on reflection of teaching practice and a requirement to reference pedagogic literature. In 2008/9 the assignments were:

- A teaching journal and portfolio
- An analysis of assessment procedures
- An action research project investigating an issue in student learning
- Conducting a reciprocal peer observation of teaching with a colleague

Each assignment is graded as a piece of Masters level work on a pass / fail basis only. In either case detailed feedback from all assessors (minimum of 2) is provided. Unsatisfactory work may be altered and resubmitted for subsequent reassessment. Students are required to pass all 4 assignments within 2 years of enrolling on the course to be awarded a certificate.

4) THE ROYAL INSTITUTE OF TECHNOLOGY, STOCKHOLM, SWEDEN

To be eligible for a position as Senior Lecturer in Sweden one must be educated in *teaching and learning in higher education* (in Swedish literally *higher education pedagogy*). This requirement is stated in the Higher Education Ordinance, (Chapter 4, Section 7) and applies to all HE institutions since 2003:

"A person shall be qualified for appointment as senior lecturer [...] if he or she
1. has completed a doctorate [...],
2. has taken a course in teaching and learning in higher education [...], and
3. has demonstrated teaching skills."
Lecturers can also be hired under the condition to take the courses within two years.

An agreement was made in 2005 by all Swedish universities to recognise each other's courses. To make this possible, a common set of intended learning outcomes was agreed, together with the decision that such training should correspond to 10 weeks full time study.
At the Royal Institute of Technology (KTH), a package of courses corresponding to the national requirement is offered by the KTH Learning Lab. See Figure 1.

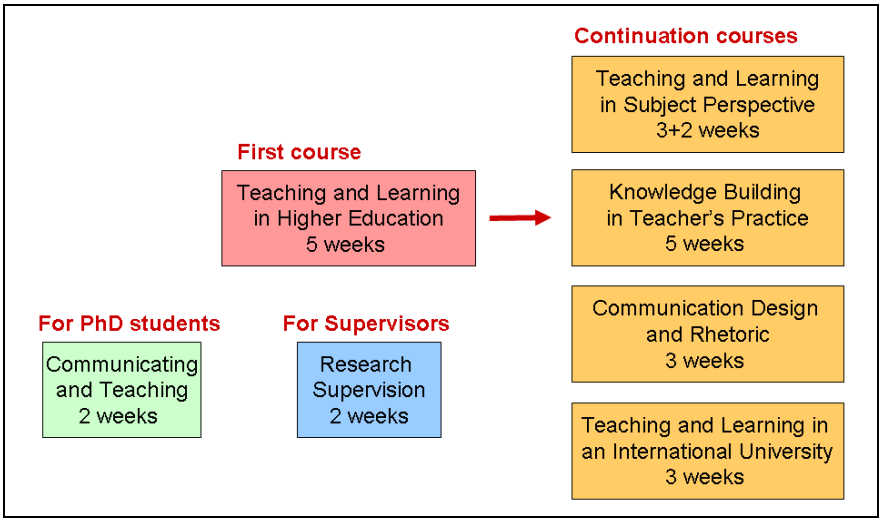

Figure 1. Course package offered at the KTH Learning Lab

Participants start with the five-week course Teaching and Learning in Higher Education (TLHE), after which they can select any of the continuation courses to fill up the course portfolio to the required 10 weeks. Many teachers opt to include the Research Supervision course in their package. Younger teachers may also have taken a basic teaching course while they were PhD students and this can be part of their package. In the following, the TLHE course is described more closely.

THE COURSE 'TEACHING AND LEARNING IN HIGHER EDUCATION'

Since 2004, the THLE course has been taken by more than 350 teaching staff, with an additional 100 people currently in pipeline. The course corresponds to 5 weeks full time, scheduled over a semester with 14 half-day meetings about once a week. Between meetings there is literature to read and a written assignment to prepare for the meeting. In addition, there are three larger assessment tasks required to pass the course. The first half of the course, called Course Design, is a practical exercise where the participant develops a course in which he/she teaches. The goal is to be able to make conscious and informed course design choices, driven by a student learning perspective. Course Design is assessed based on documentation of the 'makeover course'. The second part, called Reflective Practice, aims to deepen the learning perspective through further application of it to areas such as course evaluation, student diversity, one's own contribution to the organization etc. Assessment is based on transcribing and analyzing interviews with two students and a teaching philosophy statement.

Below some principles that have been guiding the development and running of the TLHE course are discussed.

It started as a spin-off from the CDIO implementation of KTH.

Within the CDIO implementation process at KTH (from 2001) a series of workshops were developed for teachers who were responsible for courses in the first CDIO programme. These workshops contained the essentials of course development (designing intended learning outcomes, learning activities, and assessment) and this later became the backbone of the TLHE course. One could say that the TLHE course is *what we wished every teacher should have been able to do* when we were developing our first CDIO program. The CDIO experience was a strong platform for developing the TLHE course, we had developed and validated an engineering-flavoured approach to course development, we had data from KTH and other partner institutions that we could use as an empirical base, and we had established legitimacy and built trust relationships with many faculty.

It should have an engineering education flavour and a functional approach.

Engineering faculty should be able to identify with the course content, and recognise their own kinds of subjects, students, teaching and assessment methods, the most common problems, and how these problems can be addressed in ways that works here – and within existing resources. When we read about phenomena and concepts in the literature, this is complemented with student quotes illustrating how these phenomena can be recognised when they appear in our context, as demonstrated in [4]. Faculty who have previously taken the TLHE course are invited back to show how their specific interventions have worked. We use their examples as case studies to analyze and learn from, and their appearance also helps affirm the local credibility and legitimacy of the course content. The applicability of the course content has been key to the success of the course. A typical quote: "*I had expected a great deal of "philosophic" reasoning that would be hard to apply in practice. Instead, the theory of the course backed up a large toolbox of concrete teaching methods and strategies. I am struck by the substance of the course*."

Change is built in.

Participants are encouraged to change their teaching practice already while taking this course, it is not something they are expected to do ”later”. Several of the written assignments in the TLHE course are documents that they have use for, e. g. they create the documents necessary to launch the makeover course in its new format. This helps participants reach all the way and implement the change. This increases their benefit, as they are aquiring the formally required merit, and at the same time improving their teaching. One participant put it: “*I think it is a very good idea to make [the work in the course] something that a (good) teacher would have to do anyway. It makes you very motivated to do it well, and it is encouraging to work on something that is going to be useful, not just for assessment of the course*.” This is also a way to increase the benefit for the university. 350 teaching staff who have taken the course equals 350 courses that had a makeover.

It is necessary to win acceptance by faculty.

Since the TLHE course is in practice compulsory for new faculty it was necessary to establish a positive image around the course, otherwise resistance would be strong. A comment from a previous course participant: “*Overall it is very good course. Actually it is one of the best courses I ever attended. I was more or less forced to attend this course since it is required for KTH teachers. But it turns out as an enjoyable venture*.” The fact that the course takes five weeks full time is a particular challenge – just think about adding five weeks on top of all other commitments. One message to participants is that the course is serious and takes time. A typical comment: “*The course takes time. It is not ‘free’ credits*.” But the other message is that their effort will pay back in their teaching, because they will be able to teach more effectively and cope with their teaching better. Many previous participants testify to this: “*Well invested time*.”; “*I must say that it is so much more fun to go to work and meet the students now that I’ve worked on the course design, than previously when I taught more ‘quick and dirty*’.”; “*You get incredible inspiration and ideas on how to develop your own courses. Little tactics and interventions with enormous leverage*.”

It is intended to enable and strategically drive educational development.

The results of this faculty competence development can be seen not only on the level of the individual course or faculty member. When a critical mass of teachers in a division or department share the framework (set of concepts, models, strategies and tools) aquired in the course, it will affect the educational climate of that department. We are starting to see such signs. Also, many alumni of the course sit in the governing bodies of the university – another area where they can apply this competence. It is just a matter of time (say a decade) before a majority of the faculty will have this competence.

To conclude, KTH has used the mandatory national requirement as an opportunity for creating a mechanism for strategic educational development. One of the reasons we could do this was the experience of CDIO implementation, which turned out as a useful starting point.

5) FACULTY DEVELOPMENT AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

With the mission to “advance knowledge and educate students in science, technology, and other areas of scholarship that will best serve the nation and the world in the 21st century” (http://web.mit.edu/facts/mission.html), MIT has always put teaching and research as the primary purpose. To achieve this purpose, the MIT faculty plays a very important role. As of October 2008, the Institute has 1,009 faculty members (http://web.mit.edu/facts/faculty.html).

They instruct undergraduate and graduate students, and engage in research. The Institute provides them not only the best resources to conduct teaching and research, but also the opportunities to develop themselves, as teacher, advisor, administrator or researcher.

Faculty development in the MIT community is a very comprehensive effort. Various offices and initiatives have formed a widely spread network, providing a full range of services to the MIT community. There are Institute-level offices with the function of services, support and collaborations in the campus, and educational specialists on department level, who can provide specific disciplinary and pedagogical consultation. There is also other on-campus resource that the faculty can access and get support.

I. Institute-level Offices

The Office of the Dean for Undergraduate Education (DUE) sits at the core to provide systematical and institute-level faculty development resources to the MIT community. Three offices under the supervision of DUE – the Teaching and Learning Laboratory (TLL), the Office of Faculty Support and the Office of Educational Innovation and Technology (OEIT) – set their missions on support and develop faculty in a wide range of educational activities. Each of these offices has their own focus on faculty development: the TLL on teaching and learning research, training and consultation; the Office of Faculty Support mainly on undergraduate curriculum development and faculty government support; and the Office of Educational Innovation and Technology mostly on the innovative technology development and dissemination.

Teaching and Learning Laboratory

MIT established the TLL in 1997, with the goal "to strengthen ongoing educational efforts at MIT and develop innovations in pedagogy and technology" (http://web.mit.edu/tll/about-tll/index.html). The Laboratory has three interrelated functions: instructional support, research and assessment. They support one another and allow TLL to provide a full range of services to the MIT community.

The programmes and services TLL provides include consultations, workshops, orientations and courses. Faculty members from the community could improve teaching and instruction skills through workshops and courses; they could consult the staff from TLL about their syllabus design, teaching and assessment method; they could find teaching materials from TLL's library and website. New faculty of the community could also participate in a New Faculty Teaching Orientation at the beginning of the fall semester. The orientation is designed to help them think strategically about teaching, learn more about active learning and interactive teaching.

The TLL employs 7 staff and has 5 associate groups with over 15 experts and specialists from both inside and outside of campus. Their disciplinary backgrounds include educational psychology, educational technology, sociology, history, communications, management, science and engineering. Therefore, they could provide comprehensive services and consultation to the educational activities in MIT, especially in science and engineering education.

Office of Faculty Support

The Office of Faculty Support has its mission to help the faculty development and support faculty governance. Their services emphasize on undergraduate education and support the committees on Undergraduate Education. The Office is responsible for the distribution of several funds for education improvement. Faculty can apply for resources from these funds to initiate innovative educational projects. The Office also manages the Student Subject

Evaluation process. The process gets feedback and evaluation of the course and instructor from the students, which can help Faculty improve their teaching. With the effort of 9 staff, the Office has built a communication bridge among faculty, staff, the five Schools and the central administration.

Office of Educational Innovation and Technology

The OEIT aims to promote the development and dissemination of innovative uses of technology in teaching and learning. It assists faculty in "locating, building and integrating technologies that support a wide range of pedagogical models" (http://web.mit.edu/oeit/learn/index.html). The Educational Technology Consultants support the educational technology needs of MIT's academic departments and faculty. They can help find technologies to support instruction in specific disciplines, identify possible resources, participate in select projects, and help with long-term educational technology planning. Faculty consultation includes pedagogical uses of technology on instructional design, educational assessment, project support and so on. The OEIT employs 18 staff and gives a solid technology support to faculty members on teaching and research.

II. Department-level Support

Some of the departments in MIT employ their own educational specialist to instruct education activities and help to establish the department-level faculty support. Compared with the staff from institute-level offices, these department-level specialists can provide more discipline-oriented services for the faculty. They have a more concrete idea on the curriculum of the programmes in the department and know better of the requirements of each course. Faculty members can get professional suggestions on designing, teaching and assessment.

The Department of Aeronautics and Astronautics, which adopts CDIO as the framework of curricular planning and outcome–based assessment, is one of the examples. There are two educational specialists in the Department of Aeronautics and Astronautics, both having a Ph.D. Degree in education. Their job includes course design and development, curriculum design, instructional and assessment materials design and development and individual consultation. Each academic year, they collect a memo document from each instructor of the course and compare the outcome of the course with the 12 CDIO Standards. The result of the analysis is given to the department and faculty and helps them improve their teaching. The specialists are also responsible for designing workshops and special projects on different topics in engineering education and helping faculty in the Department.

III. On-campus Resources

The Institute employs about 11,500 individuals in 2008 as research, library, and administrative staff, as well as many others who directly or indirectly support the teaching and research purpose. This number makes the staff/faculty ratio in MIT reach 11/1, which gives a solid foundation and good support to faculty activities.

The website Faculty Resources (http://web.mit.edu/faculty/) integrates most of the online resources related to faculty life in the MIT community. Faculty could find link lists on Advising and Teaching, Benefits and Services, Governance, Relocating, Research and so on. It provides a convenient way to search information and get help in the campus. There's also a periodic Faculty Newsletter to keep the faculty informed of the important events in campus.

CONCLUSION

The aim of this paper is to describe the efforts of five higher education institutions to adequately train their faculty for teaching and help them facilitate learning. These institutions have developed and successfully sustained a training programme process that effectively encompasses the basic skills and knowledge that contribute to teaching excellence. This process is facilitated by faculty development centres, education departments or a concerted effort between these two entities. Each institution has developed its own faculty development model and is engaged in enhancing the quality of teaching and learning. Although models vary from one institution to another, their objectives are usually very similar. All in all, their purpose is to provide programmes and resources designed to promote teaching methods that are consistent with the research on how people learn, present opportunities for faculties to reflect on their work, to encourage pedagogical innovations and initiatives, to offer consultancy in the areas of curriculum, teaching, learning and assessment, to enhance teaching and learning, and to promote pedagogically sound applications of educational technology to teaching and learning.

While five models is quite short of a representative sample, the comparison of these faculty development models does allow making certain interesting observations. First and foremost, the perpetuity of any faculty development model strongly depends on the institution's support and the administrators' faith that this is the right thing to do. This is a very important condition to consider before thinking of offering such a service. If the administration is unwilling to allocate resources, it is very probable that such an enterprise will not function.

Second, thriving models show clear evidence of a continuing improvement approach, and apparent necessity for collaboration among specialists. This highlights the fact that teaching is a complex skill that requires the people involved work in a very serious and well structured matter to ensure that faculty feel they are well prepared with respect to required knowledge and skills they will apply during their career. The average 12 month length of the programmes, their often compulsory nature, and the sometimes heavy assessment requirements testifies of the seriousness of the process.

Third, all faculty development models described in this paper provide sound instructional design services to assist new faculty members in enhancing their teaching skills, deepen their understanding of the learning process, and improving courses.

Finally, one transcendent wish of all the models is to create a stimulating learning environment, to help faculty achieve their academic goals, and to learn with the experience and expertise of their colleagues.

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Biographical Information

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Helene Leong-Wee has been in the education service for the past 20 years. She was a teacher and senior curriculum specialist in the Ministry of Education (Singapore) involved in the development and introduction of the teaching of critical and creative thinking skills in schools in Singapore. She has conducted numerous workshops on promoting critical and creative thinking, and creative problem solving for teachers and students.
She is currently the Deputy Director of the Educational Development Department at Singapore Polytechnic. As Deputy Director, she oversees the professional development programmes as well as the implementation of new initiatives adopted by the polytechnic. As such, she is actively involved in assisting engineering schools in their implementation of CDIO. This includes rewriting existing syllabuses as well as designing new syllabuses to integrate personal and interpersonal, and design build skills. Besides staff development, she is also an external assessor for the Ministry of Education (Singapore)'s School Excellence Model and an Academic Quality Councillor in Singapore Polytechnic.

Mark Nivan Singh is currently the co-ordinator for the Certificate in Teaching (Higher Education) competency based course in Singapore Polytechnic where lecturers are mentored in their journey to be more effective lecturers. He conducts workshops in the area of Effective Lesson Designs, Creative Teaching, Assessing Learning and also in the area of Facilitation Skills. Mark has also developed course content on the area of Classroom Management and also for blended learning in the area of assessment for SP's lecturers.

Over the past 8 years, Mark has been extensively involved in training, development of professional development activities for teachers and also partnering teaching professionals in a variety of educational contexts. Mark was responsible for writing the entire Literature course content for his school when he was teaching and this also included designing authentic and performance based assessment for his students. Mark has also worked with various schools in the area of *Multiple Intelligences* conducting workshops for these schools when he was at the Ministry of Education Staff Training Branch.

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Appendix 1

Learning Roadmap for Staff of Singapore Polytechnic (Academic)

Learning Dimensions				
Professional Knowledge and Practice				
Subject Knowledge		**Learning Design Management**	**Assessment**	**Student Management**
Discipline Knowledge	CDIO skills+	The range of decisions and knowledge bases (e.g. Principles of Learning, Pedagogic Content Knowledge) involved in the planning, preparation and delivery of learning.	The processes, methods and procedures used to assess and promote desired learning outcomes.	The methods and activities that enhance the students' cognitive, affective and moral development.
The technical knowledge and skills that lecturers must acquire.	The relevant CDIO-skills that lecturers must acquire.			
• Mastery of Subject Discipline	• Mastery of Skills	• Science of Learning • Lesson Design • Problem/Project Based Learning • Learning Resource Development and Use • Creative Teaching • Facilitation • E-learning pedagogy • Active Learning	• Principles of Assessment • Assessing Learner performance • Online Assessment • Authentic assessment	• Classroom Management • Pastoral Care • Counselling

[+ These CDIO skills refer to the 13 CDIO skills in Parts 2, 3 and 4 of the CDIO Syllabus. The actual training will vary depending on the areas for which your school/department is developing]

FACILITATING INDEPENDENT LEARNING USING PROJECT-BASED METHOD

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ABSTRACT

Many engineering disciplines require practitioners to be conversant with codes or standards of practice that are relevant to their area of discipline. Introducing the content of these codes and standards in a class using traditional approach can be challenging as the topics are typically dry and uninteresting. There may also be a danger of the lesson being too theoretical. Students may not know how to apply this knowledge in real situations; which is the more important learning outcome of such topics. In this paper, we share how a project-based method can be used to enhance students' learning of such topics. Building Refurbishment, a module offered by the School of Engineering in Ngee Ann Polytechnic uses project-based method to deliver a topic on *Refurbishment for Barrier-Free Accessibility in Buildings*. The content of this topic is largely based on the document - **Code on Accessibility in Building Environment** published by the Building and Construction Authority of Singapore. Students work in teams to submit a proposal to refurbish a chosen type of building, for a class of user (elderly, visually impaired, disabled persons and etc) that would satisfy the requirements under the Code. In the process, students have to perform background research by studying sections of the Code that relates to the building type and user class they have selected. They then have to conduct an on site survey of a real building. In this exercise, students play the role of building auditors and make an assessment of the building's compliance and non-compliance in providing barrier-free accessibility based on the guidelines in the Code. Using the results of their survey, students work on their proposal by listing all findings and recommendations for areas that require refurbishments. They have to support their statements made in the proposal by quoting the relevant guidelines from the Code. The use of the project-based method to deliver this topic has resulted in many desirable outcomes. Firstly, students are given greater autonomy in their learning. They go through the Code on their own; formulate their own understanding through discussions with other teammates and consultation sessions with tutors. This facilitates independent learning, an important lifelong learning skill for students to acquire. The need to conduct an audit and submit a refurbishment proposal has encouraged students to go deeper into the topic. They now have to know how to use the Code, where to locate the relevant information, understand the guidelines and then apply them to their project. The entire process has helped to deepen students' learning. Finally, the fact that real buildings are involved has helped students relate what they have learnt to real life, thus making a potentially dry topic interesting, meaningful and relevant.

KEYWORDS

Project-based learning, experiential learning, learning design.

INTRODUCTION

'Building Refurbishment', a 3rd year module offered by Ngee Ann Polytechnic's School of Engineering, sits within the curriculum for the diploma in Real Estate Business as well as other cognate diploma programmes in built environment. The aim of this module is to equip emerging professionals in built environment with the fundamentals of building adaptation to enable them to manage both the maintenance of buildings as well as changes in the context of buildings. The practice of building refurbishment, also referred to as building adaption, covers a wide range of works to buildings beyond maintenance. These include alterations, extensions, improvements, as well as partial to full conversions of use and renovations.

Given that this is a single module carrying 3 credit units, it has to complement the other modules on building construction and maintenance to ensure that students develop an appreciation of the critical issues involved in building adaption such as barrier free accessibility and sustainable adaptation as well as the basic know-how involved in deciding on and planning for refurbishment activities. Basic know-how included the ability to conduct an analysis and evaluation of a building's compliance with building codes and make recommendation for building adaptation activities.

In deciding on the nature of the learning experience for students in this module, the module design took into consideration that given the wide scope of building refurbishment possibilities, a single module carrying 3 credit units would not be able to 'cover' all building situations and contingencies. The module would therefore have to complement and draw on the skills and knowledge acquired in other modules on building maintenance and construction and provide students with a learning experience that was more applied than what they would likely experience if the module adopted a more teacher- and content-centered approach (which would typically see students listening to and learning from lectures given on the various topics and instructions on how to carry out various building adaptation processes). Key features of the learning experiences designed for this module therefore include active and experiential elements that involve students in crafting, monitoring, and critiquing their learning.

This paper discusses a project-based learning experience adopted in this module for the topic 'Refurbishment for Barrier-Free Accessibility in Buildings' and outlines the benefits to learning and some of the key challenges faced.

PROJECT–BASED EXPERIENCE

All new buildings in Singapore have to meet the requirements for barrier-free accessibility for the physically challenged, visually impaired and elderly users. Owners of existing buildings are encouraged to incorporate new features to satisfy the *Code on Accessibility in Building Environment* when refurbishment works are carried out to their properties.

In this project, which runs over 2 weeks (See Appendix A for the Project Schedule), students must plan an audit of a real building with respect to the Code on Accessibility in Building Environment, conduct the audit, construct the report of audit and make recommendations, present the findings and propose the changes, review the findings and proposals from other audits, and reflect on their competency level in the practice of building refurbishment.

The design of the project-based learning experience puts students in the driving seat and requires their active involvement from the start where they select their building and their teammates till the end of the project where they reflect on what they have learned. Tutors

take more of a coach-consultant approach guiding students through as they navigate the various phases of the experience.

Outline of Project Expectations:

Prior to the audit, students are expected to:

- Choose a building to be audited and the class of users to work on.
- Select their audit teammates.
- Conduct the necessary research and gather the necessary information to carry out the audit. This includes getting the necessary approval to conduct the audit on the premises.
- Design the audit exercise including the necessary methods and instruments needed in the conduct of the audit.

One the day of the audit, students are expected to

- Carry out the audit in their teams

On completion of the audit, students are expected to

- Develop a proposal for refurbishment to comply with the Barrier-Free Accessibility Code.
- Put together a report of the audit findings and their recommendations
- Present their findings to their classmates for critique and feedback.
- Reflect on what they have learned

THE PROJECT IN CDIO TERMS

Described as a CDIO experience, this project-based learning experience appears to have distinct elements of the conceive, design and implement stages.

Conceive

Students have to decide on the teammates for this project. They have to discuss and select the class of user that is of interest to them. They have to decide on a suitable building for audit by researching on the history of the building. The students have to think of ways to convince the building management in getting permission to audit the building of interest. Relevant auditing strategies have to be conceptualized for development.

Design

The students will be required to do on-line search for the relevant code, and study the relevant section in the code pertaining to their selected class of user. They are then required to plan out the audit strategy.

At the post-audit stage, they need to determine how to present their findings to their classmates and design a user-friendly viewing interface for the various potential readers of the project report.

Implement

Students will go to the selected building to do the audit. It will be carried out through visual assessment and, if possible, interviews with the building users. The audit report will be put together using the various e-tools and platforms.

KEY LEARNING BENEFITS OF THIS EXPERIENCE

Beyond developing an awareness and a basic understanding of the contents of the Code on Accessibility in Building Environment, this learning experience has multi-faceted learning benefits as outlined below.

Develops discipline specific knowledge and thinking & project-handling skills

Through working on their own project, students not only learnt about the Code on Accessibility in Building Environment, but also sharpened their project-handling know-how which requires them to identify and clarify the nature of the problem/situation to be addressed, find the relevant information that would inform their work and decision-making activities, formulate their plan of action, carry out the plan and make the necessary recommendations.

The following snapshots of student working documents of their audit findings and proposals show evidence of the students' understanding and application of the Code they were working with as well as their ability to analyse and make recommendations.

Figure 1. Student audit finding, application of the code and proposal

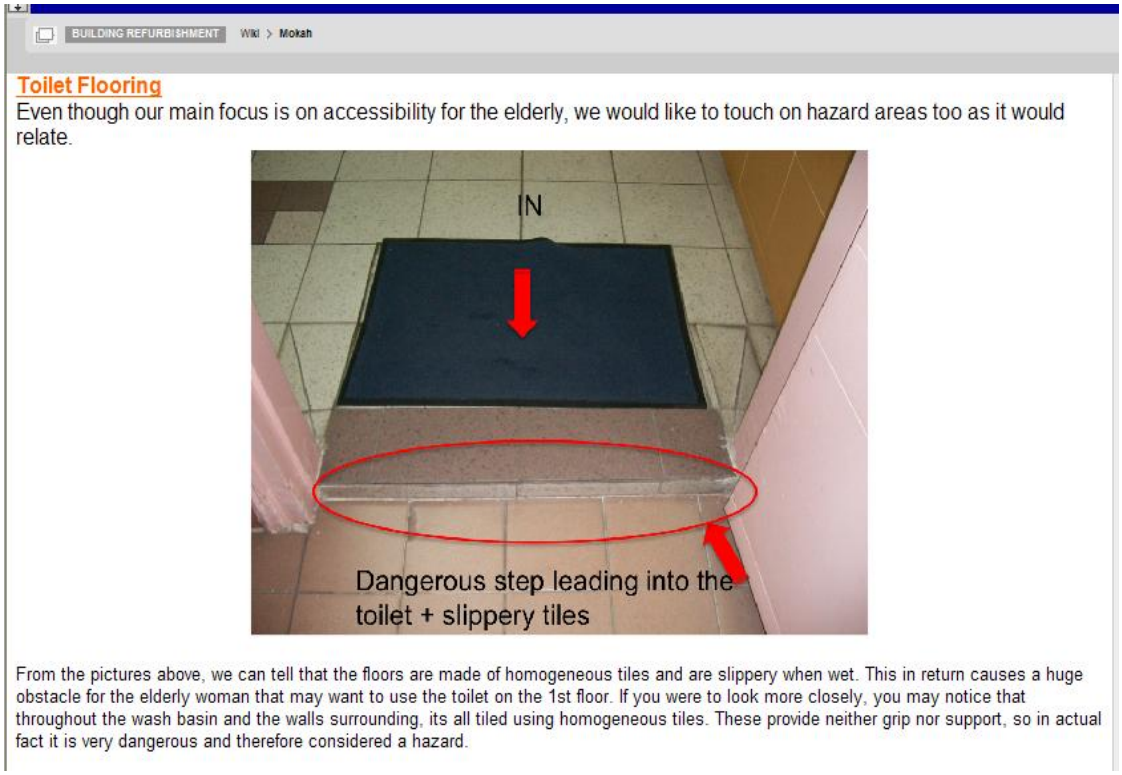

Figure 2. Audit finding and analysis

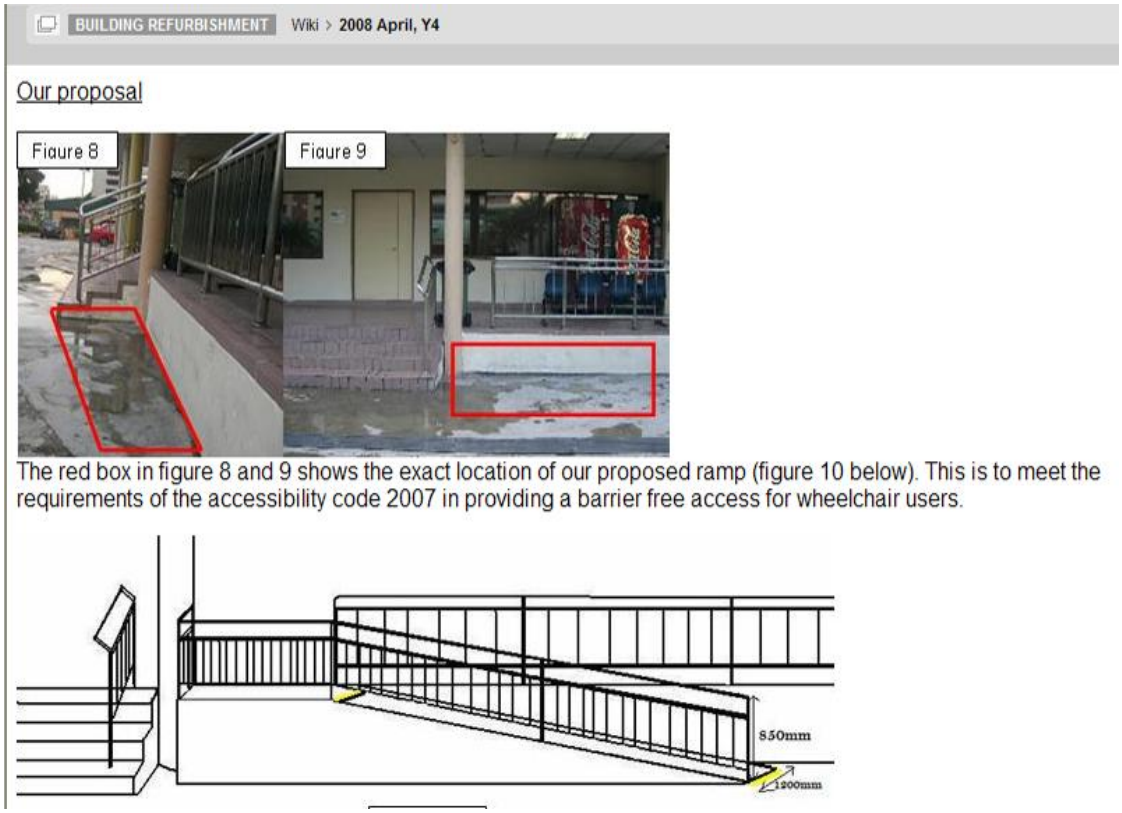

Figure 3. Student audit finding and proposal

Additionally, through reviewing and critiquing the findings and recommendations of other project groups, students gain valuable exposure to a broader range of building types, adaption issues, and recommendations, as well as deeper insights into alternative ways to report and present their findings and proposals as can be seen from the different styles above.

Develops interest through active and experiential learning environment

That students are given some control to decide on what they learn, how they learn, with whom they learn tends to increase their involvement in and awareness of their own learning.

Reflections on their own learning have tended to display more accountability for as well as a deeper awareness of the outcomes of their own development as a building professional. This can be seen from a sampling of student reflection extracts below.

> "In addition, I had also learnt to be more attentive and sensitive to the various features that are provided in the mall through the site assessment audit. This is because the audit would require me to be observing every single part of the mall carefully, and not to miss out any feature as that feature might be a possible problem faced by the elderly users." – Student A
>
> "Since my class of users was for the blind, the project has pointed out much differences that a few changes can make in the lives of the blind and how their life can be made easier and letting them be more independent. Brainstorming and looking out for other risks were also a part of the project in which the learning process was very fun." – Student B
>
> "The LCL learning has done just that – make us understand the importance of constantly having to keep up with the vast paradigm shift and adjust accordingly. Buildings cannot stay the same forever. The facilities provided are especially important for a functionally friendly building to the users. A good example is the project handed to us during LCL learning which is to understand and apply the newly revised barrier free act and incorporate it to shopping centers." - Student C

(NB: Names of students have been anonymised.)

Develops collaborative and team-based work skills

Students developed and sharpened their team-based work skills as the project required them to establish project team goals, a work plan, member roles and responsibilities, a team communication plan indicating the channels of communication (including e-platforms and tools) to be used by the team and a plan to monitor the progress of the project.

Sharpens professional communication skills

The project required them to plan for and establish communication with Building Management in order to seek and gain permission to conduct an on-site building audit. They also had to plan for and conduct information gathering exercises such as interviews and surveys.

Students also had to construct a report of their audit findings and recommendations to be presented to and critiqued by their classmates.

Sharpens Professionalism

The project enables 2 key professional and ethical practices to be honed:

- Respect for the rights of property owners and users of the property where students must first seek permission from building owners to conduct the audit, and then seek permission from users to gather information and use it for their purposes.

- Respect of intellectual property and the use of information and original works. Students must ensure that their work is their own and that they have acknowledged and cited all sources referenced appropriately.

Develops e-competencies

The nature of the project made it necessary and natural for students to make use of e-tools and platforms to enable the collaboration, productivity, and professional presentation.

For example, to decide on a building to audit and to plan for such an audit, students need to find out information about the particular building and about the Code. To do so, they had to hone their information search skills using the various internet search engines and the appropriate library databases.

Another point at which e-tools and platforms were the natural work partner for the students was for working collaboratively across time and space in between in-class times to collect, document and log information and data on-site during the audit. Tools used by students for these purposes included the wiki, blog, discussion forums and Flickr.

CONCLUDING REMARKS

As a conclusion this paper reviews 3 common arguments against the use of experiential and active learning approaches such as what has been adopted in the module 'Building Refurbishment'.

The approach is time and resource ineffective

Students need more time and effort to learn about a small aspect of what can be covered in a one or two hour lecture on the topic. Tutors have to expend more time and effort tracking and coaching different groups of students who may be at different points of development at any one time.

The experience with Building Refurbishment.

Project-based learning in the Building Refurbishment module has indeed required an investment of student and tutor time and effort. However, as can be seen from the outline of benefits gained (as described in the section above), content coverage by the lecturer has been exchanged for a multi-faceted, more holistic learning and development of the students.

Such approaches work if students are interested, motivated, and mature

Students need a certain level of motivation and maturity to self-direct. Students at Polytechnic level may therefore not be able to benefit from such a learning experience.

The experience with Building Refurbishment

As can be seen from the examples of student reflections in the section above and in Appendix B, despite the fact that such active and experiential learning experiences require more effort , energy, time, and self-direction, student satisfaction with their learning and development is positive (See Appendix B for student feedback on the whole module).

The assessment of student knowledge is more subjective than in a more content-centered, examination-based approach

It is difficult to ensure fairness in the assessment of students' performance in projects of this nature.

The experience with Building Refurbishment

This is an area for further work and enhancement for this module. While there are currently points at which the tutor assesses the work, points at which students give peer reviews, and points at which students self-evaluate through their reflections, a clearer outline of the assessment points and their respective objectives and rubrics would help to pace and guide both the students and their tutors through the process.

Biographical Information

Mok Thai Koon is a Lecturer in the School of Engineering at Ngee Ann Polytechnic. His background includes 12 years of site construction and management experience in the private sector. He teaches Building Refurbishment and Advanced Building Technology.

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APPENDIX A: PROJECT SCHEDULE

The students are briefed on the project during 5th week of the term. Two consecutive weeks of lectures and tutorials hours (6 hours) were allocated for this project. Presentation of the project will be done during the first week of term two.

Table 1
Project Schedule

Tasks/Activities	Timeline
1. Preliminary discussions among team members - Decide on the building to audit. Research on the historical background of the building. Read up the Code on Accessibility in Building Environment.	Week 06 (Term 1)
2. Site assessment – Site survey and audit existing conditions. Take video/photos and conduct interviews if permissible. Begin working	Week 07 (Term 1)

on the report and submit the report by end of the week	
3. Presentation and give comments on other groups' proposals.	Week 13 (Term 2)
4. Write their reflection on discussion board in MeL.	Week 14 (Term 2)

APPENDIX B: MODULE EXPERIENCE SURVEY

Summary of Oct 2008 Module Experience Survey on the module 'Building Refurbishment'

- 93% of students agreed that the module helped them to develop useful skills and knowledge
- 91% of students agreed that the module stretches their thinking
- 98% of students agreed that the teaching and learning approaches are appropriate for this module/project.
- 93% of students agreed that the module activities enhanced their overall learning.
- 86% of students agreed that the module provided a good learning experience.

FACILITATING THE LEARNING ENVIRONMENT: INITIATIVES WITHIN THE PIEp RESEARCH SCHOOL

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ABSTRACT

Research schools have become common phenomena in the academic world. However, we find lack of studies investigating their influence and role in the academia. This study attempts to address this gap by describing how a specific research school has evolved into an effective learning environment for the enrolled PhD students. The Product Innovation Engineering program (PIEp) is currently the largest research initiative in Product Innovation in Sweden. The PIEp research school is a part of this program, with the aim to increase innovation capabilities in the Swedish industries. Through an action-based research approach the authors, who are research school participants themselves, present the processes and the chain of events to offer knowledge transfer and to give insight into this special research environment. In this pursuit, the findings are presented in three different themes,1) the role of common interest groups, 2) common interest group activities, and c) a tiger team workshop. This paper holds major implications for other research schools and funding organizations.

KEYWORDS

Learning environment, product innovation engineering, research school, common interest group, tiger team

INTRODUCTION

Student Centred Learning Environments (SCLEs) is a generic description of different learning methods that strive for improvements (e.g. problem-based, project-based, open-ended learning environments, constructivist learning environments) [1]. Instead of forcing direct instructions, SCLEs focus on how information can more effectively be conveyed by teachers and understood by learners (i.e. students). Fundamental to these learning environments is the affordances they provide learners for effecting their environment and making meaning. To become efficient learners, it is important that the design of a learning environment pay attention to four basic issues: the role of context, the role of content, the role of facilitation, and the role of assessment [2]. This paper will try to address these four pillars as the evolving learning environment of PIEp is presented.

In the last decade, it could be seen that there is an increased focus by national and international funding organizations for promoting graduate research schools. Their popularity has grown due to an increased focus on effectively handling national and international problems. Many would also argue that the research schools' unique organizational structure and revolutionary role in promoting learning makes them an attractive consortium. However, until now there is hardly any official consensus regarding the characteristics or definition of a research school [1]. In the authors' opinion a research school can be regarded as a collaborative learning environment where researchers from different disciplines and universities work together for a common purpose. These individual researchers are the core of such a research school and the outcome from the research school largely depends on their initiatives. These individuals can be PhD students, under-graduate students or even senior researches. However, this study mainly focuses on the PhD students and how the research school promotes a learning environment.

In a short time span, Sweden has become renowned for establishing several research schools. For example, a recent program was the Engineering Design Research and Education Agenda (ENDREA) and its research school, the ENDREA graduate school (EGS). This was a part of the ProViking research program, which was financed by the Swedish Foundation for Strategic Research [3]. The EGS program was initiated with the aim of educating licentiates and doctors with certain key capabilities, which were believed to be demanded by the Swedish industry at that time [4]. Although, similar in several aspects, research schools also have differences between them; in particular, the management model, number of universities involved, funding provided to PhD students, and most importantly the goal in focus.

A recent addition to the Swedish research schools has been the Swedish national Product Innovation Engineering program (PIEp) research school, which is the largest research initiative in Product Innovation in Sweden. There were 20 PhD candidates involved in two kick-off meetings in March/April 2008. PIEp follows an unusual management model where individual researchers are enabled to self-determine their contribution and their role in the school. This program aims at promoting innovation driven research as well as the transformation of these research results into commercially viable products and services. Thus the financial investment is returned to society by new value and possibly by newly created companies. As this is the target of the program, which will be outlined in the following sections, we make an attempt to explain how after the first year of its formation, the management model and other initiatives have led to a possibility for a better learning environment for PhD students. It is important to clearly state here that, in Sweden, the higher education is partly adapted to the Bologna system of three cycles (3-2-3). In the last cycle, the PhD level, Swedish doctoral students are employed by the university and, in most cases, also conduct lecturing tasks and supervision of students.

Within the CDIO initiative, the authors have found common ground in terms of focus on functionality: a shift from analysis to synthesis, from the traditional top-down-organization of education to student responsibility. In a previous article [8] describing the overall PIEp program, the utilization of the CDIO framework in the design of PIEp is outlined. This previous article [ibid] focuses on the undergraduate activities of PIEp and the step is hereby made to include the CDIO framework in the graduate education (the research school) as well.

Thus, the purpose of this study is to describe in a narrative form how the PIEp research school has evolved into an effective learning environment for the PhD students. The reason for our focus on PIEp is driven by two rationales: first, its reputation for being the largest research initiative in Product Innovation in Sweden and, second, due to our active involvement in several PIEp activities, we have the possibility to provide detailed insights. The context of the investigation of this study is the research schools, as it is relatively rare

and new in the literature. We have struggled to find similar studies with focus on research schools as an effective learning environment for PhD students.

METHODOLOGY

The study presented is based on the events and experiences from the newly founded research school of PIEp. In an action-based research approach the authors, who are research school participants themselves, present the processes and chain of events to offer knowledge transfer and to give insight into this special research environment. Interviews with other enrolled PhD students and board members, focus group discussions and archival analysis further add to the foundation of the study.

PRODUCT INNOVATION ENGINEERING PROGRAM – PIEp

In 2006, a large scaled, long-term national program was launched to enhance product innovation engineering capabilities in Sweden. Its roots had already been planted the year before by representatives from the Royal Institute of Technology (KTH) in Stockholm, Sweden together with a number of other universities. With confirmation of government funding in 2006 [5], the program was named Product Innovation Engineering program, abbreviated PIEp [6]. Today six universities or nodes participate in the venture: Luleå University of Technology (LTU), The Design Institute, Umeå University, the Centre for Technology Medicine and Health (KTH and the Karolinska Institute), Jönköping University and Faculty of Engineering, Lund University.

PIEp's management, and the enrolled researchers, are committed to a system change towards innovation and entrepreneurship in institutes of higher education and research [7]. An organized network of senior researchers, PhD students, lecturers and students is seen as the seed for this change. In three areas of activity, namely research in product innovation, education for product innovation and industrial collaboration for product innovation [8], the development of new innovative products and/or new businesses is promoted. Therefore the program spans from theoretical to practical aspects, from research in innovation to directed activities aimed at strengthening Swedish innovative product development. PIEp's implantation embraces efforts in research, education and development projects. The first mentioned will help to understand and make use of the innovation process in a scientific environment. In educating students and PhD students, this knowledge is transferred to the next generation. Creative sessions and the building of networks promote the innovation climate towards participating industrial partners. This study focuses on research and education and will therefore only briefly return to the involvement of participating companies.

PIEp Education

PIEp's structure comprises five activity fields. Two fields focus on process and organization oriented research for innovation (innovation knowledge and innovation management). Two further fields relate to product and business oriented development (innovation experience and innovation business). The core, however, merges the fields above and focuses on education (PIEp Education). Feedback, knowledge and experiences are communicated all across and between the five fields. Figure 1 below illustrates the 'resource system' and learning environment of PIEp together with some keywords and key activities of the respective activity fields [9,10,11].

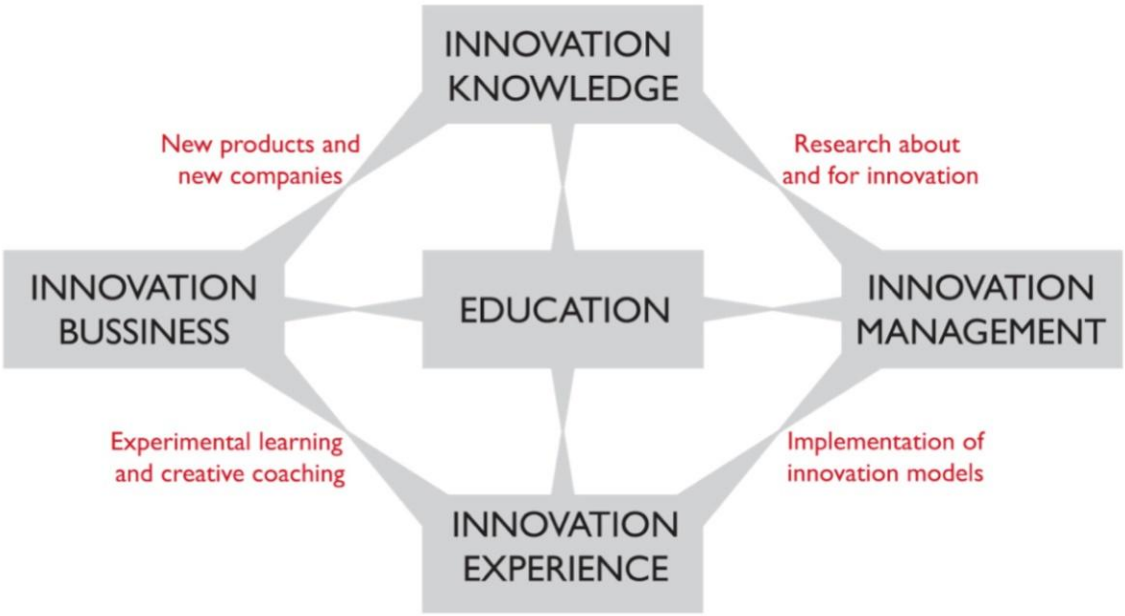

Figure 1. The Learning Environment and Resource Domains of PIEp.

The main activities involved in PIEp Education include a research school for doctoral students, a network for teaching personnel, promotion of new courses in innovation engineering, exchange programs for students, and better utilization of all existing mechanisms to aid the commercialization of new ideas. A bottom-up approach, which ensures alignment with the objectives of PIEp at an early stage, has been selected as the most promising strategy. The whole expertise in the entire PIEp network can thereby closely communicate.

The overall goal of leading and supporting a system shift of higher engineering education toward increased innovation and entrepreneurship depends highly on PIEp Education and the notion of 'students as agents of change'. The structure and all mechanisms in PIEp are primarily designed to achieve this goal.

PIEp Research School

The PIEp research school aims to educate PhD students with distinguished qualities. As a PIEp-student, you act as an ambassador equipped with a new thinking that embraces innovation experience and innovation management [12]. Creating a changed mentality is an important change mechanism as competent and growing networks ease the entry of innovative businesses. Each PhD student is responsible for making use of the activities that are posted and circulated within the research school. With individualization behind the selections made, the PIEp intention is to support and lower all forms of thresholds.

In the planning to stage a new research school program, medical technology was seen as historically important in the Swedish industry. However, without the capability to successfully convert substantially good ideas into products, most realizations have occurred outside of Sweden. Sponsored by governmental funding, one of the first objectives became to find ways of promoting new domestic ventures before losing track of the competences that drive such opportunity [13]. In March/April 2008, the first 20 PhD students were invited to two kick-off workshops at Stanford University and in Minneapolis, respectively. The first addressed engineering and business students and the latter focused on medical technology.
As a result of these two workshops, the milestone of the research school began to take form:

- A financial budget (individual virtual ‘backpacks’) enables the PhD students in the program to travel to other universities and to meet national and international key players.
- The formation of networks is supported that concentrate on specific problems and bundle competences to find solutions.
- Because of the aim to increase utilization of research results for new products and businesses, creating synergies between innovators, innovation researchers and coaches is named as the third fundamental.
- Finally, every PIEp PhD graduates with an additional certificate stating her/his successful participation in the program. This certificate is introduced as a proof of excellence and of successfully applied research.

Formal meetings within the PIEp PhD research school are held bi-annually; a meeting during the fall, and a workshop in spring. The first has always been held at the KTH in Stockholm whereas the latter is preferably held abroad. These meetings serve as an opportunity for PhD students to communicate, reflect, plan and network. Important decisions are usually made during those meetings when all PhD students are present and able to contribute.

Between the two annual meetings, informal meetings are arranged in Stockholm which, due to its size, is the home to a greater portion of the involved PhD students. The location varies and aims to inspire communication so that the PhD students can stay updated on each others’ research. The third opportunity to meet other enrolled PhD students is provided by workshops and events arranged by the common interest groups, so-called CIGs.

Empowering the PhD students

The management model in the research school differs from the traditional graduate research school structure. The participating PhD students are given a great share of influence on the direction of the program but nonetheless they are also expected to take responsibilities for their actions and decisions. For example, the financial “backpack” serving the students in their travel ambitions has to be used carefully as it would not last for infinite journeys to conferences and meetings.

Proactive students can find great support in the research school when they can convince and motivate others towards their vision. Each student is encouraged to make a difference. Every student may influence the next upcoming goal, workshop or any other event. The openness for new ideas and innovation is reflected in the dynamics of the research school. The willingness to test prototypes is not restricted to product design. Driven by pro-activeness, the PIEp research school organization workshop (Hamburg) was the result of three dedicated PhD students. A *loose reigns* management style allowed individual PhD students to take charge of the entire scheduling and planning, which is rare in other research schools.

Common Interest Group (CIG)

During the Hamburg workshop, five areas of specific interest to the participating students were identified, which later were formalized into the formation of CIGs. Existing CIGs mainly have the intention to influence research by sharing, reflecting and producing excellent research. The CIGs at PIEp are also capable of initiating activities within PIEp and thereby create and influence decision-making within PIEp. To provide uniqueness between each CIG, formation is made with regard to the PIEp relevant research areas where dissemination to new and existing members has a catalyzing effect. The currently active CIGs are:

The Medical Technology (MedTech CIG)
This CIG comprises researchers interested in any kind of medical engineering with the purpose of offering new possibilities for cooperation, supervision, feedback and, in general, new ideas. The strong emphasis of the research school on medical engineering is reflected by the size of the group. CIG meetings are scheduled regularly to exploit the group members' various backgrounds and competences for each of the PhD thesis projects. Synergies, such as sharing and borrowing laboratory equipment, have been identified and the first study originating from this CIG's work has just been planned. Furthermore, a paper about medical engineering PhD students' views on innovation education has been submitted to an international design conference and the work will continue. Subjects like this, which are not in the PhD students' research focus, can be addressed and investigated within the CIG, where a single PhD student would neither have the time nor competence to work on such a topic beside the PhD thesis.

The Open Innovation CIG (OICIG)
This CIG mainly focuses on the researchers related to product innovation development at a company level. The CIG consists of eight PhD students and one senior researcher from an engineering and business background. The group has regular phone meetings, writes several scientific papers in collaboration, maintains an internal blog and regularly shares information. Recently, one of their initiatives was to develop a PhD course in open innovation for the PIEp research school, mainly driven by the motive to make other PIEp PhD students better understand the emerging field of innovation. To better understand open innovaitona workshop was put together with Dr. Ulrich Lichtenthaler from WHU - Otto Beisheim School of Management (Germany). As an acknowledged scholar, he is one of the leading researchers in the field of open innovation and technology management. During the workshop heprovided with a detailed review of the research field and gave feedback on PhD students' work-in-progress. These kinds of initiatives can be seen at contributing to the overall research school knowledge.

The Innovation Capability CIG (ICAP)
The focus of this group concerns internal and external factors that influence our innovative capability. The purpose is to enhance participants' interest and research areas, highlighting factors such as creativity, commitment, collaborative skills, team dynamics, user preferences, and business processes. Currently, participant focus has been to stage the prioritized dilemma of promoting creativity in class. An upcoming workshop on creativity and its applicability in education aims to share and increase the collective knowledge in the area. Also, sharing experiences have been achieved with international group members at Stanford. Ongoing plans propose the idea of using a real time interface to share and analyze team projects by peers with different perspectives. About nine people are involved in the CIG, the majority of whom are senior researchers. The common denominator with the active PhD students is an interest in team dynamics, and facilitation of education in NPD projects.

The CIG for Cognitive Aspects of Innovation (CAI)
The purpose of this CIG is to build a network of PhD students and researchers that are interested in learning more about the cognitive aspects of the innovation process. The CIG consists of six PhD students who all have an interest in a better understanding of the cognitive aspects of innovation. That is, those aspects related to how individuals and organizations learn, how people communicate with each other, create concepts and make sense of the world. To give a few example of their focus, the following questions can be used: How do power and trust between people influence the process of knowing? Is innovation an emergent process impossible to be designed and managed? How are practical solutions for supporting cognitive aspects going to be developed? The group stays in contact; especially their 'core group' that consists of three to four CAI members through mail and phone conferences.

The International Relations CIG (IRCIG)
People with extensive personal networks, and those interested in cultivating new and existing contacts, gather in this CIG. Three nationalities amongst the group members represent this intention and the amount of countries they have lived and/or worked in is much greater. The group also has a strong interest in organizing events. So far, two workshops which were organised by the IRCIG have successfully been held and further workshops and meetings are in the planning stage. For instance, an upcoming summer school is planned in relation to the annual ICED conference at Stanford. One detail which differs for the IRCIG if compared to the other CIGs is that membership acquirement requires a higher threshold of participation and active planning processes to ensure a continued high dynamics in the group.

The Management CIG
The Management CIG was the latest addition to the exiting CIGs. During several internal meetings it was felt that the level of internal communication was low and some CIGs were working in isolation. Another challenge was related to decision making: it was not possible to make quick decisions during the usual PIEp workshop, especially when all participants were present. Thus, the management CIG was established involving the CIG coordinators and the research school head. The coordinators represent their CIG's interests and also make decisions on its behalf; these decisions or pieces of information are communicated through them to their respective CIGs at a later date. During December 2008 they had the first meeting near Stockholm and several issues regarding the future were discussed. Also an internal website was launched which was maintained by the CIG coordinators.

Research School Activities

The PIEp research school mainly organizes activities for doctoral students. Most of the PhD students are employed and funded by their node university or an industrial partner. However, the research school provides a nurturing learning environment and complements the respective universities' education by providing national and international networks possibilities, though its mobility programs and funding support. For example, a PIEp doctoral student can utilize the 'backpack' funding support to participate in courses at other universities, or get involved in international/national/industrial rotation, or help the establishment of CIGs among the PIEp network of doctoral students. Activities are held at the local node universities as well as in cooperation with PIEp's international partners. Rather than focusing on explaining how the research school initiatives can be viewed as a learning environment, we will present, in a short historical overview, different activities, which have be fulfilled in the last year.

- Within the first eleven months of the research school, six medium sized (i.e. including 5 to 10 PhD students) or major sized (including 10 PhD students or more) workshops have been conducted. Organised and coordinated by the CIG for international relations, where all PIEp PhD students were invited for a three-day workshop in Hamburg, Germany. Networking opportunities with related researchers from two German universities and two Japanese universities were initiated. The major amount of the time was however spent improving internal networking and working on team building activities. The CIGs, which now form the backbone of the research school's structure, were founded during this period.
- During the fall of 2008, a Tiger Team Writing Workshop (TTWW) was held at the most northern node of PIEp, Luleå University of Technology. A so-called Tiger Team is a group of experts from multiple disciplines cooperating to solve a specific problem at the highest efficiency and effectiveness possible. The TTWW was organized to aid in research and to specifically promote conference articles for the International Conference on Engineering Design (ICED) conference at Stanford, USA, in August 2009. Follow-ups during the next 6 weeks ensured that milestones were

accomplished and that feedback by experienced senior researchers was given to the PhD students working on the various papers. The process was highly dynamic. Eventually 12 papers were intended for submission to the ICED conference, but 13 additional papers were planned and written as well (please refer to Appendix A for a matrix of the papers written). Although the official supervision ended with the deadline for paper submission to the ICED conference, the cooperation started during the TTWW and its appending period. Most cooperation continued beyond the ICED topic. The current study may be considered as a proof.

- In October 2008 the MedTech CIG held a workshop in Stockholm, at one of the PIEp nodes. Joint research activities, and the use of synergies, were discussed while visiting the local laboratories. This activity was followed by a second MedTech CIG workshop at the end of March 2009. This time the environment was the node in Jönköping to provide the possibility of viewing a different lab in order to provide a deeper insight into one another's research possibilities.
- Invited by a senior researcher within biomedical engineering, the CIG for international relations travelled to the University of Strathclyde in Glasgow, Scotland in November 2008. The foundation for collaboration was laid and will be further evaluated during 2009. Several research projects on both sides are liable to profit from a joint effort. Further meetings and discussions have also been scheduled with entrepreneurial researchers from the Hunter Entrepreneurship Centre at University of Strathclyde.
- In November 2008, a two day research school annual meeting was organized. During the first day there was a parallel session where the CIG coordinator used the opportunity to hold an internal meeting. As most of the CIG members are located in different parts of Sweden, this kind of meeting provides an excellent opportunity to meet each other. Later in the day there was joint meeting where the research school participants met with the PIEp board members. The second day was used for exchanging information about each CIG's past events, lessons learned and future plans.
- In addition, other activities scheduled for 2008 concluded with a LEGO workshop held by the CAI CIG. The group invited an external lecturer using their given budget and personal networks. This opportunity was very successful and inspiring to the participants. In March 2009, the CAI group continued with a one-day workshop on psychological aspects of innovation. In May there is an upcoming ICAP creativity event that addresses how to inhibit improved ways in working with creativity in education. As mentioned earlier, the latest workshop has been an internal meeting of the MedTech CIG which will be continued in June. One of the four further activities planned before September 2009 is the summer school which will be held in conjunction with the ICED conference at Stanford, the most prominent one.

PIEp AS A LEARNING ENVIRONMENT

PIEp was established with the aim to foster innovativeness within the Swedish society and this is supposed to be achieved by having several PhD research projects transformed into commercially viable businesses. Thus, the research school was created with the ambition of having the possibility for students from different disciplines to meet, interact and learn from each other. In many ways this was a learning environment, which worked as a support for PhD students with innovative ideas to find other students with business or other background and to try to think about possible ways in which they could sell their idea or business.

In literature 'learning environment' is often mentioned in context with several other terms that give us some ideas about the definition. These terms are interpretation, meaning making, contextualized, authentic, socially negotiated, co-constructed, collaborative, articulation and reflection, emergent, self-regulation, fluid [1]. Being a successful learner, in the case of PhD students, involves a variety of cognitive strategies and self-regulation procedures to plan and

pursue goals. The PhD students are also faced with ability, and motivation to interpret new knowledge, formulation of questions and openness for continuant reorganizing of thinking. These are fundamentals that basically are quite open to everyone that has a desire to learn. However, given the context of a unique CIG, each participant has includes his/her own research interest into the specific group. And based on individual excitement and motivation to participate the first indications have begun to emerge.
In the pursuit of explaining how the PIEp research school has evolved into an effective learning environment for the PhD students. We would like to discuss three different themes, 1) the role of common interest group, 2) CIG activities and, 3) Tiger team workshop.

The role of common interest group: The creation of CIGs was one of the cornerstones in the short history since the establishment of the research school because PhD students have since then been able to work with those students with whom they share similar interests. Further, to enhance the possibility for higher interaction and learning, CIGs have been given freedom to decide independently and to use the assigned funding to support the decisions. This means that they have been able to use their funds to interact with the other CIGs, to meet well know researches and, finally, to arrange workshops/seminars. The role of each CIG coordinator has been pivotal here as he/she has been responsible for the information flow into and out of the CIG towards the rest of the research school. Finally, some challenges which emerged due of formation of different CIGs were resolved by the function of a Management CIG. Thus, we believe that it is not an overstatement to propagate CIGs as a free environment supporting collaboration, interaction, and learning.

CIG activities: In the previous section some of the key activities conducted by the CIGs (e.g. LEGO workshop, creativity in education, etc) have been highlighted. It is important to understand the logic behind having these activities. Usually the activities are organised to eliminate some form of limitation or to satisfy curiosity within a particular CIG, but the impact of such actions have far reaching effects. When students meet during a workshop or other sessions they are given the unique opportunity to learn and reflect on new ideas and thoughts which otherwise would not be possible. There is an additional advantage: Students' perception of belonging to the research school increases and they associate themselves with the research school due to these regular events. Sometimes this has been referred to as the *"PIEp spirit"* within the research school. This shows the type of a comfortable and meaningful environment which the research school has been able to establish within its short lifetime.

Tiger team writing workshop (TTWW): The reason for choosing to elaborate on this particular workshop mainly relates to the ambition to present, in a very academically driven argument, the research school as a learning environment. The TTWW is one of the recent major group events and it should be pointed out that several PhD students had already established their formal and informal ties prior to TTWW. So when the possibility to write a paper together appeared, students could easily and quickly form different groups and start the discussion regarding possible papers. In total twenty-five paper ideas were formulized and discussed by twenty-two participants. Furthermore, each participant contributed by being the reader of other papers. Most of the papers were aimed for the well-known conference in engineering design (ICED09). From the twelve papers which were sent to the double-blind peer review process, nine were accepted. Given that most of these students had not worked together earlier nor had planned for the papers and large numbers of students have background in Medtech field writing paper for engineering conference was troublesome. However, TTWW s shows an excellent example of the nurturing environment of research school. Also when not all papers were accepted for the conference students learned a lot from the paper-writing process they also got a chance for academic recognition.

THE PIEp RESEARCH SCHOOL AND THE CDIO INITIATIVE

PIEp and CDIO share the same ultimate goal – to produce the next generation of engineers based on an increased need for a system change of traditional engineering education. Both initiatives are founded on heavy industrial support and massive engagement from academic institutes and individual educators – all eager to cross the chasm between slow-changing academia and the need for new skills required in real world engineering. By focusing on these skills, the CDIO initiative is also characterized by strong influence of student-driven courses, projects and interdisciplinarity – that all constitutes examples of a teaching and learning reform.

From a PIEp perspective, the CDIO initiative clearly shows 'how it could be done' – as a manual of how to create the reform. Further, the focus on student-driven activities in a PIEp perspective clearly promotes entrepreneurship and entrepreneurial students. By joining forces it is also clear how these two initiatives can help each other reach the ultimate goal and also how the CDIO initiative can be applied to post-graduate education, for doctoral students in a research school.

CONCLUSIONS

We believe that the PIEp research school within its short history has been able to create and maintain an effective learning environment. There are several lesson learned which can be implemented or adopted by other research schools, and also provides valuable feedback to the CDIO initiative. One of them refers to the advantage of having students taking initiatives in the operations and direction of the research school. However, we are also concerned for how this research school is set to be developing as it has only recently begun to take its form. With current global uncertainties, even academia must be prepared for changes. Plausible changes should be able to cut in on management rigidness and inflexibility, emphasizing self-directedness, motivation and commitment by students' initiatives. Finally, we would like to motivate other researches to reflect on our study and present their experiences from other research schools. There is still a lot to learn about how research schools should be organized and managed.

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Biographical Information

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Appendix A

		CTMH	CTMH	CTMH	CTMH	CTMH	CTMH	KTH	KTH	KTH	KTH	KTH	MdH	MdH	HiG	HiJ	LTH	LTH	LTU	LTU	LTU	LTU	LTU
		Frida	Dennis	Carl	Nina	Rickard	Xiaogai	Ernesto	Anders	Ingrid	Diana	Martin	Stefan	Joakim	Lars	David	Per	Malin	Vinit	Pär	Christian	Peter	Andreas
1	Further Development of VIPET in Industrial Design Practice **(ICED'09)**																L						R
2	Decision Making in the Virtual Enterprise **(ICED'09)**													R					C	C	L		C
3	Open Innovation Capabilities for Small Firms **(ICED'09)**		R										C		R				L		C		
4	The Design Process in Small Companies **(ICED'09)**							R							L				R				R
5	Best Practice in NPD - A Concept Suitable for the Small Company?														L				R				
6	Open Innovation - Quite Natural for the Innovative Small Company														L				C				
7	"If we are strategic we die"		R	R	R										L							R	
8	The Innovative Idea Generation in Small Companies			R											L				R			R	
9	Selection of Innovation Ideas in Smaller Companies			R				R					R	R	L								
10	Packaging Innovation **(ICED'09?)**				R													L					R
11	Measuring the User Centered Innovation Process			L															R	R			R
12	Performance Evaluation SOTA **(PMA'09)**			R							C		L	R								R	
13	Performance Indicators as Support in Complex Product Development **(ICED'09)**										L		C						R			R	
14	Pushing the Limits of Lessons Learned								R			R	R							L	R	C	
15	Redefining Decision Making in Innovation #1							L		C				C							R		
16	Redefining Decision Making in Innovation #2 **(ICED'09)**							C		C				L						C	R		
17	Redefining Decision Making in Innovation #3							C		L				C									
18	Research Perspectives **(ICED'09)**							L				R		C									R
19	Idea Evaluation and Selection							L					R	C								R	
20	Decision Making in Disruptive Innovation							L															
21	Learning, Knowledge, Decision Making							C						C							C		
22	Learning in a Stage-Gate Process **(ICED'09)**											R	R	C						C	L		
23	CTMH - in Transition Towards Innovation Driven MedTech Research **(ICED'09)**	C	C	L	C	C	C									C							R
24	Embracing Entrepreneurial Behaviour in a Research School	R	C		R				C			R					R		C				
25	PIEp Research School - Educating Innovators	R	C				R	R				L					R		R	C		C	C

NOTE: It is up to the LEAD AUTHOR to discuss with and decide about eventual CO-AUTHORS. READERS can be added without discussion with the LEAD AUTHOR.
E-mail Andreas.C.Larsson@ltu.se if you would like to be added as a READER. Contact the LEAD AUTHOR if you would like to be a CO-AUTHOR.

L = LEAD AUTHOR	L
C = CO-AUTHOR	C
R = READER	R
TEAMS CALLED TO STATUS UPDATES	

Matrix visualizing the papers originating from the TTWW and the authors per paper

First and Fourth Year Design-build Team Projects: a Comparison

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ABSTRACT

The new Software Engineering degree program has been designed as a collaborative effort between the School of Electrical and Information Engineering and the School of IT at the University of Sydney. The design of the new curriculum is based on the ACS, ACM and IEEE curriculum recommendations and the Software Engineering Body of Knowledge (SWEBOK), as well as the results of a detailed industry review. Close attention was paid to Computing Curriculum 2001 (CC2001) and to Software Engineering 2004 (SE2004). The CDIO framework was used to ensure the new program incorporates the full set of knowledge, skills and attitudes that students should possess as they graduate from university. As part of this exercise, team projects are being introduced to all years of study, from first through to fourth year. This paper compares team based student design-build projects taken by students in the first and fourth years of study. The objective is to determine what changes there are, if any, in the students' approach to their projects in terms of the CDIO principles. The students' approach is assessed for conception, information gathering and analysis, experimentation (where necessary), design process, implementation, testing and presentation. The results indicate a broad improvement in approach. The paper will present results in each of the above areas and make some recommendations concerning the imparting of CDIO skills.

KEYWORDS

CDIO, curriculum design, design-build experiences

INTRODUCTION

The new Software Engineering degree program implemented in the School of Electrical and Information Engineering at the University of Sydney is based on the Australian Computer Society (ACS), the American Association of Computing Machinery (ACM) and the Institue of Electrical and Electronic Engineers (IEEE) curriculum recommendations along with the Software Engineering Body of Knowledge (SWEBOK), as well as the results of a detailed industry review. Close attention was paid to Computing Curriculum 2001 (CC2001) and to Software Engineering 2004 (SE2004) both published jointly by the IEEE and ACM. The CDIO framework was used to ensure the new program incorporates the full set of knowledge, skills and attitudes that students should possess as they graduate from university.

The philosophy of the degree program is to produce graduates who combine a high level of software skills with the design approach inculcated by an Engineering education and who will be able to apply engineering principles to the problem of managing complexity in the design of large software systems, ranging from global scale distributed enterprise networks to embedded systems, including components of software, systems, telecommunications and engineering management. Typical graduates might lead the development of complex

software applications in specialist areas such as banking and insurance, telecommunications, real-time systems, multimedia and industrial control, bringing to bear skills in disciplined engineering design and a systems engineering approach.

In order to equip graduates with the skills they need for the modern workplace, the new program has introduced project-based learning extensively through all four years of study, following the recommendations of the CDIO framework and modern PBL trends. This paper describes two of the design-build experiences used in the first year introduction to engineering course and one of the final year courses and compares the students' approaches and performance to determine if they are acquiring both the technical skills and team skills we seek to impart.

Alignment with CDIO

Conceive

Conceiving of software systems is dealt with in several ways. In the team projects in years 1, 3 and 4 students are expected to brainstorm and then refine their ideas by applying fundamental mathematical, abstraction and modeling skills. Mathematical thinking prepares students for all stages of system development from design to the correctness of the final implementation [ACM Communications, September 2003].

There is thus a strong focus on mathematics during the first year (12 credit points), along with foundation units in Software, Computer Engineering and the Engineering Profession. In second year a full unit of discrete mathematics and graph theory is offered. Software abstraction and modeling skills are developed in most units, particularly in INFO2110 System Analysis and Modeling. In the electives, students may study domain specific modeling in depth, for example in ELEC5614 Real Time Computing.

Software Design

A core issue in CDIO is that of Design, and this is dealt in the program in INFO1103 Introduction to Programming, INFO1105 Data Structures and INFO3220 Object Oriented Design which build students' skills in software development, covering object-oriented software development with design-by-contract, which is the state-of-the-art in industry. Students are then expected to use these skills in the team project in 3rd year and the research project in 4th year. Part of the design process includes Software Risk Analysis, which is dealt with in depth in INFO2110 System Analysis and Modeling. ELEC5618 Software Quality Engineering addresses risk as an essential issue in any software project.

Software Implementation

Implementation issues are addressed in INFO1103 Introduction to Programming and INFO1105 Data Structures in first year, and then at increasingly advanced levels in the later years to considerations of large scale systems in COMP5348 Enterprise Scale Software Development. Domain specific implementation issues are considered in recommended electives such as Real-time Computing and Multimedia. A key part of the implementation process is Software Testing, Verification, Validation and Quality Assurance

These topics are addressed in INFO2110 System Analysis and Modeling, the Software Design units and ELEC5618 Software Quality Engineering. The concepts are reinforced in all the software development units and students are required to demonstrate their skill in this area in the software project.

Operate

Software operation requires installation, configuration and maintenance. Maintenance of large software projects can be very expensive, consuming more resources than the C, D and I phases combined. These issues are addressed in INFO3402 Management of IT Projects,

ELEC5618 Software Quality Engineering and COMP5348 Enterprise Scale Software Development. INFO3402 is taught by a team of industry professionals.

Team Project Based Learning

CDIO emphasizes the need for students to undertake authentic, team-based activities, termed Design Build experiences onto which more abstract learning can be mapped (CDIO Standard 5, Crawley 2007). These also provide the natural context in which to teach many CDIO syllabus skills such as teamwork, communications, designing and implementing. Although the software engineering process is treated specifically in INFO3402 Management of IT Projects, it is instilled in students from the word go in all relevant units. Problem-based learning is used, in conjunction with increasingly demanding projects, to introduce design-by-contract, refactoring, good abstractions, high-level terms including pre- and post-conditions, ability to produce a design with appropriate information-hiding, evaluation of the quality of a design, verification and validation, etc. Students are expected to display all of these skills in the 3rd year team project and in the 4th year engineering capstone project. Every student must complete a final-year capstone project (worth twice as much as other units), either individually or as a team. In the capstone project, students bring together all the wealth of knowledge gained over the previous 3 years. A wide range of topics are made available to the students, and they are also encouraged to suggest their own topics. Many students choose to undertake original research for this project; others may choose an industry-based project, working with an industry co-supervisor.

The outcomes of the final project comprise a working piece of software or system, along with a project report, typically of around 50 pages, including details of the project management. Students also give a 15 minute presentation on their work. The best 30 projects from all the degree streams in the School, chosen out of about 120, are then also presented at the Faculty's annual open day, to which many local industrial and commercial enterprises are invited.

Starting in first year, in ELEC1601 Foundations of Computer Engineering, students work in small groups, so they experience many of the issues of team interaction that are important in practice. Also, students take responsibility for planning their own learning to meet required objectives, so they will develop skills to learn from resources including reference materials and examples. As the program progresses, students undertake more advanced projects in the advanced elective units of study, leading to a full team-based project in 3rd year and a research-based thesis project in the final year.

In ELEC1601 students working in groups design, program and test a small system involving sensing and control. The project allocated in 2008 required students to assemble a small robot buggy kit, controlled by a PIC microprocessor and equipped with contact sensors and program it to negotiate a maze then at the end of the maze to move in a dance and play a tune.

In ELEC5614 Real Time Computing, the fourth year course, students used model-based engineering to design, program and simulate a parking garage management system for a parking garage on the campus which would sense cars entering and leaving each level and display at the entrance to the garage the total number of free spaces and at the entrance to each level the number of free spaces on that level.

Both projects required software development. The first year project required kit assembly and a visible physical result, while the 4th year project required simulation in Rational's Rose Technical Developer environment, requiring a mix of model-based engineering and coding..

Assessment

To facilitate comparison, both projects were assessed identically. Students were required to form teams, produce an initial individual assessment, proposal and project plan. The next

step was to submit a group design, followed by a group implementation progress report. This was followed by a group demonstration of the working system followed by an individual overall project report assessing the outcomes and including a reflective review of the project.

The first year buggy project demo took the form of a race-off of the buggys, which were required to traverse the maze in less than 6 minutes to qualify as have completed this phase. Only one team's buggy did not meet this requirement with times ranging from 2:10 to 5:43 minutes.

The fourth year project required the simulation to process a file of car arrival data. Students were given a test file for development and then had to process a different file for the demo, showing where the cars parked. The data only gave times of entry to the parking garage and to the section chosen. The software was free to place the cars anywhere in the section.

Both projects, following [14], required students to display innovation, to conduct research and experiments into the problem in order to optimise the solution, to manage the team by allocating work fairly and tracking and integrating its completion, dealing with time and resource budgets and show a connection between theory and practice.

Performance

As we wished to track improvement in the students' performance, we chose as metrics the following criteria shown in the table below. The four reports were submitted online and graded online using the WebCT learning management system. Students were given explicit instructions as to the requirements for each report For the demos, two external industry practitioners were invited to assist with the grading. Students' grading criteria were more stringent in 4th year, where students were required to show greater management skills and a more organized attack on the problem. Actual grades do not differ widely, indicating the criteria were met. The report and demo grades were released to the students, but the innovation through management assessments were kept for internal use only. For the 1st year projects, there were 171 students in 30 groups of 5 ot 6, while for the 4th year project there were 22 students in 7 groups of 3 or 4.

Table 1. Project outcomes

Requirement item/performance (out of 5)	4th yr	1st yr
Innovation – inventive solution	3.82	3.61
Modeling and analysis	4.31	4.05
Planning and project management	4.42	3.91
Theory and analysis	4.11	4.32
Time management	4.19	3.87
Team management	4.35	4.01
Report 1: Initial evaluation	4	3.58
Report 2: Initial design	4.29	4.33
Report 3: Implementation	4.31	4.28
Report 4: Quality of solution and reflection	4.06	4.45
Project demo and presentation	3.94	4.42

The most distinctive outcome from the evaluation is that the 4th year students were better at managing their teams. They also devoted more effort to evaluating the problem and planning their attack before coding. They were not as good at reflective evaluation. The final demo

results were also weaker, perhaps because the performance requirements wer more stringent.

Conclusion

The SE program provides a strong, up-to-date curriculum that is relevant to the needs of Australian Industry and meets the recommendations of EA/ACS, IEEE/ACM SE2004 and SWEBOK. It follows the CDIO framework and provides students ample opportunities to develop core skills, to specialize and to test their abilities in a series of projects that demand increasing capabilities through the four years of the program. Between the 1st and 4th year projects students show a clear improvement in approach, taking more care over the initial phases of analysis and knowledge acquisition and showing better management skills.

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FIRST YEAR DESIGN AND COMMUNICATION: CHALLENGES AND OPPORTUNITIES

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ABSTRACT

This paper reports on the challenges associated with running a design and communication program for a large cohort of first year students. By aligning the program's learning outcomes, learning activities, and assessment techniques with the CDIO syllabus, the authors show that there is the opportunity to realise the program's objectives in a sustainable manner.

KEYWORDS

Curriculum design, design-implement experiences, active and experiential learning.

INTRODUCTION

In the fall of 2002, the Schulich School of Engineering introduced a design and problem-solving stream to its first year, common core engineering program. This curriculum stream is embodied by two unique, inquiry-based learning courses: ENGG 251 (Design and Communication I) in the fall term and ENGG 253 (Design and Communication II) in the winter term. The idea for these courses came out of an internal engineering common core curriculum redesign process that began in 2000 that was intended to address recommendations by the Canadian Academy of Engineering [1], the Canadian Engineering Accreditation Board [2], and a University of Calgary curriculum redesign initiative [3], as well as address the needs of top-achieving students, re-balance faculty teaching workload, and increase the amount of "experiential learning" in our engineering programs.

In many ways, these courses appeared to achieve the original objectives set out by the 2000 curriculum redesign team. In particular, they demonstrated that it is possible to deliver a hands-on design and communication experience to 600 students per year in a design studio environment that is facilitated by an interdisciplinary team of instructors and graduate students. As well, the courses received a number of accolades from peers in the engineering education community (e.g., "best paper" awards [4] and [5]). However, this initial success did come at a price: as the first year cohort increased by 20% to 720 students per year in the Fall of 2006, the water level lowered sufficiently to further expose the rocks that had been lurking beneath the surface since the courses' inception.

In this paper we report on the challenges associated with running an experiential learning program of the size and complexity of ENGG 251/253. We begin with a summary of a recent study conducted by the Schulich School of Engineering into these courses. This study uncovered a number of issues relating to the courses' operation and the courses' relationship to the engineering common core curriculum. Most notably, the sustainability of the current operating model came into question: i.e., the long-term viability of the instructional model and the financial sustainability of the overall course model.

In order to address the issues raised in this report, the authors have looked closely at the ENGG 251/253 learning outcomes, learning activities, and assessment techniques in the context of the Schulich School of Engineering common core. In the second part of the paper, we place the ENGG 251/253 intended learning outcomes in the context the CDIO syllabus [6] and compare this existing model with a single-term version of ENGG 251/253 that was piloted in the Fall of 2008. The preliminary results of this study show that a single-term version of first year design and communication can address three of the four top-level items of the CDIO syllabus (i.e., items 2 through 4) in a more sustainable manner, with a smaller "footprint" in the common core curriculum.

FIRST YEAR DESIGN AND COMMUNICATION

The Schulich School of Engineering, like most other engineering programs in Canada, provides students with a common first year program before they choose their engineering discipline. Prior to the fall of 2002, this first year program consisted of fairly standard introductory natural science, mathematics and engineering science courses with only a minimal introduction to engineering design. Given increasing emphasis on professional skills development as well as increasing interest in experiential learning in the academic community, the Schulich School of Engineering embarked on a curriculum redesign process that resulted in substantial changes to the way first year, common core engineering was taught at the University of Calgary.

In this section, we provide some background on the motivation for change to the Schulich School of Engineering's first year engineering curriculum and focus our attention on the development of two unique first year design and communication courses. We then summarise the challenges faced in operating these courses and in their impact on first year engineering students.

Common Core Curriculum Redesign

The first year, common core curriculum redesign process that began in 2000 at the Schulich School of Engineering was motivated by a number of factors both internal and external to the University of Calgary. More specifically, the Canadian Academy of Engineering [1] recognised that graduates of engineering schools should have more than just technical and problem-solving skills: they should also be well practised in "soft" or "professional" skills such as team work, communication, project management, etc. Although students were introduced to these concepts in first year prior to curriculum redesign, it was felt that the heavy technical content of the program left little time for students to practice these skills or to digest all of the first year subject matter.

Given the growing interest around this time in moving away from the traditional "chalk and talk" lecture format classes, towards "experiential learning", the University of Calgary embarked on a campus-wide curriculum redesign process [3] that influenced the structure and scope of first year engineering common core curriculum redesign. More specifically, it was felt that, by transforming the traditional lecture-based design, practice and communication courses into a year-long "hands-on" design and communication experience, students would gain core competencies - like those described by the Canadian Academy of Engineering - by the end of first year, they would understand the relevance of lecture material

and appreciate the application of theory from other courses through the integration of subject matter in first year design and communication, and high-achieving students would have ample opportunities to be challenged.

To achieve these goals, it was felt that the first year design and communication courses should be primarily “hands-on”. As a result, the courses were structured with 4-1/2 hours of laboratory time per week and only 1 hour of lecture time per week. However, it was also recognised that it was necessary to also teach the “orientation to engineering” topics that would be utilised in the design and communication courses: i.e., learning how to learn, study skills, time management, interpersonal relations, and an overview of all the engineering disciplines. As a result, two “orientation to engineering” courses were proposed to complement the “hands-on” design and communication experiences.

When it came to implementing the curriculum changes however, compromises were made in order to fit the fall and winter term design and communication courses into the first year curriculum while balancing the needs of the various departments for common core courses. As a result, it was soon recognised that the additional courses on “orientation to engineering” could not fit into the curriculum without increasing the overall number of courses in first year. In fact, given that first year design, practice and communication was taught in a single first year course prior the curriculum redesign change, the new design and communications courses resulted in a core first year course (dynamics) being moved to second year. The overall change to the first year curriculum and its impact on second year common core is illustrated in Figure 1.

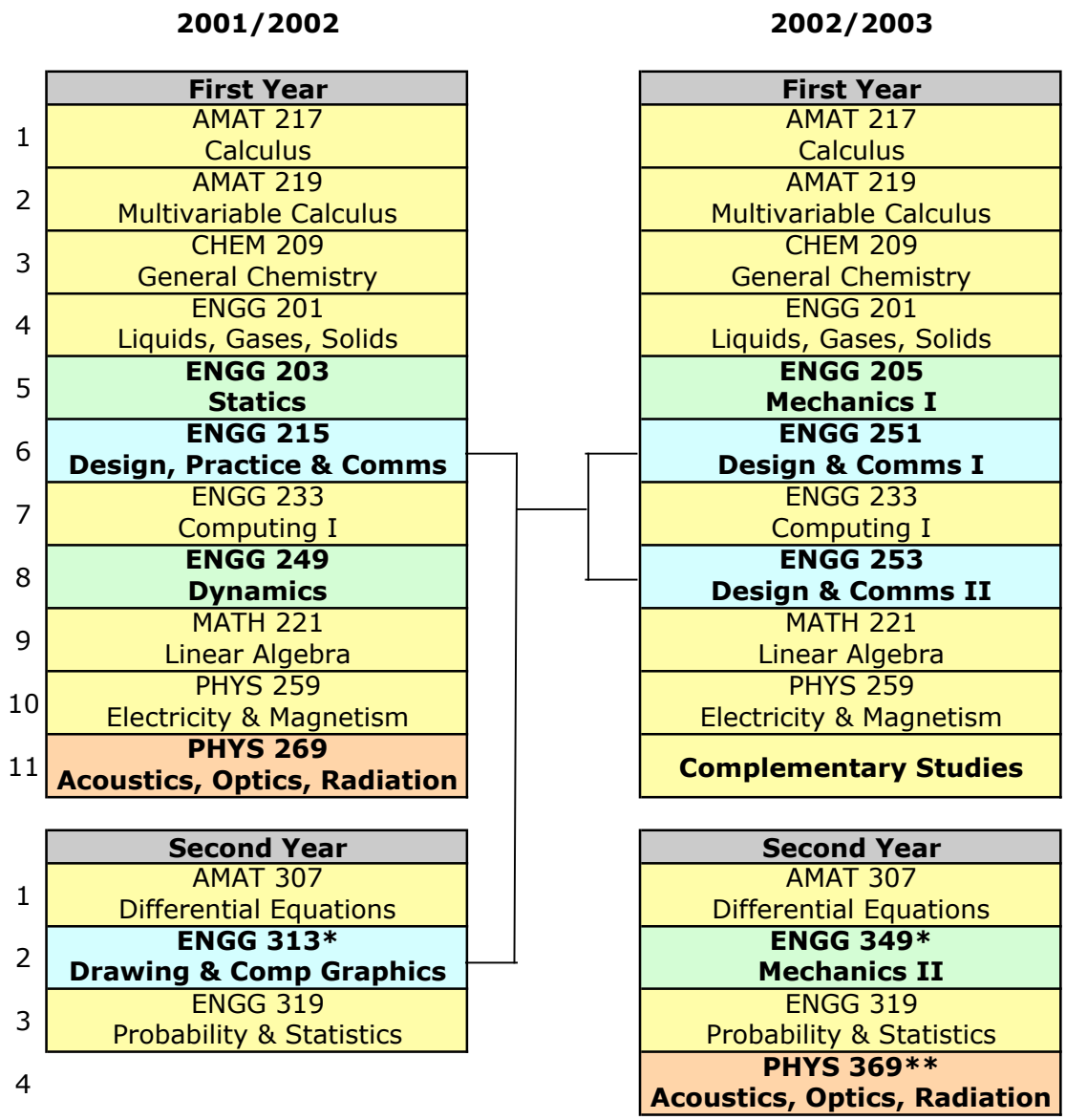
The end result of the curriculum redesign process was a substantial “hands-on” design and communication experience, offered in two courses that spanned both semesters of first year (ENGG 251 and ENGG 253). These courses provided ample opportunities to introduce and utilise many aspects of the CDIO syllabus, but provided little opportunity for teaching these concepts.

Initial Experiences and Observations

As would be expected with the introduction of two experiential learning courses, the total number of instruction hours increased substantially. For example, the total number of instruction hours almost doubled with the new design and communication stream shown in Figure 1: i.e., from 952.5 hours for ENGG 215/313 to 1,879.6 for ENGG 251/253. This increase in instruction hours created a number of operational challenges.

As can be seen in Figure 1, design, practice and communication (i.e., ENGG 215/313) was previously split over two years. Since the second course on graphical communication (i.e., ENGG 313 “Drawing and Computer Graphics”), was not taken by three of the School’s nine programs (i.e., Computer, Electrical, and Software Engineering), and since enrolment in second year courses tends to be lower than enrolment in first year courses (i.e., given first year attrition), the change to two first year design and communication courses resulted in a substantial increase in enrolment in this aspect of the first year program.

One may argue that this enrolment change was offset by moving “Engineering Mechanics II” (ENGG 349) to second year (this course is not taken by Computer, Electrical, and Software Engineering). However, our experience has shown that experiential learning courses are much more sensitive to large increases in student enrolment than are more traditional lecture-based natural science and engineering science courses like “dynamics”: i.e., substantially increasing the number of students who take a second design and communication course in first year is not offset by an equivalent reduction in the number of students who take “Engineering Mechanics II” in second year.



* except ENCM, ENEL, ENSF
** excpet ENCH, ENOG

Figure 1. Common core curriculum changes from 2001/2002 to 2002/2003

The increase in contact hours and student enrolment created a number of operational challenges when ENGG 251/253 was introduced in the fall of 2002. For example, time-tabling a cohort of 600 students in first year was always a challenge: however, with a course in each term that required a 4-1/2 block of time per week for “hands-on” learning, the time-table became extremely complicated. The result was a very rigid schedule that offered little flexibility for transfer students and/or students who needed to pick-up incomplete courses.

Increased contact hours, combined with the extra teaching workload associated with experiential learning activities, also resulted in a much larger instructor and teaching assistant team. For example, in 2001/2002, the design, practice and communication courses (ENGG 215/313) required 2 instructors per term (three in fall and one in winter) and 17 teaching assistants per term. The move to first year design and communication (ENGG 251/253) in 2002/2003 required the equivalent of 9 instructors and 34 teaching assistants per term. It should be noted as well that the teaching assistant load increased from 40 hours/

term to 60 hours/term. In other words, the change resulted in instructor requirements increasing by a factor of 4.5, and if one factors for actual teaching assistant hours, teaching assistant requirements increasing by a factor of 3.

This significant increase in teaching workload resulted from the increased demands of experiential learning instruction, a desire by the instructor team to run new projects every year (to avoid "roadmaps"), and an increase in student enrolment. Another big factor was course co-ordination. Given the size of the class - and the size of the teaching team - co-ordination became a significant part of the instructors' teaching workload.

The Courses' Impact on the Schulich School of Engineering

As noted previously, the first year design and communications courses quickly received accolades from our peers in the engineering education community for innovative curriculum design (e.g., "best paper" awards [4] and [5] and a 2005 ASME curriculum innovation award). This is certainly an important achievement for the faculty involved in the courses' design. However, it is also important to ask ourselves whether or not the courses are achieving the goals of the original curriculum redesign process in terms of our students' experience and their outcomes relative to the Schulich School of Engineering's common core and departmental curricula and industries needs for future professional engineers.

We conclude this section by first looking at our students' perspective on these courses, then focusing on the courses' outcomes relative to our programs at the Schulich School of Engineering. The next section of this paper will focus on the broader issue of the courses' learning outcomes and their relationship to the CDIO syllabus.

Student impressions of ENGG 251/253 were obtained from interviews with our first and second year students and written comments from the student evaluations of the courses. In general, our students feel that ENGG 251/253 is a good idea and is useful. In particular, students noted that the courses gave them practice and confidence with oral presentations, reports and teamwork; they felt that the engineering drawing instruction was useful; and, they felt that the material on the design process led to greater creativity. An unexpected benefit was also noted: our students consistently noted that the course resulted in camaraderie among students (given the number of team-based activities that they were involved in).

Despite these positive aspects of these courses, all interviewed students agree that appropriate organisation was a challenge and assessment is problematic. These problems appeared to derive from two general areas: (1) class size and complexity, and (2) course management and co-ordination.

The main difficulty appears to be a result of the course instructors' very heavy reliance on the large team of teaching assistants to teach the 4-1/2 hour labs and assess student work. From the student perspective, it appears that there is very little to no interaction with the course instructors: all of their contact is with the teaching assistants. Since the number of teaching assistants is very large, communication becomes an issue. Despite the instructors' best intentions, it is very difficult to get a consistent message out to the students; as a result, students often feel that there is no one to turn to with a question (i.e., they feel that their teaching assistants often do not know the answer) and that they are always directed to the online course management system (Blackboard [7]). Given this hierarchical structure of instruction, students feel removed from the full-time academic instructor team: i.e., students sometimes felt that instructors did not adequately consider their concerns about the course.

The heavy reliance on a large team of teaching assistants also leads to inconsistencies with respect to assessment. For example, students note that there is inconsistency across graders (i.e., "easy" v. "tough" graders) and across assessments (i.e., different grades for the same level of work). Although it is not surprising that there is inconsistency across graders (given the large number of graders), the inconsistency across assessments may be explained by increasing expectations as the course progresses.

The high number of students, instructors, and teaching assistants to be co-ordinated certainly makes organisation problematic. However, some of the instructors' decisions around course management and co-ordination may exacerbate the problem. For example, there is a reluctance to provide "too much" information to students because of the fear that it will stifle student creativity. This is certainly a laudable goal, however given that 34 teaching assistants must be coached to provide the right amount of information - not too much, but not too little - the system can easily break down to one where the student does not know the expectations for a given project and does not know where to turn to for help.

This also leads to a feeling amongst some students that assessment is unfair: i.e., how can they feel that they have been assessed fairly on a project when they don't know what the expectations are for the project?

It should be mentioned that these are student *impressions* of the current first year design and communication courses. A considerable amount of effort is put into course co-ordination and project design by the teaching team; yet, despite this, co-ordinating such a large class and teaching team has its challenges.

One may argue that it is all worthwhile however, if the courses are achieving a clear set of desirable outcomes. In the next section we place these courses in the context of the CDIO syllabus to try to answer this question.

FIRST YEAR DESIGN & COMMUNICATION AND THE CDIO SYLLABUS

Before we look at the learning outcomes for first year design and communication, it is useful to revisit the original objectives for these courses. Given that the original plan was to support first year design and communication with two "orientation to engineering" courses, the original objective was simply to provide students with a significant "hands-on" design experience in the first-year program that integrates subject matter from other common first year courses so that students understand the relevance of lecture material and appreciate the application of theory. However, given that "orientation to engineering" was also rolled into first year design and communication, the courses were also required to place emphasis on students achieving core-competencies by the end of first year.

Although these courses do appear to provide students with a significant "hands-on" learning experience, they fall short of the other objectives with respect to core subject matter integration and core competencies. This is partially because the courses are expected to deliver more than was originally expected of them; but also because they are inherently designed for instructors to "introduce" and for students to "utilise" CDIO syllabus sub-topics [6] through "hands-on" experiences and are not well-suited for instructors to "teach" syllabus sub-topics.

The learning outcomes for the first year design and communication courses fall into three subject areas as summarised in Table 1. The subject area is shown in the top of each column, with the associated intended learning outcomes below.

Learning activities are primarily set-up in the form of projects that integrate at least two, and typically, all three of the course subject areas. Although first year design and communication is structured as two, single-term courses, it effectively runs like a single, two-term course with increasingly challenging projects: i.e., two three-week projects and one seven week project in the first term (ENGG 251) and two half-term projects in the second term (ENGG 253). The earlier (three-week) projects tend to focus on introducing students to the course, team work, hands-on problem solving, and the design process; the longer projects in the first and second terms provide students with the opportunity to utilise these skills and tackle more difficult, multi-step projects with multiple deliverables.

Table 1
First Year Design and Communication Intended Learning Outcomes

Engineering Design	Visual Communication	Oral & Written Communication
Apply engineering design strategies to a wide variety of real-world, open-ended problems.	Develop the ability to sketch preliminary design concepts using isometric and orthographic projections.	Demonstrate effective written communication skills: audience focus, clear purpose, concise and effective content.
Develop design solutions within the constraints of time and resources.	Demonstrate a basic understanding of dimensioning and tolerancing.	Report progress and results using a variety of written, oral and visual formats.
Work effectively in teams.	Incorporate multiple design styles and visualization methods to generate design concepts throughout the design project.	

The two-term format gives the teaching team the opportunity to gradually ease students into more challenging projects by the second term and affords student teams with more opportunities to practice design and communication. However, it is not clear that, after one term and three projects, the second course is adding much more in terms of learning outcomes. In particular, the benefits of extra practice in the second term must be weighed with the challenges noted previously. Given that many of the challenges result from the large class size and high contact hours associated with the existing courses, we felt that it would be worthwhile to test a smaller-scale version of the courses that would be more manageable and sustainable in the long-term. The idea was to pilot a single-term version of the course with an even balance between lecture and lab hours: this would allow for a smaller student cohort (i.e., it could be run for one half of our first year cohort in the first term, and for the second half in the second term), more opportunities to introduce and teach subject matter, but also ample opportunities to utilise skills in the project-based labs/seminars.

In the spring/summer of 2008, a single-term course was developed with the objective of introducing students to design, communication and leadership, and to try to provide students with a better understanding of what engineering is. This course was piloted with a small group of students (20 students) in the fall of 2008.
Table 2 provides an overview of the current first year design and communication courses' learning outcomes and the pilot course's learning outcomes in the context of the CDIO syllabus. For detailed descriptions of the CDIO syllabus items and the sub-topics emphasised in the CDIO syllabus, please refer to [6]. It should be noted that, given that first year design and communication (ENGG 251/253) introduces new projects every year, the learning outcomes may vary somewhat. For example, recent projects used homelessness as a theme area and resulted in many of the sub-topics in "societal & external context" being addressed. For consistency, Table 2 only reflects those learning outcomes that are addressed every year, regardless of the projects.

Table 2
First Year Design and Communication and the CDIO Syllabus

CDIO SYLLABUS ITEM	FIRST-YEAR COURSE	INTRODUCE/ TEACH/ UTILIZE	EMPHASIZED SUBTOPICS IN CDIO SYLLABUS
2.1 Engineering Reasoning & Problem Solving	ENGG 251	T, U	2.1.1,2.1.2,2.1.5
	ENGG 253	T, U	2.1.1,2.1.2,2.1.3, 2.1.4,2.1.5
	Pilot	T,U	2.1.1,2.1.2,2.1.5
2.2 Experimentation & Knowledge Discovery	ENGG 251	T,U	2.2.1-2
	ENGG 253	T, U	2.2.1-2, 2.2.3
	Pilot	T, U	2.2.2
2.3 System Thinking	ENGG 251	T,U	2.3.1,2.3.3,2.3.4
	ENGG 253	T,U	2.3.1,2.3.3,2.3.4
	Pilot	T,U	2.3.1,2.3.3,2.3.4
2.4 Personal Skills & Attitudes	ENGG 251	T,U	2.4.1,2.4.2,2.4.3,2.4.4,2.4.5,2.4.7
	ENGG 253	T,U	2.4.1,2.4.2,2.4.3,2.4.4,2.4.5,2.4.7
	Pilot	T,U	2.4.3,2.4.4,2.4.5,2.4.7
2.5 Professional Skills & Attitudes	ENGG 251	I	2.5.1,2.5.2,2.5.4
	ENGG 253	I	2.5.1,2.5.2,2.5.4
	Pilot	I	2.5.1,2.5.2,2.5.4
3.1 Teamwork	ENGG 251	T, U	3.1.1,3.1.2,3.1.4
	ENGG 253	I, U	3.1.1,3.1.2,3.1.3,3.1.4
	Pilot	T, U	3.1.1,3.1.2,3.1.4
3.2 Communications	ENGG 251	T, U	3.2.1,3.2.2,3.2.4,3.2.5,3.2.6
	ENGG 253	T, U	3.2.1,3.2.2,3.2.4,3.2.5,3.2.6
	Pilot	T, U	3.2.4,3.2.5,3.2.6
4.1 Societal & External Context	ENGG 251	T	4.1.2-4.1.3
	ENGG 253	T	4.1.2-4.1.4,4.1.6
	Pilot	I	4.1.2-4.1.4
4.2 Enterprise & Business Context	ENGG 251	I	4.2.4
	ENGG 253	I	4.2.4
	Pilot	I	4.2.4
4.3 Conceiving & Engineering Systems	ENGG 251	T, U	4.3.1,4.3.2,4.2.4
	ENGG 253	T, U	4.3.1,4.3.2,4.2.4
	Pilot	T, U	4.3.1,4.3.2,4.2.4
4.4 Designing	ENGG 251	T, U	4.4.1-5
	ENGG 253	T, U	4.4.1-5
	Pilot	T, U	4.4.1,4.4.2,4.4.4,4.4.5
4.5 Implementing	ENGG 251	T,U	4.5.1,4.5.3
	ENGG 253	T,U	4.5.1,4.5.3
	Pilot	T,U	4.5.1,4.5.3,4.5.5-6
4.6 Operating	ENGG 251	I	4.6.5
	ENGG 253	I	4.6.5
	Pilot		

This assessment of the current first year design and communication courses' learning outcomes and the pilot course's learning outcomes was performed by the instructors of these courses. In all cases, the course syllabus (i.e., "course outline") was used as a starting point; the courses' detailed syllabi, learning activities and assessment tools were then analysed in the context of the CDIO syllabus to develop the summary shown in Table 2.

Our comparison with the CDIO syllabus is intended to supplement similar comparisons of first year design courses at other CDIO institutions (e.g., [8] and [9]) and also help inform our

work on intended learning outcomes for these courses. For example, from a learning outcomes point of view, it can be seen from Table 2, there is very little difference between the learning outcomes of the existing design and communication courses and the single term pilot course. The main difference is that the two course model spends more time on first year design and communication than the one course model, and as a result provides more opportunities for students to utilise the syllabus sub-topics (this is not necessarily reflected in Table 2). However, without proportionally higher opportunities to introduce and teach these syllabus, the value of this extra practice time is not clear.

The existing first year design and communication course also devotes more of its syllabus to communications that the one term pilot course. A full-time, oral and written communications instructor and a full-time graphical communications instructor are assigned to the two term design and communication course, and the one-hour per week lectures are split 50% for oral & written communication and 50% for graphical communication. Alternatively, the one term pilot course relies on the course instructor to integrate oral & written communication into the curriculum, but still relies on a full-time graphical communication instructor for the drawing labs/seminars.

While the existing ENGG 251/253 model appears to be effective for drawing instruction, a recent audit of the oral and written communication aspect of the courses has shown that this aspect of the communications curriculum is not as effective. More specifically, students require more one-on-one feedback and assessment on their writing and presentations and many opportunities to practice. Although students have the opportunity to give one individual presentation in ENGG 251 and one individual presentation in ENGG 253, it is very difficult to provide the level of feedback and one-on-one attention to individual writing in classes the size of ENGG 251 and ENGG 253. Smaller classes, with more opportunities for oral and written communication practice are part of the engineering common core curriculum in second year (as part of a core technical communication course); although, the single-term course has less of an emphasis on communications strategy and structure, these outcomes are already part of the engineering common core curriculum and are offered in a manner that is more conducive to oral and written communication practice and assessment.

Finally, it should be noted that there is very little difference between the learning outcomes from the first term of the current design and communication model (ENGG 251) and from the second term (ENGG 253). Again, the two-term model provides students with more opportunities to practice introductory design and communication skills; however, given the challenges noted previously, it is not clear that this extra practice is justified.

SUMMARY AND NEXT STEPS

Based on our experience with the single term pilot course, it appears that students can receive a sufficient introduction to design, communication and leadership within the framework of a single course. Extending this experience over an entire year may blur the objectives of the course from the perspective of the students.

However, based on our experience with the two term design and communications courses, care must be taken to ensure that the single term courses does not become an attempt to “do everything”. The course should focus mostly on design, teamwork, leadership and communications. As well, there should be a brief introduction to the engineering profession and the various engineering disciplines.

As noted previously, the single term design course’s contact hours are spread evenly across lectures and labs (as opposed to the current model’s heavy weighting on lab hours). This will likely involve a slight increase in the outside-of-class work by our students, but a much more manageable timetable. This model also gives the instructors the opportunity to introduce students to concepts in design, communications and engineering more readily than with the current model, sends a better message about the importance of the material, and increases students’ “connection” with their course instructor.

Looking forward, the Schulich School of Engineering is now in the process of reviewing the first year curriculum with this work on first year design and communication as a basis. This is only one part of the puzzle however. As noted previously, the change to design, communication and problem solving in 2002/2003 resulted in other major changes to the first and second year curriculum. The School's curriculum committees are now looking at the overall picture in order structure our first and second year programs in a way that serves the needs of each of our nine engineering programs.

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GUIDELINES FOR COOPERATION BETWEEN INDUSTRY AND ACADEMIA IN DESIGN PROJECTS

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ABSTRACT
The cooperation between firms and academia is often seen as an effective way to provide disciplinary skills and knowledge of system building for inexperienced students. In theory, cooperation has many advantages: The students get first-hand knowledge of the industrial environment and experiences of working with professional designers. In this way they get an opportunity to feel the pace of realistic projects as well as an opportunity to show their skills for future employment. Not only the students benefit from this cooperation; the firms gain new innovative ideas and knowledge of the latest development techniques. They also get good leverage on the resources invested since the amount of hours spent by the student teams could be tenfold the contribution of the firms.

In real life, the cooperation between firms and academia can be both time-consuming as well as troublesome. One reason for this is that their objectives are different: The teachers want the students to learn and the companies want to make money. To overcome unnecessary barriers in cooperative design projects, a set of guidelines have been created at the School of Engineering at Jönköping University in Sweden. The guidelines have been developed from the experiences of collaborating with more than 30 different companies between the years 2000 to 2006. One finding is the importance of aligning the expected project outcome between students, teachers and companies. Another important aspect is to ensure that the standard of the work is high enough in order to satisfy the firms. This is achieved by a careful selection of projects and by comprehensive coaching of the students using a proven framework for learning design.

KEYWORDS
Industrial cooperation, design projects, guidelines.

INTRODUCTION
Before any implementation of a cooperative design-build-test (c-DBT) experience the first step is to consider the reasons for starting the cooperation. Is the reason that it is beneficial for the students and a true improvement of the learning environment? Or is it just a matter of making the program look more attractive to students and other University stakeholders by offering some variation to the standard coursework?

Compared to traditional classes, a DBT experience usually needs significantly more resources [1]. In our experience, a collaborative DBT project is no exception but rather more expensive and complicated, especially since the outcome is hard to predict in advance. Other reasons are the costs for material and travel, the time spent on finding projects and the need to ensure that the rules for examination can be fulfilled. On top of this there are usually

discussions on intellectual property rights that can result in legal consequences if they are not properly solved. These questions must be solved for every participating company.

In spite of the troubles to set up the cooperation, it is usually well worth it for all participants. Through course evaluations we know that the students are positive to the experience of collaboration with companies, even when the technical output of the projects did not meet its goals. In almost all cases, the firms too were satisfied with the cooperation, which is foremost displayed in the requests for new projects. The aim of this paper is to share our experiences and to offer guidelines for setting up and maintaining carefully managed design-build-test projects in cooperation with the industry.

The CDIO perspective

A cooperative design-build-test project fulfills at least three CDIO standards [2]. Students developing a product by involvement of industrial partners correspond to standard 7: Integrated Learning Experiences. The physical output of the project is a model or prototype built from the information created by the students such as drawings or CAD- models. Usually students make most parts themselves in our workshop, some parts are manufactured by the participating company and other parts are printed in our 3D printer. This corresponds to standards 5: Design-Build Experiences and 6: CDIO Workspaces.

The learning context

To understand the context of the c-DBT projects at the Department of Mechanical Engineering, a short description of the education structure is given. In the Bachelor program a plan for design-build-test projects is used which includes a systematically varied sequence of DBT- experiences across the latter half of the program. When students are to learn practical engineering by designing and building a physical object it is important to avoid that the design work becomes an ineffective happening. Therefore a framework for design projects is used to provide a clear structure and a context where students can practice their engineering skills and knowledge from previous courses.

The first 1.5 years of the program consists of a traditional setting with individual studies of basic subjects such as manufacturing technology, material technology, mathematics and physics. The following year is quite different with design courses in collaborating groups. The last six months consists again of mostly individual work. The first significant project starts at the end of the second year and is a cooperation between courses in industrial and engineering design, emphasizing creativity and skills of team work. This is a ten week full time assignment capturing the design intent from idea to CAD drawings and model/prototype manufacturing. A comprehensive description of the framework used for design projects can be found in [3].

The second project is the subject of this paper. It is a cooperative DBT experience between the School of Engineering and companies in the surrounding area. Compared to traditional capstone- or thesis work, it is a much quicker, more carefully managed and less extensive assignment where the project part accounts for 4 ECTS. The teams consist of 4-6 students applying their skills in teamwork, design and project planning/execution gained in the first project. The goal is to acquire disciplinary skills by designing something useful for a demanding customer. The lectures in this course focuses on methods such as QFD, selection procedures, Design for Manufacturing and other practical tasks that are directly applicable to the project.

The third project is the 15 ECTS Bachelor thesis work which is usually carried out by two students together at a suitable company. The thesis is the largest and most important work in the program, showing to what extent students are able to apply and add to knowledge gained during previous studies. During the thesis work, students are judged on their ability to identify and analyze problems. They are expected to describe the method of work and how the

solutions fit into the context of the assignment. The thesis comprises a theoretical approach to the subject and a clear presence of analytical and developmental work.

PLANNING FOR A DESIGN-BUILD-TEST COOPERATION

Cooperation between industry and academia is common practice in Sweden and has been going on for decades. Most engineering students do their final project in cooperation with a company and up to recently they also had to do at least two months of internship before receiving their exams. In our case we wanted to offer another type of experience managed in a similar way as industrial projects. The role of the project groups resembles design consultants working in a controlled environment on a well defined task. The support and guidance from teachers and the advisor on the company gives the students an opportunity to participate in the rapid pace of realistic projects exercising their skills form engineering subjects.

In order to create a base for the projects basic questions must be asked:

1. What do we want the students to learn from the companies?
2. What do the companies want from the students?
3. What will the teachers gain from the cooperation?

The first year of collaborative projects were run without these questions explicitly answered. The main reason for cooperation was to increase the “fun factor” in the course and also to add some realistic pressure by bringing in external stakeholders in the process. The effort however was repaid when one company used the students design as a model for a new product. This showed that the students’ skills were good enough to create a commercial product and encouraged the set up of coming collaborative projects.

What do we want the students to learn from the companies?

The main reason to include externals stakeholders in education is that they offer competence and experiences that is seldom available in the academic system. Therefore the most important learning outcome of the projects must be a transfer of disciplinary knowledge between the professional designers and students. In our projects, the transfer is mainly done through meetings where students’ designs are revived at different stages in the process.

The consequences of the statement above set the context for when industry cooperation is valuable to the students and when the costs exceed the benefits. It is not effective if knowledge available among the teachers is taught by industry and therefore mainly creative tasks where the result is of the type “concept development” should be avoided. The methods of innovation and creativity are usually well represented on universities and in our case the students acquire this type of skills in earlier courses.

What do the companies want from the students?

There are various reasons for engaging in student projects but one similarity is that educating students is not a part of their business plan. Our participating companies often mention reasons of goodwill and marketing as well as the opportunity to get new ideas and to explore low-priority technical solutions. The goodwill often consists of the opportunity to attract future employees and customers and is often mentioned by firms with less attractive products and locations.

The companies usually do not intend to use the project results immediately but are instead interested in the new opportunities that may arise when young people treat concrete problems in different ways than their experienced designers. Therefore companies are often interested in “concept development” which is ineffective in transferring disciplinary knowledge as discussed above. Another point of interest for the companies is to get help with labor

intense research processes, such as finding new information through searches in patent databases or market analysis. This type of analysis is usually of mutual interest of students and firms, since the students are given input to the design process in the form of product knowledge and alternative ways to solve its functions and the firms are given valuable information.

What will the teachers gain from the cooperation?

The benefits for the teacher's are not easy to pinpoint. Clearly there must be some incentives in order to make the teachers committed to the work, especially if the c-DBT project is promoted and initiate by the academic management. In our projects we have found that the teachers gain new knowledge and make new contacts in a pleasant way.

EXPERIENCES OF COOPERATIVE DBT PROJECTS

Our view of cooperation with firms in carefully managed projects has gradually evolved through guided projects on more than 30 different companies. After seven years of different set-up of c-DBT projects we have created guidelines that have proven valuable in the process of reaching the different goals set by the students, academia and companies. The type and size of the company can influence the results and we have cooperated with small companies, large companies as well as individual inventors and public service institutions.
The size of the groups has varied between three and six students per project. One year all groups worked for a single company, another year there were ten groups working for ten companies.

Descriptions of the c-DBT projects

The groups of students act like a consulting firm integrating the industrial design and engineering processes in a controlled project environment. The purpose of a well defined assignment and the controlled process is to speed up the work so that the whole design chain can be run through before the end of the course.

The companies are not required to coach the students in their designing; their role is to act as project sponsors and supervise the work. The students need a company contact and advisor that has enough time and knowledge to give professional feedback. The framework guides inexperienced students through the process, and frequent hand-ins sets a steady pace and gives short feedback loops. It is also easy to monitor the progress for both teachers and companies when different tasks are handed in every week.

The assignments are coming from the companies and the technical goal of the project is to develop products according to specifications. The course provides lectures on different aspects of product design and the project is the arena to implement it. Most of the work is done on campus, but with frequent contact with the companies.

The set-up consists of three parts:

- The DBT- project framework
- A company contract/assignment
- The cooperation guidelines

Our DBT framework [3] is used as a cornerstone in our c-DBT projects and consists of a formal development and project execution model, training in group-dynamics by professionals and extensive coaching or the students. Before the framework had reached its current stage of development, the output of projects would be very variable. Some groups of students had a natural ability to fulfill both the goals of the course and of the companies while others could not fulfill any of them, and there were no effective mechanisms to catch and correct projects on the wrong track

The company contract/assignment is a document containing the project description and the preliminary technical specification. The specifications are usually flexible and are used as a base for development. The contract usually does not contain any information on intellectual properties rights. These rights control the ownership of potential inventions and are usually only discussed orally before the projects starts. The reason for this is that companies are reluctant to sign complicated contracts before any results are present. Neither are we willing to sign off the students´ rights to their own inventions. Whenever a project shows a patentable invention a contract can be negotiated.

The cooperation guidelines are used by the teachers to find and evaluate appropriate projects and companies. Their purpose is to help avoid unsuitable projects, assignments or companies.

Student skills required before participating in cooperative projects

In order to make the most of the opportunity of working with professional designers it is important that the students are well prepared. Besides a basic technical knowledge, they also need to have some knowledge of their technical discipline and of practical teamwork according to figure 1. To make the project execution run smoothly we have found that previous experiences of development projects is very valuable for the students to focus on the work at hand rather than how the work should be done.

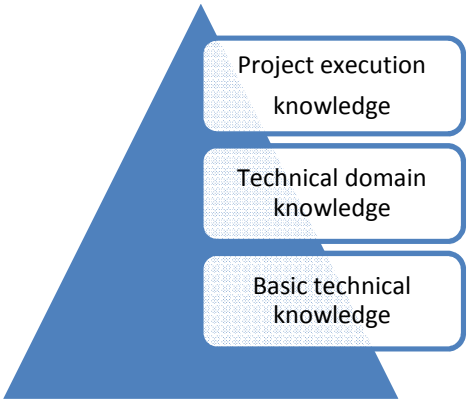

Figure 1. Skills needed in cooperative projects.

Finding the projects and companies

Finding appropriate projects includes more than just finding the cooperating companies: Bear in mind that the object is to expose the students for professional designers and their working practices, not to produce drawings or prototypes. We recommend working only with firms and individuals owning sufficient knowledge in the engineering domain. Knowledge in management or marketing cannot help students gain disciplinary skills. All types of companies offer unique project characteristics that need to be considered: The size of a firm influences the maturity of formal development and other processes and the type of business influences the speed of technology change. Some organizations spend 2% of turnover on development while others spend 20%.

In most DBT-projects the assignment is crucial. The students spends most of their time working on the project rather than reading course literature so careful planning is needed in order to create a satisfactory project. However, in c-DBT projects it is not possible to adapt the assignment perfectly to the course requirements and therefore the search and selection of projects is very important.

The assignment must fulfill the following requirements:

- Appropriate size
- Correct project type
- Suitable time frame

Fulfilling two out of three requirements will not be enough: A too large assignment will not be able to finish on time, an incorrect project character will not give an effective learning learning and a bad timing is not attractive to the company or school.

It may seem impossible to set up suitable projects, but the good news is that the firms are usually interested in compromising and the assignment can be twisted so suit the course. If the assignment is too small the teacher can add tasks, if it is too big, individual tasks can usually be divided among different groups of students. If the time frame is unsuitable the project could be saved for next year. If the project type has a wrong character, for example mostly "concept development", tasks can be reduced so that other parts of development also can be implemented.

A search for appropriate projects is often time consuming but also a good excuse to leave the office. In our experience suitable projects usually can be found through the personal contacts of academic staff, alumni networks and in favorable companies such as donors. If the project yields good results, the companies are usually interested in hosting projects the coming years. It is a good idea to cooperate with one company for two consecutive years, after this their most suitable projects are already used and they usually need to rest in order to have new proposals.

The re-design projects

One class of design projects that usually fulfills all requirements is the improvement of an existing product. A re-design activity is also the most common task in industry which prepares the students for a future engineering career, and there are usually many potential re-design projects in a company. Although it may seem as if the re-design is less creative than an explorative project, the potential different solutions to the task are still almost infinite. One positive effect of the constrained design options is that it hinders any lengthy searches for alternative product types and quickly leads to result. In this type of project the goal is to learn industrial procedures for creating, calculating, selecting, modeling and documenting products. In the case of re-design there is a lot of available data and documents that can serve as a guide for learning design work.

Arguments for cooperation

Even though the companies do not expect to get an ideal output, they expect reasonable results and there are at least two arguments to convince them that the projects will be worth the time spent and that the quality is good enough:

- Good leverage on time invested
- Commitment from the teachers

When a group of five students are spending a total of 500 hours effectively on the project they will make significant contribution if they are managed in the right direction. To further ensure that the standard of the work is high enough we always assigns two separate groups to the same project and so far at least one group in every case have created a satisfactory solution. Having two groups increases the competition without increasing the workload on the company too much and it is a suitable compromise between redundancy and time spent.

The teachers commit to invest time in comprehensive coaching of the students, provided that the firms also will take an active role in the projects spending an average of 15 to 30 hours

per assignment. The technical output of the project is depending on the guidance of the firms and the teachers cannot replace the knowledge of the professional engineers.

Alignment of goals

The adequate quality of design work is found by the alignment of the expected project outcome between students, teachers and companies. An alignment of the visions is crucial since the objectives of the participants are very different: The teachers want the students to learn and the companies want to make money. A first alignment is the preliminary specification that sets the context for the project. Other alignments are done through the project checkpoints. Students share their initial ideas, get feedback from teachers and firms and continue to refine the most promising ones. The company participates in important steps such as concept selection and shares disciplinary knowledge by comments and suggestions. One important role for the teacher is to assure that the project scope does not expand and stop any additional assignments unless the basic requirements are not fulfilled.

Common problem in cooperative projects

During the years we have encountered a variety of problems and the most common ones are listed in Table 1. In this table is also a brief description of the countermeasures that we used to minimize them.

Table 1
Common problems in collaborative projects

Problem	**Primary cause**	**Effect**	**Countermeasure**
Time delay	Students have not enough experience of development	Not reaching learning goals, not delivering results	Academic design project before collaborative project ensures first-hand experiences of product design projects
Time delay	Project too extensive	Not reaching learning goals, not delivering results	Ensure proper project size before project start.
Project breakdown	Students have to little skills in teamwork	Poor overall result	Acquire teamwork skills before collaborative project
Project not reaching company goals	Changing specification during project	Company not satisfied	Teacher intervention- ensure that project scope is not increasing or significantly changed
Project not reaching company goals	Too little company commitment	Company and students not satisfied	Make sure that company has enough resources before project starts
Project not reaching company goals	Project result not up to expectations	Company not interested in future cooperation	Redundant projects- at least two groups working on the same project
Students not reaching learning goals	Too high project workload	Teachers not satisfied	Teacher intervention- ensure that projects do not overtake other learning activities.
Students not reaching learning goals	Unsuitable project character	Teachers not satisfied	Ensure suitable project character before project start.
Company or students not satisfied	Disagreement over intellectual property rights		IPR contract is negotiated before project ends

The countermeasures include activities before the c-DBT project or direct teacher interventions and this stresses the importance of having enough resources to coach the students in their work. All of the problems are addressed in our guidelines.

Guidelines for cooperative DBT projects
Our experiences can be summarized in the following prescriptive guidelines for controlled cooperative DBT projects:

- Use a proven framework for design projects
- Students should have at least one similar experience before working in a company project
- Students should have basic knowledge and personal experiences of group dynamics.
- Two student groups per project enables redundancy without giving the company to much extra work
- Cooperate with competent companies and avoid inventors or organizations without disciplinary knowledge
- Use the company competence that is not available in the academic system
- Avoid cooperation in mainly creative projects since it is not an effective use of the company knowledge
- Search for re-design assignments to speed up project progress and use as a template for disciplinary knowledge.
- Don´t accept unsuitable projects
- Continuously align the project goals between students, firms and teachers
- Balance the need to learn and the pursuit of results
- Ensure that the company has resources available for the students and avoid too many groups on a single company
- Ensure that the teachers are given enough time for proper coaching
- Create a strategy for handling issues with intellectual properties rights

Comparison to an earlier study
A Comparison between the guidelines for c-DBT projects and an earlier study [4] shows a high correspondence between the findings, suggesting that the guidelines are suitable also for capstone design projects:

- *"The scope of the project must be appropriate…"*
- *"projects that are investigative rather than design oriented should be vetted by the course coordinator…"*
- *"Project scope should include a clear list of expected outcomes…the more detail included in the problem definition, the higher the likelihood of success for the project…"*
- *"The way in which the team of students works together will play a large role in the success of the project…"*
- *"Support and guidance from the industry advisor is critical throughout the project…A clear understanding of the course objectives…. by the industry advisor is also needed."*
- *"The academic supervisors involved in the projects must take an active role…"*
- *"Only through regular interaction between everyone involved will projects come to a successful conclusion…"*

CONCLUSIONS
There is no secret formula for a successful implementation of a cooperative design-build-test experience. We have however created guidelines that are relevant in our context of projects managed in a similar way as industrial projects. The guidelines also correspond to advice given in other studies. One factor of success is a careful selection of projects and a comprehensive coaching of the students using a proven framework for learning design. This ensures that the standard of work is high enough to satisfy the firms. Another factor is the continuous alignment the expected project outcome between students, teachers and companies.

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ICT SHOWROOM – A JOINT STUDENT PROJECT EXHIBITION AND COMPETITION OF THREE UNIVERSITIES

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ABSTRACT

Project-oriented courses are important tools to learn core engineering knowledge, skills and attitudes. However, it is not always that easy to motivate the faculty to create these types of learning activities or to facilitate the students to utilize the opportunity to join a design-build project. Turku University of Applied Sciences, University of Turku and Åbo Akademi University have a set of project-based courses in their programs. After the ICT education units of these institutions moved into the same campus, efforts to further improve the co-operation was launched. One initiative was to facilitate the student projects somehow and, simultaneously, to get both students and faculty members to get familiar with each other and their ongoing activities. The result was ICT Showroom, an exhibition and competition event open for all student projects of the campus. In this paper, the ICT Showroom Student Project Exhibition and Competition event is described. The background of the idea, concept and practical issues and experiences are documented.

KEYWORDS

Project-based learning, competition, collaboration, change management

INTRODUCTION

As promoted also in the CDIO standards, project-oriented courses are important tools to learn core engineering knowledge, skills and attitudes. Hands-on opportunities to get familiar with the product and system lifecycle development and deployment are important for the students to develop their product and system building skills, as well as the ability to apply engineering science. [1]

However, it is not always that easy to motivate the faculty to create these types of learning activities or to facilitate the students to utilize the opportunity to join a design-build project. Thus, different actions to promote the project-oriented approach both among the teaching

staff and the students are required in order to make the achieved teaching and learning results visible to the community and spread the spirit of design-build activities and best practices further.

Turku University of Applied Sciences, University of Turku and Åbo Akademi University (all located in Turku, Finland) have a set of project-based courses in their degree programs. After the ICT education units of these institutions moved into the same campus in autumn 2006, efforts to further improve the co-operation was launched. An initiative by the authors was to facilitate the student projects somehow and, simultaneously, to get both students and faculty members to become familiar with each other and their ongoing activities.

The challenge was that the profiles of the degree programs in and within the universities differ significantly from each other. For example, there is an undergraduate program in Arts & Media as well as a graduate program in Microelectronics – and many others. Thus, the concept should allow participation of different types of students and projects and, if possible, even facilitate co-operation between students from different disciplines or even different universities.

The decision was to develop a joint competition between the student projects that focused not only on technical implementation details but also on the business ideas behind the project, as well as on the presentation skills of the teams. The result of this brainstorming was ICT Showroom – an exhibition and competition open for all student projects of the campus. The intention was to create an event with good spirit and relaxed atmosphere – but still set up a real competition with an industrial jury and considerable prizes for the winner team.

The marketing of the pilot implementation was started late autumn 2007. The number of participating teams was finally almost doubled from the original goal; 42 teams presented their work at the exhibition March 2008. Local industry decided to sponsor a significant prize for the winning team, as well as to send their representatives to a jury to award the winner. The first event was a success and the second round with a slightly improved concept took place with about the same amount of competing teams in March 2009. One of the improvements to the concept for 2009 was a new visual image for the event as shown in Figure 1, designed by Media and Advertisement students of Turku University of Applied Sciences.

In this paper we present the ICT Showroom Student Project Exhibition and Competition event, a concept that successfully facilitates both students and faculty to develop, implement and join project studies, share ideas and learn from each other over institutional boundaries. The background of the idea is described, the concept and practical arrangement issues documented, and experiences as well as future directions discussed.

Figure 1. ICT Showroom ’09 visual image (designed by the Media & Advertisement students of Turku University of Applied Sciences).

OTHER EVENTS WITH SIMILAR GOALS – A BRIEF REVIEW

Different types of student competitions have been arranged in very many universities. However, in this case the challenge was to tailor a concept which enables participation of students from different disciplines and degree program profiles. Moreover, the rules and assessment criteria should be such that even teams in the beginning of their studies could have a fair game against those already close to their graduation. A brief review of other events with similar goals was performed for benchmarking purposes:

- The Innomaraton is a joint event of University of Lapland, Rovaniemi University of Applied Sciences and Kemi-Tornio University of Applied Sciences in Finland. The main idea of the marathon is that the local companies provide assignments to student groups which then create innovative solutions to the given problems. The best solutions participate in a final evaluation round, and a winner is selected by a jury that consists of entrepreneurs, regional developers and university teachers. [2]

- Lahti Science Day is an annual event organized by the Lahti University Consortium and the Universities of Applied Science of the Päijät-Häme region in Finland. The goal of the event is to present ongoing research and development activities and other state-of-the-art topics to the local companies and other stakeholders, as well as to serve as a networking platform. [3]

- For more than a decade, the Kenyan chapter of The Institute of Electrical and Electronic Engineers (IEEE) has held the annual Engineering Student's Exhibition. The goal of the exhibition containing a competition (several series) is to drive students to develop their skills and to give them a deeper insight into technology coupled with market demand. The preparation and presentation of projects will challenge them to mix and match their theoretical and practical skills. The exhibitions have been networking opportunities for local and international participants, too. [4]

- The Mechanical and Mechatronic students from the Department of Engineering at the University of Melbourne must complete a final year project. These projects are showcased for the engineering industry, fellow university students, lecturers and secondary school students at the Meridian exhibition event. Through Meridian it is hoped the university will be able to strengthen its links with not only the leaders in industry, but that it will also be able to promote the benefits of engineering to the future generations of engineering students. Meridian '08 also organized a design challenge for the students to participate in. Participating students received promotional material from various sponsors. [5]

Despite the fact that these examples represent only a brief snapshot of the student project events, they contain many elements common to the vision behind the ICT Showroom concept.

BACKGROUND

Project-based courses

The Computer Technology and Computer Science curriculums at Åbo Akademi University have for many years had a joint project course where the participants form groups and perform a project with a larger scope than normal exercises during standard course. The groups have been of size 3-6 persons. The project work has normally been software development, where the groups followed some software process prototype selected by the group.

The length of the course was two semesters, starting directly after the summer holidays in September, and running until mid spring, around Easter. The course itself was started with lectures on software processes and software projects, where after the students formed teams and started to work on projects. The projects were either ideas by the teams themselves, or projects assigned by the lecturers. The teams presented the status of their projects in regular project course meetings once a month. The projects teams were supposed to finalize the projects until the end of the project, but many times the projects overrun, and the final version was delivered late.

Also the Information Technology curriculum of Turku University of Applied Sciences has a long tradition of project-oriented way of working. The second year students have a mandatory Software Engineering project in their program and, especially, the final year students work closely with different projects often based on external assignments. However, there were no common platform to present the results and learn from the other student's project ideas and implementations.

Similarly, the Computer Science and Information Technology curriculums at the University of Turku include several courses containing project work. Currently such courses are found for example in the areas of Mobile Communication and Software Engineering. Also, Master's projects are often viable for inclusion to the ICT Showroom event. Before the event, there was no forum for student teams or research groups to present their projects or research results on campus.

Challenges with student motivation

One basic problem with the courses has been the lack of motivation for doing project work on a regular basis and delivering a final deliverable at the assigned time. Another problem was that the general curriculums did not include education on project skills. For instance, the normal Computer Science curriculum at Åbo Akademi University includes theoretical knowledge on Mathematics, Data structures, Programming languages Databases etc., but when it comes to running live projects, the students were basically on their own. To tackle this problem, lectures with project management basics where introduced in the course, and checkpoints such as kick-off meetings, milestones and definite deadlines where strongly emphasized in the course. However, lack of motivation was still a problem. As nobody did check or need the results of the projects, the groups were not motivated to keep up the pace during the project.

Internal exhibition

To deal with the lack of motivation, the teams participating the project course of Åbo Akademi University during the academic year 2006-2007 were asked to produce posters on their projects and present them during a course internal exhibition, to which all personnel of the department was invited. This was a definitive spark for the project work, and all teams were much more motivated to deliver a good project on time. The exhibition was open for two hours in a normal lecture room. In addition to the posters, the teams produced live demos of their projects. The rather simple possibility to demonstrate the projects to an audience, proved to be a very strong motivator for performing and finalizing the work in time.

Immediately following the success of the internal exhibition, the idea of having an even larger audience and larger pool of projects was born. A core organization group was formed, and a common event for the students of the campus was planned for the academic year 2007-2008, combining all project work done in the ICT House.

ICT SHOWROOM

The concept

The institutions participating in the event are the Information and Communication Technology related departments of Turku University of Applied Sciences, University of Turku and Åbo Akademi University. All three departments have been physically located in the same campus and in fact in the same building, the Turku ICT House, since autumn 2006. The first floor of the ICT House serves as the venue for the ICT Showroom event, allowing event guests to walk through the entire building and view the display stands with ease.

The event accepts two kinds of contributions: student projects made during the past year as a part of coursework in one of the departments, and research project presentations. For both types of contributions, the organizers provide a poster stand and a table for demonstrations. For the student projects, the organizers print the posters and cover the poster expenses. The student projects participate in the competition part of the event, where a jury evaluates each participating student project and selects a winning team.

In order to have a non-biased jury, it was decided to invite 4-6 local industry professionals to both act as members in the jury and to sponsor the prizes given to the winning teams. The jury assesses the technical contribution and quality, commercialization potential and presentation of the student projects. However, there are no exact criteria for the evaluations, allowing for different annual emphasis based on the jury composition. The jury spends two hours in the event familiarizing themselves with the student projects, discussing the ideas and solutions used in the projects with each student team. The jury members give immediate feedback to the students about their views on the operability and implementation of the project. After the evaluation round the jury members have a meeting to discuss the student projects and to select a winner and one or more other projects that in their view deserve a certificate of appreciation. To motivate the student teams to really do their best, the organizers have each year made sure that the prize received by the winning team is something substantial and makes the effort in the event worthwhile. In 2008, the price was an Internet tablet device, and in 2009 a mini-laptop for each team member.

Figure 1. Teams setting up their stands and presenting their projects at the ICT Showroom ’09 exhibition.

In addition to the student project competition, the event also includes a public vote in which visitors of the event may vote their favourite presentation and technical content. A certificate of appreciation is given to the winning team of each category. One of the voters is randomly picked to win a prize, which is typically a high quality digital audio player.

Even though the research projects are not included in the competition, the research groups benefit from the event in the sense that they can practice their presentation skills and use the event as a testbed for their demonstrations in preparation for scientific conference exhibitions. For this reason, research projects are allowed to bring their own presentation equipment and material to the event if they so wish - they are not required to limit themselves to the poster stands and tables provided by the organizers. Another advantage for the research projects is that they, using the ICT Showroom, can provide such presentation material that is normally not presented on scientific conferences. On scientific conferences, the emphasis is on new contributions, normally on deep technical details that the project is providing. The ICT Showroom gives a more practical overview of the project; information that you typically provide to a broader audience focusing on the problems the projects will solve.

Schedule and arrangements

The overall schedule of the first ICT Showroom is shown in Table 1, column 2007-2008. In the Kick-off event the ICT Showroom concept was presented to the potential participants. The idea of the Kick-off was to make things moving and to check the initial interest in the competition. Approximately 50 students were present, which was considered satisfactory.

The registrations to the event were done using a web based system, where the participants in the first stage registered the project name, members, abstract and contact information. Later on, the posters were submitted via this system, and then collectively printed at a print house by the organizers. In addition, a program leaflet and other documentation (e.g. team and jury instructions) were prepared in advance.

The exhibition was planned to last for four hours, and was announced to be open for public. During the exhibition the jury visited the teams, and in the afternoon the winners were announced. The key figures of the two first events are presented in Table 1.

Table 1
Key figures of the two first ICT Showroom events

	2007-2008	**2008-2009**
Announcement / Kick-off	Nov 30 / Nov 30	Dec 15 / -
1st registration deadline	Dec 15	-
Registration deadline	Jan 31	Jan 31
Poster deadline	Feb 29	Feb 27
Exhibition date	Mar 7 (Fri)	Mar 5 (Thu)
Exhibition open for public	11:00-15:00	11:00-14:00
Number of student projects	27	24
Number of research projects	15	14
Number of participants	163	132
Number of public votes	150	190
Jury size	5	6

Figure 2. The winning team the of ICT Showroom ’09 competition at the award ceremony.

In general, already the first ICT Showroom event was considered successful and the event was decided to be repeated the next academic year. The first time all practical issues had to be figured out by the organizers; during the second run in 2009, experiences and material from the first event were taken advantage of, which effectively reduced the workload of the organizing committee both beforehand and during the event. The main concept was found to be working; hence only some smaller changes were done.

In 2008, the organizers had to do much of the event disassembly (tables, poster walls); this was in part due to the schedule of the event (prize ceremony took place right after exhibition). Moreover, there was not that much external audience visiting the exhibition during the last hour. Thus, the length of the next exhibition was shortened from 4 hours to 3 hours. This proved to be a good improvement; the jury had just enough time to discuss with all teams and the exhibition was dismantled by the teams themselves while the members of the jury had their meeting. Moreover, this year a member from the foundation for the European Capital of Culture Turku 2011 was invited to join the jury to better support evaluation of projects that dealt with Digital Arts.

Public visibility and media

The intention was to get visibility in local newspapers and other media, too. Before the first ICT Showroom invitations to the media were sent out, but none turned up at the event. Also press releases both before and after the event were sent out, but the reaction by local media was poor. Only when the winning team was found to be from the Swedish speaking Åbo Akademi University, a local Swedish speaking newspaper and radio channels contacted the winners and interviewed them. But on the general level, the event in itself seemed not to be interesting enough.

A new attempt to attract media was made with a slightly different focus even during the second ICT Showroom. This time some minor hits in the local media were noticed – but no real success now either. A completely different strategy must be tried in the future. Maybe the most successful project teams and their topics should be highlighted in the press releases instead of reporting on the event in general?

FUTURE DIRECTIONS AND DISCUSSION

In this paper, the ICT Showroom student project exhibition and competition event was presented. The background, concept and practical issues concerning the event and its planning process were described.

The ICT Showroom has now been arranged twice and the experiences have been very positive. However, the concept will be further improved for future rounds; the tradition is just becoming established. Some directions for future development steps are:

- So far, the exhibition audience seemed to consist on people working or studying at the venue. The event contains a lot of potential as a tool for recruiting students to the institutions, and it could somehow be integrated into the upper secondary school recruitment programs of the universities.

- Acquiring participants to the event has shown to require a great effort – both concerning the student and research projects. Despite the fact that this most probably gets easier with time as the event truly becomes an integral part of the academic year at the campus, further actions should be planned. Getting student teams to participate requires effort from the instructors of the courses that include a practical project work.

- In order to be able to develop the concept further, it is necessary to gather detailed feed-back data from the participants, staff members, event visitors and industrial representatives. We plan to achieve this by means of designing and conducting a set of surveys.

The ICT Showroom event clearly supports the design-build learning activities described by the CDIO framework. It has grown into a multi-institutional and interdisciplinary workspace that "supports and encourages hands-on learning of product and system building, disciplinary knowledge, and social learning" [1], which in our view supports the rationale of adopting CDIO methods and standards in our engineering curriculums.

The ICT Showroom has already now proven to be a successful and easy way to facilitate project-oriented teaching and learning activities and, moreover, it has served as a networking platform for the students, staff and local companies. For example, several members of the winning team of ICT Showroom '08 were employed by one of the companies in the jury. The concept and experiences can be easily utilized also at other institutions and learning environments.

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5th International CDIO Conference

Reframing Engineering Education:
Impact and Future Direction
Singapore Polytechnic, Singapore
June 7 – 10, 2009

IMPLEMENTATION AND EFFICACY OF ACTIVE LEARNING STRATEGIES IN ENGINEERING MATHEMATICS

By Dr Charlie McCartan
School of Mechanical & Aerospace Engineering
Queen's University Belfast
N. Ireland
June 9th 2009

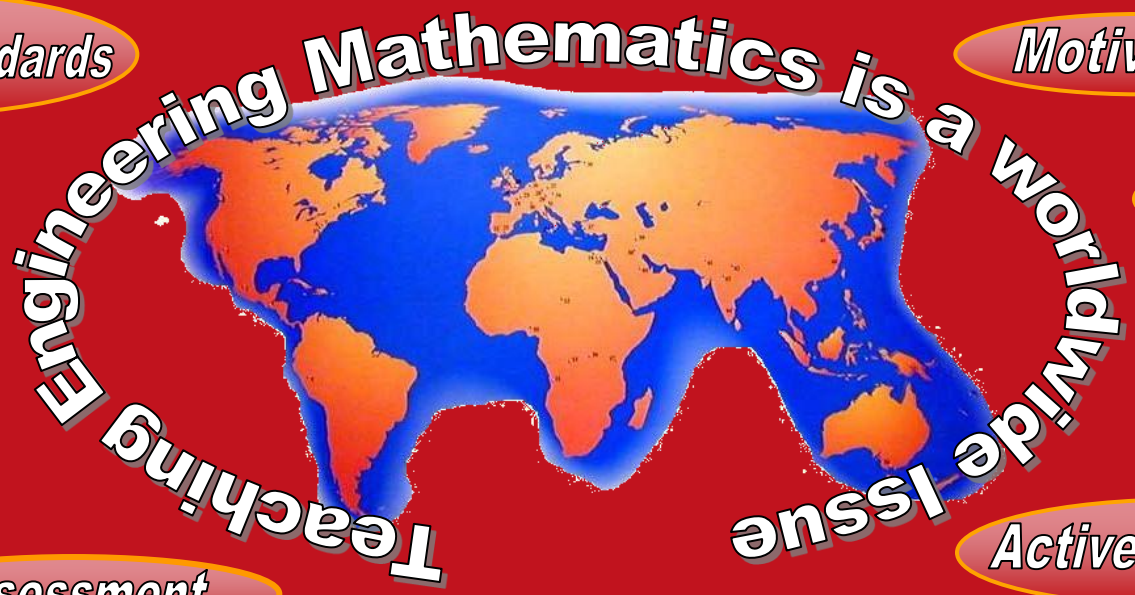
Teaching Engineering Maths!

Entrance Standards

Motivation

Teaching

Resources



Active Learning

Assessment

Content

How?

What are we going to do?

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Summary of Presentation

Introduction

- Rationale
- Existing Year 1 Mathematics Provision

2nd Year Mathematics Module Preparation

- Rationale
- Objectives
- Content

2nd Year Mathematics Module Efficacy

- Assessment Results
- Student Feedback

Conclusions

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Introduction

- **CDIO Collaborator** since 2003
- Partway through **plan to implement CDIO**
  - established BEng and MEng programs
  - New Product Design program
- Product Design Program has different entrance requirements
  - **LESS MATHS!**
- Mathematics module at Stage 1 on PD program
  - ONLY formal tuition

Rationale

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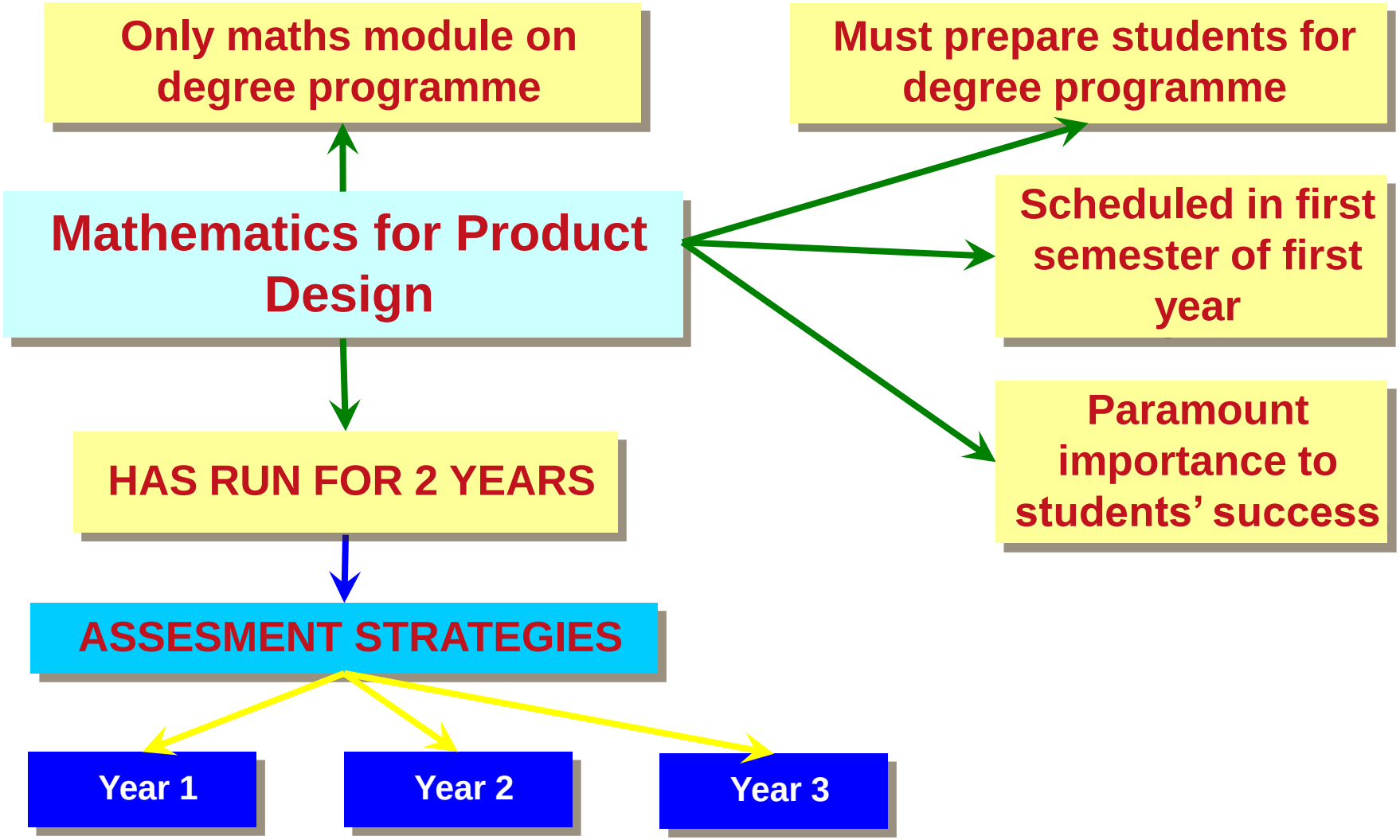
Introduction Mathematics for Product Design: Year 1 Module



Introduction

Mathematics for Product Design: Year 1 Module Preparation

Preparing the Engineering Mathematics Module

CDIO Strategy

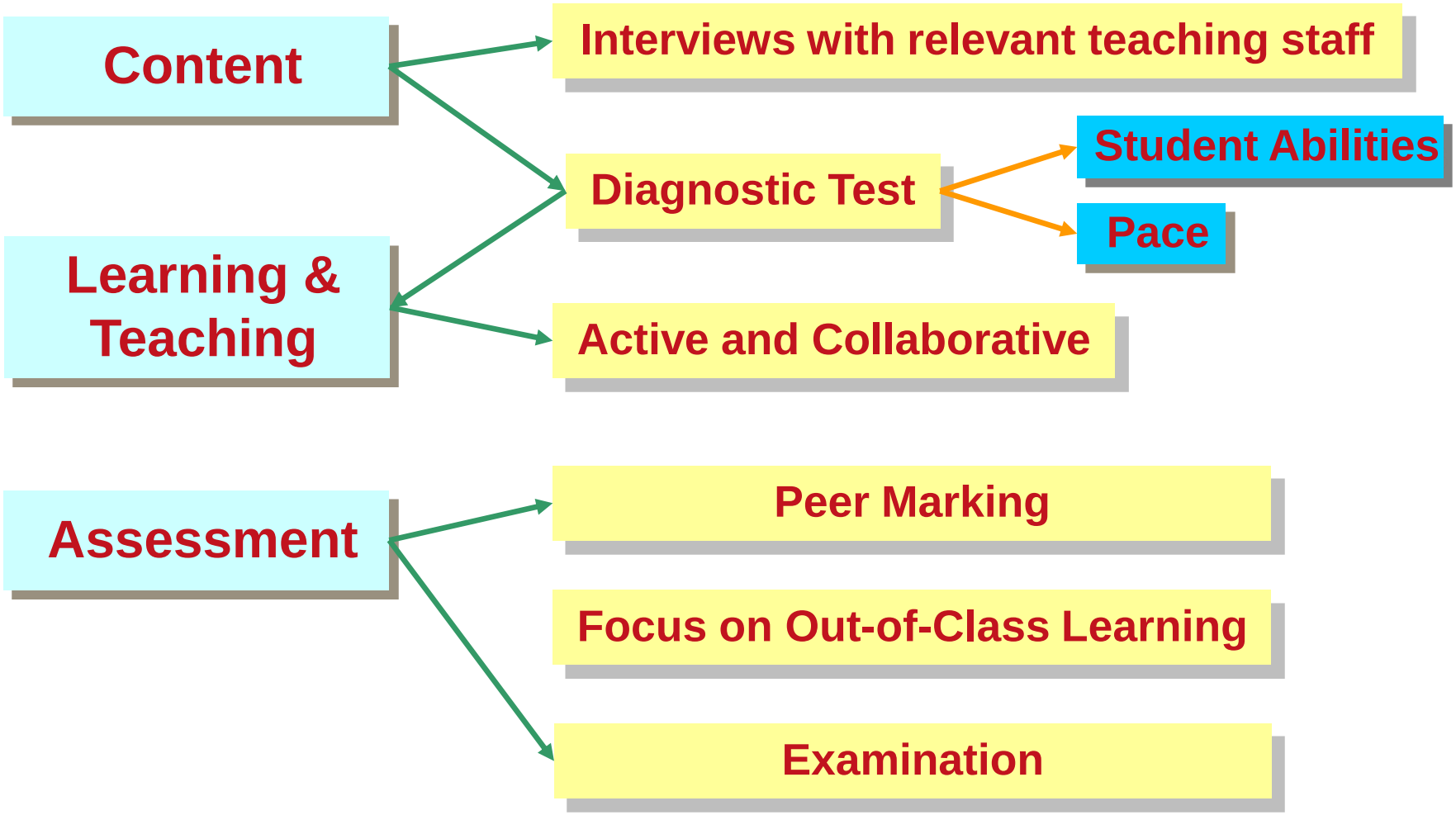
Module integrates with rest of course

- Learning Strategies
- Relevance/Applications
- Keep students motivated and engaged

Developed using best current pedagogical practices

Introduction

Overview of Year 1 Mathematics Module



Introduction

Module Evaluation – ‘Assessment is Key’

Rust

“*if work does not have marks attached many students will either not do it at all or only do it in a perfunctory way*”

Gibbs

“*assessment works best to support learning when a series of conditions are met*”

……“*what influenced students most was not the teaching but the assessment*”

However...

More was needed!

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2nd Year Engineering Mathematics Module
Preparation

RATIONALE

Active learning sessions

Homework/tutorial sheets

Examination

Second diagnostic test

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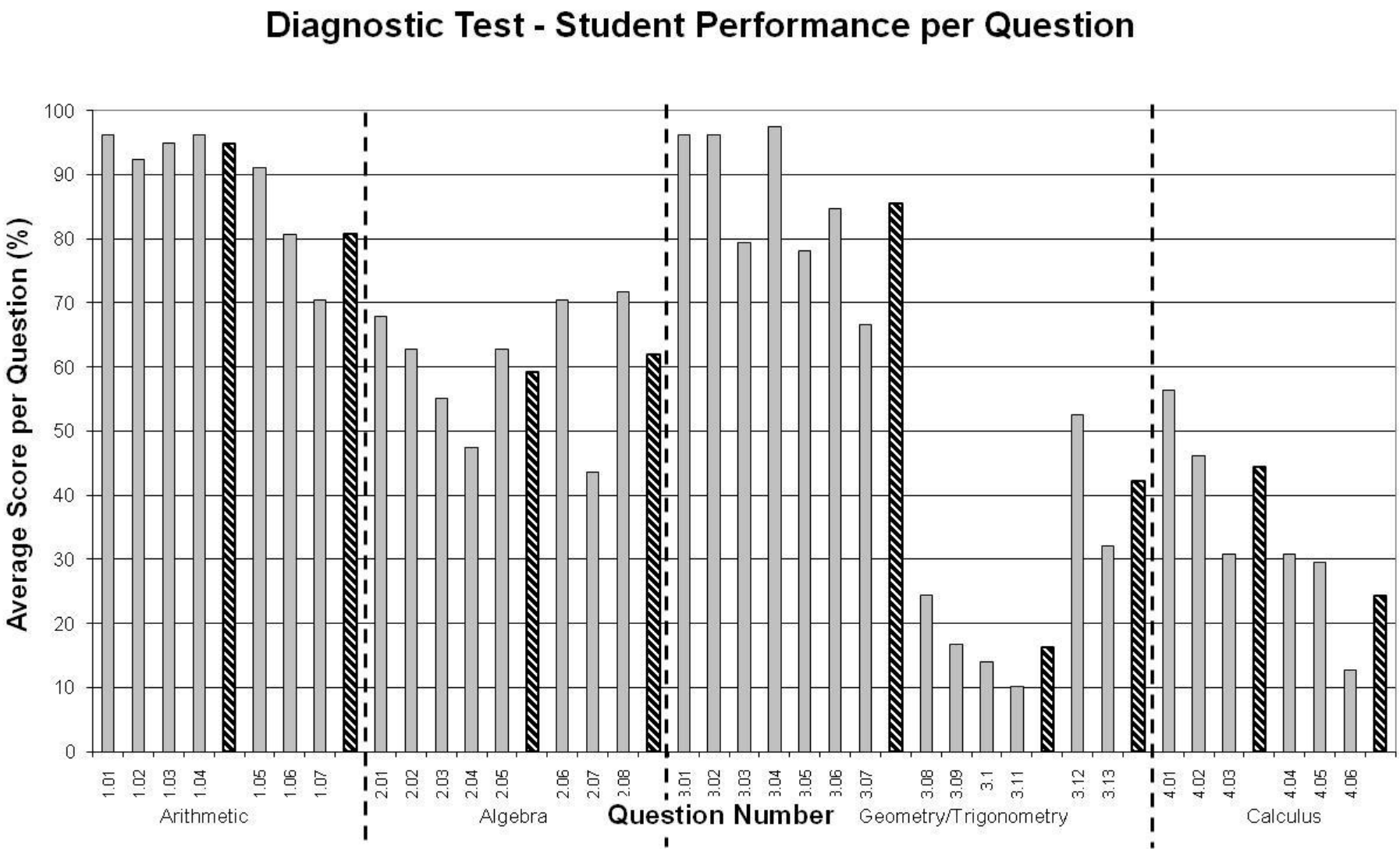
Rationale for 2nd Year Engineering Mathematics Module



Objectives for 2nd Year Engineering Mathematics Module

- Provide more practice in the mathematical methods presented in the first year course.
- Promote a deeper learning environment.
- Emphasise the relevance of mathematics to the PDD degree.
- Develop other non-disciplinary skills relevant to the CDIO syllabus.

Again...

best current pedagogical practices researched and applied

Content for 2nd Year Engineering Mathematics Module

Computer Assisted Assessment using the HELM Learning Resources

- *4 Main Topics – 4 Class Tests – Immediate Feedback*
- *Mini Lectures, Tutorial classes & Group Discussions*

Motivation to Learn

Appropriate Workspaces Essential

Analytical Design Assignments in MS Excel

- *3 Simulation Assignments – clearly defined, realistic design problems*
- *Continual feedback*
- *Promotes Deeper Learning*
- *Develops Personal, Interpersonal & Professional Skills*

2nd Year Engineering Mathematics Module
Efficacy

Did it Work?

Assessment Results	Student Feedback

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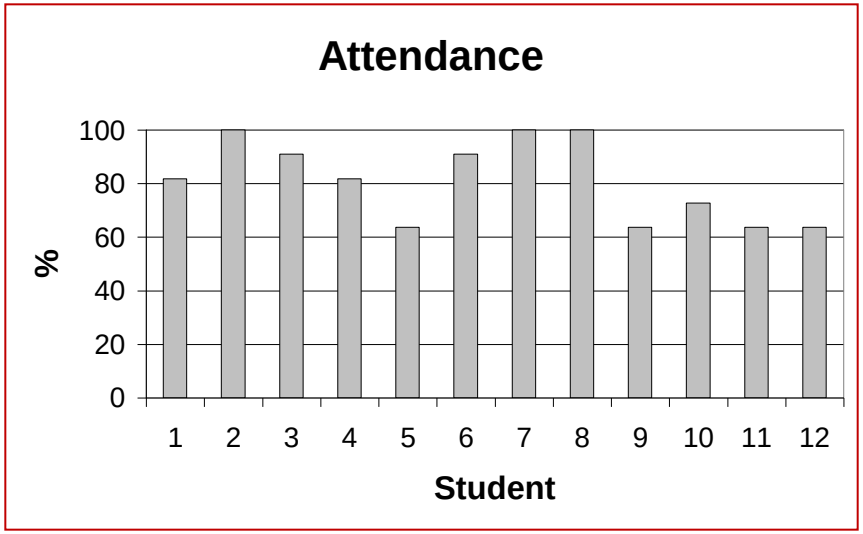
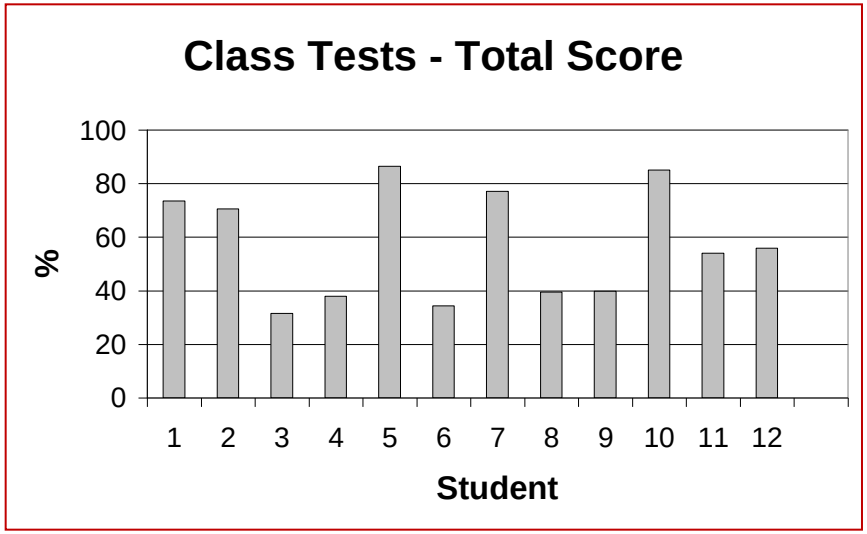
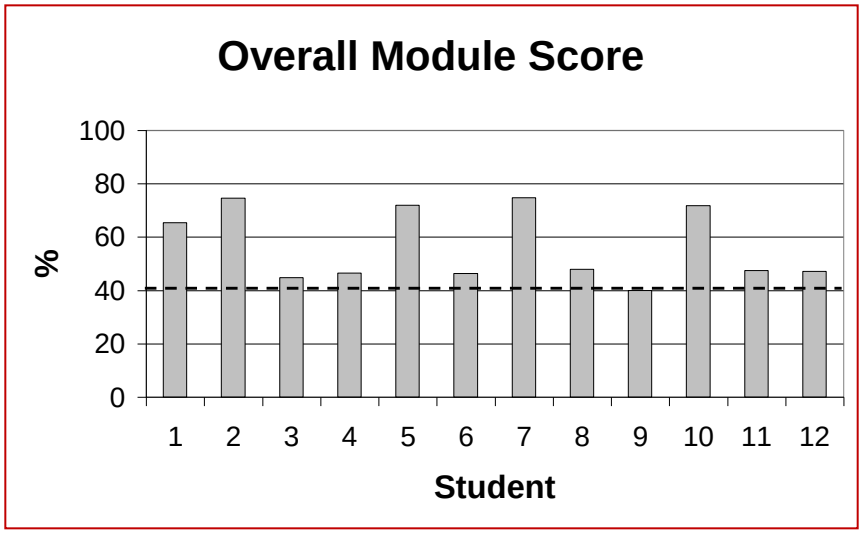
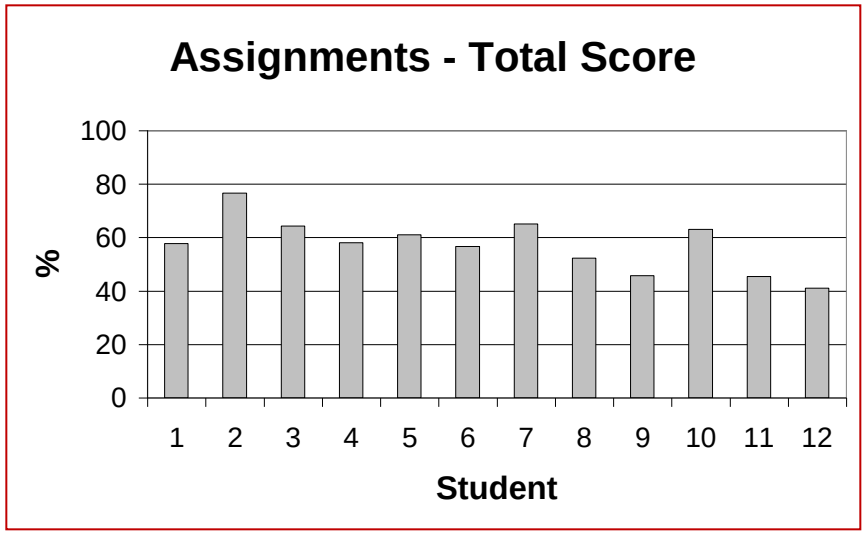
2nd Year Engineering Mathematics Module
Assessment Results









2nd Year Engineering Mathematics Module
Student Feedback

Student Module Evaluation

Questionnaire

- students clearly satisfied with:
  - the module contents
  - the teaching methods
  - the assessment methods
  - the feedback
  - the lecturer's contributions to their learning
- The results indicated a satisfaction level of over 90% for all aspects of the module

Formative Feedback

- Please indicate the most satisfying aspect(s) of this module
- Please indicate the least satisfying aspect(s) of this module

"Not many people had much Excel his made

"10:00am start"

"Giv on difficult topics such as differentiation and Integration."

Conclusions

- **New 2nd year mathematics module succeeded in motivating and engaging the students - all passed!**
- **Very positive formative feedback in relation to the CAL, CAA and real life simulation assignments.**
- **Such an active and interactive learning environment involves the students in the learning process**

– Students' understanding of basic concepts can be improved through Computer Aided Learning (CAL), Computer Assisted Assessment (CAA) and realistic simulation assignments.

– It provides students with a flexible learning medium.

– It provides the opportunity to offer constant feedback to individual students.

– It also provides instant feedback to the instructor enabling immediate and focused support for the students.

– Such two-way feedback helps develop and tailor the course.

– It provides an enjoyable and constructive learning environment which fosters a more positive attitude towards learning mathematics

Queen's University Belfast

QUESTIONS

Singapore Polytechnic

School of Digital Media and Infocomm Technology

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SINGAPORE POLYTECHNIC

Implementation of CDIO skills in Info-communication Technologies Design-Implement Projects

Helene Leong

Ho Teck June

SINGAPORE POLYTECHNIC

INTRODUCTION

This paper describes how the final year project module is implemented to promote the integration of knowledge and skills learnt in the core modules and to the application of CDIO skills in their projects.

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Final year project module

- Aim is to provide students with an opportunity to integrate and apply the knowledge and technical skills to real world problems.
- Phase 1: Project proposal & specification
- Phase 2: User & admin guides, program listings, test plan and results & a deployment kit

Match CDIO skills to project module

CDIO	Deliverables
Conceive	Brainstorm ideas & scope of project
Design	Design using UML (class, use, sequence diagram, etc) Design ERD for database
Implement	Develop the project prototype (PHP, Javascript, mySQL, Action Script & etc)
Operate	Project is operational

Literature Review

- **Crawley et al, 2007**

  Besides a good command of technical knowledge, our graduates must be equipped with a range of personal, interpersonal, professional, product and system building skills and knowledge.

=> Singapore Polytechnic has adapted the CDIO syllabus for our context and students

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Literature Review

- **Malmqvist, 2004**

  "..The product that is created in the learning event should be developed and implemented to a state where it is operationally testable by students in order to verify that it meets its requirements and to identify possible improvements".

  => In realizing solutions to a client's requirements, students apply the CDIO skills

Methodology

A questionnaire was administered to:

- 21 Diploma in Business Information Technology (DBIT) year 3 students
- 25 Diploma in Information Communications Technology (DICT) year 3 students
  - 100% responded

- The aim of the questionnaire was to find out the students' perception on the application of the personal, interpersonal, conceiving and designing skills to the final year project.

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Questionnaire on CDIO skills

- Personal skills and attitudes
- Teamwork
- Communications
- Conceiving
- Designing and Implementing

Survey: students had to choose from 5 diff. proficiency levels.

1. Not applicable
2. I am aware of the skill
3. I am able to understand and explain the skill
4. I am able to apply the skill well in the project
5. I am able to apply the skill in my other modules and projects.

Research questions:

Percentage of year 3 students who could:

- Apply personal skills and attributes to their project?
- Apply interpersonal skills to their project?
- Conceive the project scope?
- Design and implement the project?

(a) Questions on personal skill and attitude and the mean scores

Skills	**Mean**
I identified areas of self-improvement	4.02
I used a range of critical thinking skills	3.96
I identified key issues and problems to be solved	3.91
I had the opportunity to demonstrate perseverance	3.89
I had the opportunity to show initiative	3.87
I had the opportunity to demonstrate professionalism and integrity	3.83
I used a range of creative thinking tools and techniques	3.83
I managed my time and resources well	3.61

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(d) Questions on design and implement the project?

Skills	**Mean**
I selected appropriate techniques, tools and processes for the project.	3.83
I provided new and advanced IT solutions to my users.	3.80
I analysed and proposed alternative designs and solutions to my users	3.78

The overall mean for this category is the lowest of 3.80.
Reason: There are few modules whereby students could propose alternative designs and solutions for the projects

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Summary of survey results

Proficiency Level / Skills	NA	I am aware of the skill.	I am able to understand and explain the skill.	I am able to apply the skill well in the project.	I am able to apply the skill in my other modules and projects.	Mean
Teamwork Skill	0	7 (3.8%)	45 (24.46%)	73 (39.67%)	59 (32.07%)	4.00
Communications Skill	1 (0.43%)	6 (2.61%)	60 (26.09%)	90 (43.48%)	63 (27.39%)	3.95
Personal Skill and Attitude	0	14 (3.8%)	97 (26.4%)	182 (49.5%)	75 (20.4%)	3.86
Conceive Skill	0	6 (3.26%)	58 (31.52%)	84 (45.65%)	36 (19.57%)	3.82
Design Skill	0	4 (1.45%)	89 (35.51%)	122 (44.20%)	52 (18.84%)	3.80
Overall	1 (0.08%)	37 (3.0%)	349 (28.5%)	551 (45.1%)	285 (23.3%)	3.89

Table 1: Frequency distribution (with percentages in parenthesis) & means of students' perception of their proficiency levels for the 5 types of skills

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Open-ended: Skills students' learnt

Ranking:

Teamwork e.g. working dynamics

Communications skill egg presentation skills

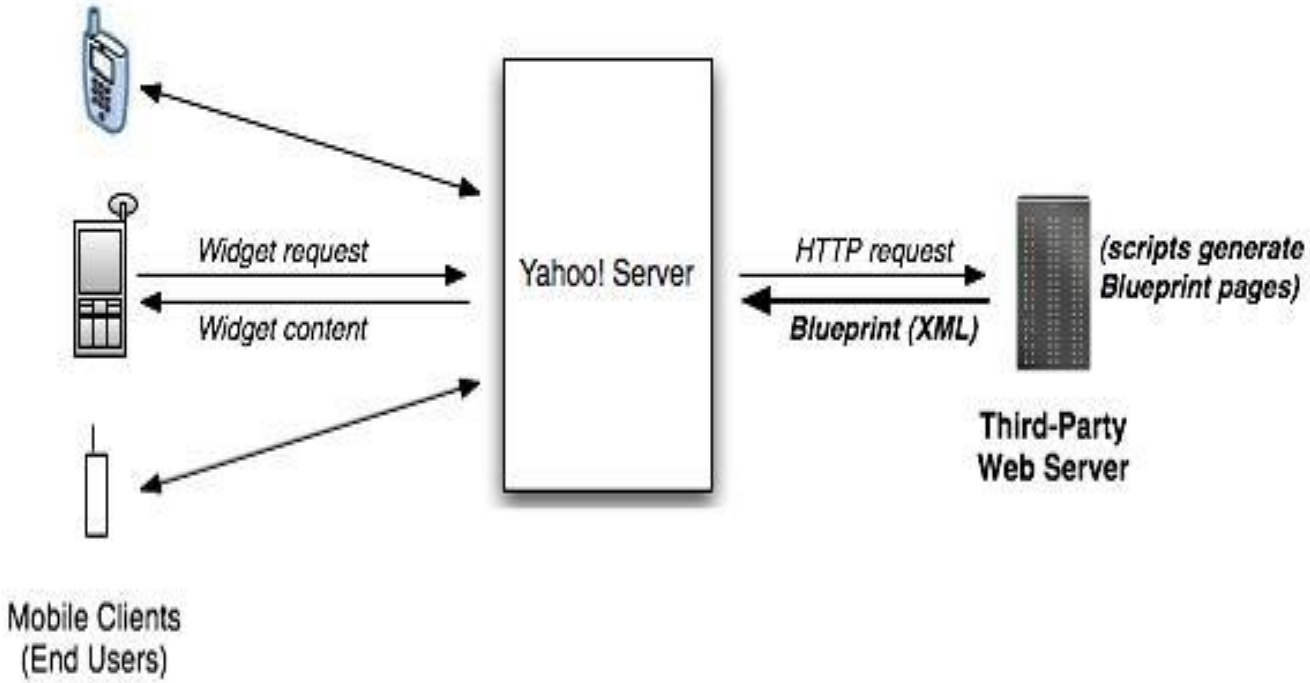
Conceive skill

Design skill

Open-ended: Challenges students encountered

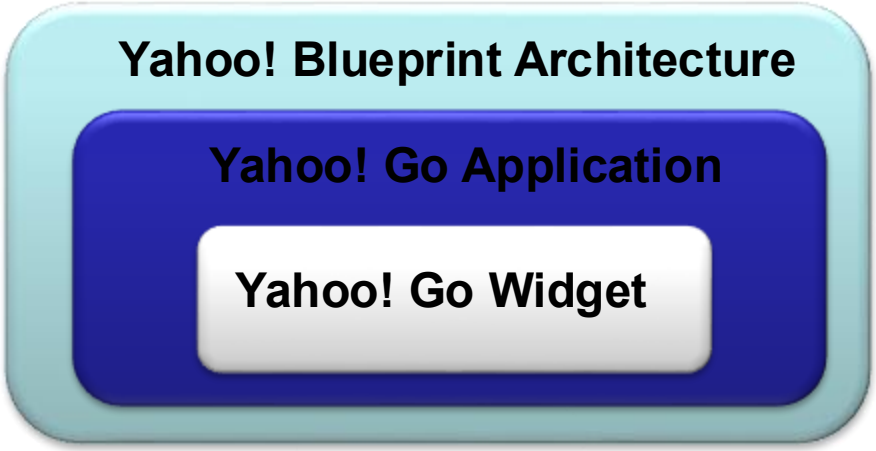
- “Time constraint as we have to complete assignments for other modules”
- “Difficult to schedule meetings?
- “Learn a new programming language egg PHP”
- “Unclear user’s requirements”

Project 1: Yahoo! Blueprint Architecture



Functions of DBIT Widget

- DBIT Information
- Food Gourmet
- Student Club
- SP Campus Map
- Latest News
- Feedback



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Project 2: Revamp a web site

- Functions
  - To demonstrate products using Flash software
  - To include a discussion forum
  - To provide a News section
  - To include a newsletter subscription section
  - To use freeware and free hosting of web application system.

Conclusion

High means? (in all modules)

- Teamwork (freq=71.7%(33),mean=4.0)
- Communication (freq=70.7%(32), mean=3.95)
- Personal skill (freq=70%(32), mean=3.86)

Lower means? (only module)

- Conceive skill – (freq=65.5%(30), mean=3.82)
- Design skill – (freq=62.0%(28), mean=3.8)

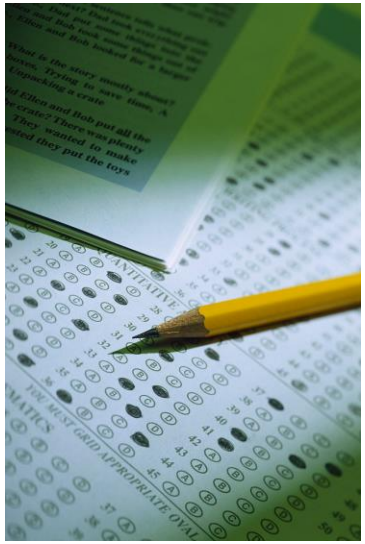
Conclusion

Aware of the 5 types of skills	3%(2)
Understand and explain 5 types of skills	28.5% (13)
Able to apply the skills well in their projects	45.1% (20)
Able to apply the 5 skills in other modules and in projects	23.3% (11)

Recommendation

- **Review the curriculum** and incorporate more **conceive and design skills** earlier, perhaps in **1st year and 2nd year** of the course curriculum.

  => this will then provide more opportunities for students to acquire and practice them.



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Assessments

- Phase 1(40%)
  - Group Assessment (20%)
  - Individual Assessment (10%)
  - Presentation (10%)
- Phase 2 (60%)
  - Group Assessment (10%)
  - Individual Assessment (30%)
  - Demonstration (20%)

IMPLEMENTING CDIO IN ELECTRICAL & ELECTRONIC ENGINEERING MODULES: PRACTICAL CHALLENGES AND HOW TO MEET THEM

Voon Ching Choo
Dennis Sale
Singapore Polytechnic

ABSTRACT

This paper presents the work of the School of Electrical & Electronic Engineering (SEEE) faculty at Singapore Polytechnic who have been reframing and redesigning their engineering curriculum to make the student learning experience more interesting and aligned to specific CDIO standards for reforming engineering education.

The CDIO framework was implemented in the school in 2008 and required a major review of existing curriculum to identify gaps between existing practices and those suggested by the guiding principles of CDIO. One major outcomes of the review was the creation and introduction of a new project-based module, 'Introduction to Engineering', which is aligned with the existing core modules, 'Principles of Electrical & Electronic Engineering' and 'Digital Electronics'. The objective was to provide a more integrated learning experience in which key theoretical concepts and principles, in the two core modules, are integrated and simultaneously applied and immediately in the new module. In the process of this curriculum re-design, 3 key CDIO skills (Personal Skills & Attitudes, Teamwork & Communication) have been systematically integrated into the module program.

In the paper, we present our key findings and significant learning from designing and implementing these first-year introductory courses in our engineering programs at the SEEE. We will show how we have customized CDIO Standards to a polytechnic context and developed integrated, active and experiential learning experiences to help students achieve both a deeper understanding of technical fundamentals and the skills and attitudes required in the wider context of real world engineering

The specific changes relating to curriculum development (e.g. learning outcomes, teaching and assessment) will be identified as well as the challenges faced by staff in attempting to make this curriculum innovation effective and achievable within the inevitable constraints that change typically creates.

Finally, we will present the summarized feedback from students and staffs, obtained through interview, students' blog and final review, and offer our present frame for future improvement and subsequent CDIO curriculum development.

KEYWORDS
Curriculum, Syllabus, Objectives, Pedagogy, Learning Tasks, Assessment

INTRODUCTION

In reframing and redesigning the engineering curriculum in the School of Electrical & Electronic Engineering (SEEE) to be aligned with specific CDIO standards, a number of generic curriculum development questions must be effectively addressed, these are:

- What present engineering courses are to be reframed and redesigned, and to what extent?
- What specific CDIO skills are to be the primary focus in the curriculum redesign?
- How would the curriculum redesign affect teaching and learning arrangements, as well as the assessment practices?
- How would such changes impact staffing and resource capabilities?
- How might the necessary changes be managed in ways that encouraged stakeholder buy-in and mitigated potential sources and areas of resistance?

In this paper, we will show how the creation of a new project-based module 'Introduction to Engineering' has been used to develop an integrated curriculum with a strong focus on active learning. We specifically focus on how we addressed the essential questions identified above, in order to customize the curriculum to a polytechnic context. Practical examples of the learning outcomes, learning tasks and assessment will be used to illustrate the key decisions taken. Specific challenges faced will be highlighted and the approaches taken to deal with them explained. Finally, based on initial feedback from staff and students, we offer our frame on this curriculum approach and possible future developments in CDIO implementation.

CURRICULUM OUTCOMES

Defining curriculum outcomes is essentially concerned with addressing the question of what skills, knowledge and attitudes are most useful to attain and for what purpose. In the specific context of engineering education, the issue of curriculum outcomes is captured by Crawley et al (1):

> What is the full set of knowledge, skills, and attitudes that engineering students should possess as they leave the university, and at what level of proficiency? (p.34)

It is exactly this question that the CDIO framework seeks to address, and was, in fact, a product of a comprehensive stakeholder focus group exercise comprised of engineering faculty, students, industry representatives, university review committees, alumni, and senior academicians. The resulting CDIO Syllabus classifies learning outcomes into four high-level categories:

1. Technical knowledge and reasoning
2. Personal and professional skills and attributes
3. Interpersonal skills: teamwork and communication
4. Conceiving, designing, implementing, and operating systems in the enterprise and societal context.

These high level categories are further subdivided and organized into four discrete rational levels. While levels 1 & 2 are generic and specified, the selection of level 3 & 4 learning outcomes and the level of proficiency is within the framing of individual educational

institutions, customized to the course context and stakeholder needs. The recommended process for establishing proficiency levels and learning outcomes is as follows:

- Review the generic CDIO Syllabus and make modifications or additions to customize it for a specific course of study within the technical and national context of the program.
- Identify and survey the important stakeholders of the program – both internal and external to the university – and validate their coverage and proficiency level to the local context
- Write specific learning outcomes that guide the design of learning and define the assessment requirements

This we felt was a critical process for the success of the curriculum innovation. Limitations in the appropriateness, clarity and currency of the learning objectives inevitably run through the instructional and assessment systems. There's limited value in teaching and assessing a knowledge or skill area in effective and efficient ways if it has little or no relevance to stakeholder interests.

Furthermore, as Diamond (2) points out:

> …it is a major mistake to take any published list of basic skills or competencies and accept it for use on another campus without revision. Not only will the specific items on such a list vary from institution to institution but the definition of each item will vary as well. The final list of competencies, their definitions, and how they should be assessed must evolve on each campus. Faculty ownership in the process is an essential element for success. (p.53)

In order to ensure that the CDIO skills at levels 3 & 4 were most appropriate to the context of students at Singapore Polytechnic a working group of representatives from the various engineering schools was established to systematically work through all the CDIO Skills, with a remit to:

- Identify which skills were most appropriate in the SP context
- Decide a viable proficiency level
- Write specific learning objectives that are measurable at level 4

To provide flexibility, individual schools are at liberty to customize objectives at level 4 to the specific engineering context where appropriate, providing there is no change in the knowledge domain covered, cognitive activity involved and proficiency level.

In further customizing the SP CDIO curriculum outcomes to the specific context of the new project-based module 'Introduction to Engineering', we worked systematically through existing curriculum objectives, with the view to:

- Move the curriculum focus towards more performance-based learning outcomes

- Write specific learning outcomes which systematically infuse selected CDIO skills (in this case, Personal Skills & Attitudes; Interpersonal Skills: Teamwork & Communication) into the content curriculum. (The SP customized CDIO skills are presented in Appendix 1)

In reviewing the existing learning outcomes we noticed a significant number were written in knowledge or comprehension terms (based on Bloom's (3) Taxonomy of Educational Objectives, which is used as the basis for writing learning outcomes in SP). As we wanted to make the module more interesting and real world focused for students, it was readily

apparent that we needed to make fairly major changes in the framing of the module's objectives.

In order to achieve this we re-visited the essential question of "what do we really want student to do at the end of this module?' From this we were able to identify a range of key engineering skills, fundamental areas of understanding and critical issues that engineers would encounter in actual engineering environments. It is then a selection and structuring process to ensure that the module has both relevance, structure and one that might excite students to what engineering can be about. Indeed, once the curriculum objectives are framed more towards a performance-based emphasis rather than knowledge recall, it focuses attention on the real world applications of the module content.

In integrating CDIO Skills with the technical content we modelled the infusion approach of Swartz (4). The infusion approach argues that generic process skills such as thinking are best learned through "conceptual infusion" with the subject content. This involves identifying the ingredients of good thinking - "the skills, competencies, attitudes, dispositions, and activities of the good thinker"- and designing these into the structure of the lesson content (p.125). The essential point is that the thinking processes and skills mutually develop the meaningful acquisition of knowledge to form understanding.

The infusion approach effectively resolves, or at least mitigates, the debate over how much content and process should be included in a curriculum offering. While there is, of course, no universal answer to this question – it is always a question of what learning outcomes are deemed most relevant in a situated context. However, there is virtual agreement among cognitive psychologists that effective thinking - however defined - needs an extensive and well organized knowledge base. As Resnick (5) summarizes:

> Study after study shows that people who know more about a topic reason more profoundly about that topic than people who know little about it. (p.4)

Similarly, Satinover (6), drawing from recent brain research makes the case for the importance of repetition in the learning process:

> …these mundane chores are precisely what turns the fourth brain from a mass of randomness into a intellect of dazzling capacity. "Genius," according to Thomas Edison, "is one percent inspiration and nine-nine percent perspiration. Of "critical thinking skills," he had nothing to say. (p.49)

However, while thinking is only developed when thinking about something, knowledge is only made meaningful through thought. As Paul (7) strongly argues:

> Thought is the key to knowledge. Knowledge is discovered by thinking, analyzed by thinking, organized by thinking, transformed by thinking, assessed by thinking, and, most importantly, *acquired* by thinking. (vii)

Our approach, therefore, was to recognize the range of important components of effective learning and derive a pedagogically sound and viable structure for the infusion of CDIO Skills. In the specific case of 2.4 'Personal Skills & Attitudes', for example this has involved identifying where in the subject content exist the richest opportunities to infuse the desired thinking and learning skills.

Having already framed the module towards real world applications, it is then possible to use cognitive modelling of the key activities to identify the types of thinking that underpin highly effective performance. This is typically achieved by firstly asking the subject specialists (in this case academic faculty) to make explicit their thinking in relation to the following question:

How would a highly competent person think in the effective execution of this activity?

A useful technique to facilitate this is to visualize the activity and try to systematically describe the stages and types of thinking involved in conducting it effectively. Using this technique in relation to the 'Introduction to Engineering' Module, we were able to identify the specific types of thinking that underpinned competence in the various topic areas. To illustrate, in 'Circuit Design & Production', the following are examples of specific level 4 learning outcomes:

- Compare and contrast the use of a strip board and bread board in circuit design
- Design an appropriate components layout on a strip board
- Analyse integrated circuit and relay datasheets

Table 1 illustrates the revised curriculum outcomes for the IE module.

Table 1

Learning Outcomes
INTRODUCTION TO THE WORLD OF ENGINEERING
Explain the main purpose and goals of the engineering profession.
Analyse the attributes of modern engineers.
Identify the impact of engineering on the environment e.g. economic, social, ecological, etc.
Identify the challenges facing engineering professionals
Identify the basis of values and ethics
Evaluate the impact of values and ethics in engineering decision making
Make sound ethical judgements on issues relating to the professional conduct of engineers

Circuit Design & Production
Explain the purposes and use of electronic circuits
Compare and contrast the use of a strip board and bread board in circuit design
Design an appropriate components layout on a strip board
Assemble components on a strip board to create a circuit
Produce a schematic diagram and artwork using CAD tools
Analyse integrated circuit and relay datasheets
Construct and test a circuit using appropriate tools
Troubleshoot a circuit using appropriate electronic equipment
Integrate circuits using appropriate wires and connectors
Explain the process of fabrication in producing a PCB

Similarly, it was then a fairly straightforward process to infuse other CDIO skills such as communication and teamwork into the module. For example, in the Introduction to Engineering module, as a significant component of the learning activities required students working in groups, this ensured a naturally occurring learning opportunity to include selected 'Teamwork' and related 'Communication' learning outcomes, such as:

- Identify goals, agenda and team procedures for completing an engineering project
- Identify the stages of team formation and their impact on team performance
- Display teamwork in completing an engineering project
- Design and deliver a presentation to a given audience using appropriate communication strategies
- Speak clearly and coherently in a range of communication situations (e.g., explaining engineering processes, procedures, etc)

ALLIGNING CURRICULUM COMPONENTS

In the CDIO framework, curriculum development follows the principles of 'component alignment'. This basically means that having derived the curriculum learning outcomes (as documented above), it is then essential to ensure that:

- The instructional strategies and resources used are those most effective and efficient for supporting the learning process to meet these learning outcomes
- The assessment systems (methods and procedures used) are those that provide the most valid and efficient assessment of the learning outcomes.

In this way, the 3 key components of the curriculum (learning outcomes, instructional strategies and assessment) are fully aligned and calibrated.

A major challenge here is to develop learning designs and teaching strategies that are able to provide authentic learning opportunities for student to acquire the necessary skills, and at the appropriate levels. In cases where complex performance (incorporating the integration of concepts, types of thinking, communication skills, etc) was involved, authentic real world tasks would be required to provide both learning and assessment opportunities. As the assessment for this module was 100% in-course assessment through two substantial project components, we were then left with the task of designing projects tasks that ensured learning and assessment opportunities calibrated to the learning outcomes. A project example (including the assessment areas is contained in **Fig 1** below:

Fig 1

Project #2 – Moving Car Transit

NOTES OF GUIDANCE

Objective:

This project requires you to design, build and test electronic circuits necessary to control a range of movements in a model car (e.g., mode forward, reverse and stop, etc).

The project is to be done in groups of 3 to 4 and will be completed by week 15.

Scope:

To meet the project requirements you will need to:

- Form a work team of and organize the necessary activities you will need to do in order to complete the technical requirement specified below. (Note: it is important that your team identifies clear roles and responsibilities, distributing and coordinating various tasks appropriately, and is able to operate as a high performing team).

- Build and test the following circuits:

    1. Light Dependent Sensor Circuit – to detect the station.
    2. Counter & Display Circuit – to display the Station number on the 7 – segment LED display.
    3. Motion Control Circuit – to activate the motor and move the car in forward or reverse direction.
    4. Voltage Regulator Circuit – to provide 5V dc supply.

- Design a Counter Limiting Circuit that is able to integrate the above circuits, enabling the car to move forward to any Station, reverse automatically and stop after hitting an emergency switch (micro switch) in both forward and reverse directions.

- Incorporate additional specific performance and/or aesthetic features which may differentiate your car from the rest (e.g., can do extra movements, perform faster in certain movements, has novel/attractive appearance, etc).

Assessment Components	**Mark weighting in %age**
Plan, Build & Test Circuits 1-4	40%
Counter Limiting Circuit Design	20%
Creativity (e.g., enhanced functionality, aesthetics)	10%
Teamwork (e.g., goal setting, management of team-roles and responsibilities, dealing with conflict/challenges, etc)	10%
Communication (e.g., clarity and cohesiveness of explanation, etc)	20 %
Total	**100%**

Using a range of performance-based tasks both acts as a means of structuring the integrated learning experience as well as providing more authentic assessment opportunities.

In this way, as Perkins (1992) suggests, “Teaching, learning, and assessment merge into one seamless enterprise” (8).

IMPLEMENTATION ISSUES

In order to facilitate the curriculum changes outlined above, a number of planning and staff development considerations were addressed. At department level, deputy director and chairmen of course management attended the CDIO overseas conference and shared the experiences and potential benefits with staff. Academic staff underwent a range of training opportunities (e.g., workshops, briefings, etc) to become familiarised with the CDIO Framework, and the specific skills involved in thinking, communication and teamwork. More than forty suitable staff were identified to teach the module which runs across 5 diplomas with total cohort of more than 900 students.

In order to mitigate staff concerns that the implementation of CDIO might not be welcomed by students and subsequently result in low student feedback for staff, a development team was set up to integrate the two core modules in term of scheduling, arranging necessary meetings and other training and administrative support.

As this was the first run of the programme, module coordinators conducted a two day training event for staff to ‘dry-run’ through the module contents, teaching plans, learning outcomes and assessments. 8 labs were extensively renovated with trapezium tables which can be combined to form different layouts for discussion or project work. The Smart board was used for better illustration and presentation, and 6 separate whiteboards on the walls were set up to facilitate group discussions. Technical officers who are competent in project work were selected to man the labs, which were opened for free access even when there were no scheduled lessons.

EVALUATION

In order to evaluate the effectiveness of the module, a number sources of feedback have been sought through the following data collection methods:

- Online blog in which students respond to designated questions posed in relation to specific CDIO activities
- Face-to-face dialogue sessions with class leaders
- Staff dialogue (both ongoing and at end of semester)

The student experience has been particularly interesting and varied. From the dialogue sessions with class leaders, it was apparent that many of the students thought the first project (designing a voltage level detector) helped their understanding of the subject content. However, some felt it was quite difficult and stressful. There may be a need to make certain revisions for projects to allow a more differentiated student experience (e.g., have a minimum level that must be met and additional components for the more competent). This was verified from staff feedback, where the need for more guidance was made apparent.

The second project (moving car transit) while stretching the capability of students, actually resulted in more than 30 groups, each made up of 3-4 students, signing up for the racing competitions across 5 diplomas. Many students displayed creativity and innovation in the designing of the car features.

Overall, students reflected that they had developed their thinking skills and more than 50 % of students expressed that this module makes engineering interesting.

KEY LEARNING & FUTURE DIRECTIONS

> ...the central problem of curriculum study is the gap between our ideals and our attempt to operationalize them. (Stenhouse, 9)

Much planning had gone into the implementation of CDIO, both in terms of curriculum reframing and redesigning, as well as resource provision and staff development activity. The curriculum development activities documented (e.g., ensuring curriculum alignment, appropriate customization of learning outcomes, incorporation of real world activities/projects and robust assessment systems), as well as the necessary staff development support, proved to be invaluable in contributing to the overall success of the implementation. However, despite this extensive planning, there are still many areas that need further improvement and calibration. Some of the more salient areas for improvement include:

- making the introductory project more comfortably achievable so as to sustain student interest.
- balancing students workloads across modules to reduce stress in this area
- a more structured schedule of the learning outcomes to be explicitly taught in the weekly activities.
- greater allocation of time for students to reflect and share learning experiences (e.g., how the learning from projects connects to other engineering related applications).

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Appendix 1

2.4 PERSONAL SKILLS AND ATTITUDES

2.4.1 Apply the thinking process

Use a range of critical thinking skills (e.g., analysis, comparison and contrast, inference and interpretation, and evaluation)

Identify the creative thinking process (e.g. generating possibilities, incubation, illumination, etc)

Use a range of creative thinking tools and techniques (e.g., Brainstorming, Mindmapping, TRIZ)

Identify contradictory perspectives and underlying assumptions

Reframe and take a range of different perspectives

Use metacognition in monitoring the quality of personal thinking

2.4.2 Analyze factors that affect thinking

Identify barriers to effective thinking (e.g., traits, dispositions, working memory, perception, lack of information, etc)

Evaluate ways to reduce barriers to effective thinking

Identify factors that promote effective thinking (motivation, openness, risk taking, exposure to varied knowledge bases and ideas, etc)

2.4.3 Manage Learning

Identify one's own learning approach

Identify approaches for self-improvement (e.g., lifelong learning, creating positive beliefs and psychological states, etc)

Display key dispositions E.G., (initiative, perseverance, flexibility) in work projects*)*

Use a range of learning strategies and skills (e.g., goal setting, learning plans, organizing/summarizing information, receiving feedback, etc)

Manage *time and resources*

3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION

TEAMWORK

Form Effective Teams

Identify the components of an effective team

Identify the stages of team formation

Identify team roles and their impact on team performance

*A*nalyze the strengths and weakness of a team

Manage and Participate in Teams

Identify goals and agenda

Apply team ground rules

Apply facilitation and conflict resolution strategies

Display teamwork, including leadership, in a range of team role situations

COMMUNICATIONS

Design appropriate communications strategies

Analyze the communication situation (e.g., in terms of purpose, audience and context *(PAC)*)

Identify key considerations in communicating across cultures and disciplines

Identify communications objectives

Read critically and select relevant content

Identify and choose appropriate communication structure and style

Select appropriate multimedia and graphical communication (e.g. email, voicemail, video conferencing, tables and charts, sketching and drawing)

Demonstrate effective written communication

Write with logical organization and clear language flow

Use concise and precise language

Use correct grammar, spelling and punctuation

Apply *appropriate* written styles with appropriate formatting conventions *to suit PAC*

Demonstrate effective oral communication

Design and deliver presentations applying communication design principles (e.g., as *in* 1.1.1 above)

Speak clearly and coherently (e.g., to be understood in a range of communicating situations)

Use appropriate nonverbal communications (e.g., posture, gestures, eye contact)

Demonstrate active and empathetic listening in a range of communication situations (e.g., working in teams, responding to questions, etc)

*Ask and a*nswer questions effectively

Incorporating design into class teaching technical communication skills

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ABSTRACT

A technical writing class is a perfect vehicle for giving students the opportunity to be creative designers and to learn more about the engineering profession as well.

In order for our students to have more experience in brainstorming, teamwork, and product development, we have incorporated into our technical communication class participation in Suffolk University's Business School's New Product Innovation Competition. Students were divided into teams and spent one month of class time brainstorming product ideas and dividing work among team members. After every class, a student was required to submit a one-page journal entry about what was accomplished during the team meeting, what issues came up, and anything else that was noteworthy about the team meeting. Students were graded on the quality of their writing as well as on their content. Before the contest entries were due, which was one month after the semester began, students were required to submit their proposals to the instructor, who would critique them, and to give oral presentations to the class. The students then would submit their re-written entries to the contest.

Students were very engaged in this assignment, which forced them to be active learners, and, in written evaluations, were very positive about this activity. This past year one of our teams placed as a finalist for a design of a watch that monitors vital signs, winning $1000 and the opportunity to meet with venture capitalists to discuss bringing their product to market beating out more than 200 other entries.

This class gave students the opportunity to develop other important CDIO skills. Other assignments include the design of an original experiment, and summarizing talks given by visits from a Suffolk alumnus of the department who works at Canon Design Inc and a group leader from a local defense laboratory. They also explored the ethical consequences of engineering decisions in an assignment on the Space Shuttle Challenger disaster.

KEYWORDS

Written communication, oral communication, design, competition, creativity

INTRODUCTION

The importance of technical writing in an engineer's career is hard to overstate; engineers spend a significant proportion of their time writing reports, memos, proposals, and giving presentations, and good communication skills are part of the CDIO and ABET outcomes. Therefore it is appropriate for engineering programs to include a course on technical writing.

Numerous textbooks exist on technical writing and some do an excellent job of outlining the important features of good technical writing such as writing clearly, accurately, forthrightly, concisely; knowing who the audience is and why they are reading the document; how to best transition between ideas. (I use *The Craft of Scientific Writing;* Alley,Michael 3rd ed., 1998) They discuss the features of writing such technical documents as memos, proposals, manuals, and resumes and give examples of good technical writing and bad technical writing. But what they generally do not do, unlike other technical textbooks, is give assignments. And therefore, the instructor is left to develop on his own, what assignments to give his students.

THE ASSIGNMENTS

Plagiarism is a problem

In my experience as a teacher of a technical writing class, I have found that if an assignment can be plagiarized, certain students will plagiarize, and therefore, writing instructors must do their utmost to develop assignments that cannot be copied from other sources. Although this task may prove daunting to English professors who assign papers on classics or history professors who ask students to research well known historical events, the technical writing instructor can have students write about original technical work that the student works on in class. Class time in a technical writing class needn't be spent on having the instructor lecture about the features of good technical writing since, unlike certain technical concepts, writing concepts are not difficult to understand. They are, however, difficult to implement, and the only way for students to learn these concepts is for students to spend a lot of time writing and re-writing.

Class time can be used in creative ways to help students develop engineering skills

Class time in a technical writing class can be used for not only providing students with material to write about but also to help students become better engineers and to develop skills that are part of the CDIO initiative. This paper mainly describes how a design contest is incorporated into my technical writing class. But the assignments also include the design and presentation of an original experiment as well as summarizing talks by an alumnus who works at an architectural design firm and an Industrial Advisory Board (IAB) member who is a group leader in a defense research laboratory. They come to answer students questions about industry; to discuss how they use writing in their jobs; and to discuss how to successfully communicate in an interview and on a resume Another assignment involves students understanding the ethical dilemmas faced by managers and engineers involve in designing the Space Shuttle Challenger. All these assignments involve students learning and gaining experience in other engineering qualities besides good communication skills valued by CDIO such as technical entrepreneurship, design and experimentation skills, connecting with industry, and understanding an engineer's ethical responsibility.

STUDENTS PARTICIPATE IN "NEW PRODUCT INNOVATION COMPETITION"

Suffolk University's Business School holds a contest each fall called "The New Product Innovation Competition", which requires students to develop a proposal for a product to bring to market. The proposals are due in early October and the award ceremony, where students

find out who won, is held in mid-November. Three cash prizes worth $3500, $1000, and $500 are awarded and winners meet with business representatives and venture capitalists from such companies as Bose, Solutions F5, and M/C Venture Partners. Since the dates of the contest are set, the design contest is the first major assignment of the semester Ideally, it would be better if the contest assignment were at the end of the semester, after students had already had experience with other technical writing assignments, but the benefits of participating in a contest with judges, monetary prizes, and the chance to meet representatives from industry, I feel outweigh this drawback.

How did it work?

The design contest assignment, in its current form, was introduced in Fall 2008. To motivate the students, and to convince them that they can develop a winning product, the organizer of the contest Dr. Sushil Bhatia of Suffolk University's Business School spoke to the students at the class' second meeting, held in the first week of September, and answered their questions. I then divided the students into teams of four and five (there were nine students in the class). The team had to decide on a team leader who is responsible for the overall quality of the project; each member of team needed to take responsibility for some part of the design, and to let me know what he/she is responsible for. Each team member received two grades: an individual grade and a team grade. The entries for the contest were due at the beginning of October, so the students had four weeks to work on this assignment.

After every class, each student had to submit a journal entry on the team meeting of that day. The students were given the following assignment about their journal entries:

- *Your journal entries for your design product should be about one page long (12 pt font; double spacing).*
- *In them you should describe what you accomplished during your team meetings, and what future work you plan.*
- *Concerns or problems should be discussed too.*
- *The journal entries must be written with good English, in a clear and concise manner.*
- *You should write a separate journal entry, for each team meeting (2 per week).*
- *Sketches can be added on too.*
- *Each individual must write his own journal entry.*

A week before their proposals were due, students were required to submit their proposals to me and to present their proposals to the class (students are given a rubric which was taken from Northwest Regional Educational Laboratory held in1998. on which the grading of the oral presentations is based). I graded and critiqued the proposals overnight (students are also given a rubric for the grading of their writing assignments which was developed by the College of Art's and Science's Dean's office), allowing students to rework their proposal before they submitted it to the contest. In the fall 2008, my class submitted two design proposals; Appendix A shows the entry for a health monitoring device which won second prize. The other design was a design of an alarm system which used a piezoelectric sensor. The products were judged on their innovativeness, clarity of presentation, value proposition, and feasibility as well as other criteria. Appendix B shows the judging evaluation form.

MY IMPRESSIONS

From the outset, students were engaged by this contest. In previous years, before this assignment was introduced, I lectured to the class about technical writing, and used the segments of the series *The Mechanical Universe and Beyond,* as well as other videos on technical topics as material for which the students could summarize. Students are certainly more active than when listening to my lectures, and they sometimes would use uncited materials in their summaries. Their journal entries are, by their nature, original and clearly demonstrate their writing deficits. One item that I did not put in to their journal assignments, which I should have, is for students to list who is doing what tasks on their teams. (I therefore asked that they put this information in their journals after their second journal entry).

The journal entries helped to clarify their thinking and understanding of their proposal, and I believe that gave the winning team an advantage over the other entries. There were over 200 of them, and three winners. Many of the entrants spent several months researching and developing their product design, so I was quite please that my students came up with a winning design in just one month). The alarm system team, I felt, did just as good a job in explaining their ideas, and I am not sure why the health monitoring device won over the alarm system. It could be because one of the judges was from the health care industry.

Although it was clear from their journal entries that not every team member contributed equally, it was clear that every team member contributed, and the teams worked well. Most of the students already knew each other (we are a small department) and they did a good job picking who the leader should be, and working with him.

STUDENT FEEDBACK

Students were asked, after they submitted their proposals but before the results of the contest were known, to give feedback anonymously on the design contest experience. I wanted the experience to be fresh in their minds, and did not want whether they won or not to influence their critiques. Most of the comments were positive and the experience was described as:

- Fun
- Exciting
- Creative
- Real-life
- Great for gaining experience in team-work
- Good for allowing journal entries to keep track of progress
- An opportunity for engineering students to meet business students
- Good research experience

The negative comments included:

- Not enough time
- Difficult to meet with team mates outside of class
- Individual projects would be better
- Instructor should give more aid on the design

Appendix C contains the student comments.

Addressing student feedback

I also felt that the students could have used more time on the contest; students basically have three weeks to develop their concept and one week to fine tune the proposal. However, as I stated earlier, I have no control over the time frame; that is decided by the business school. One goal of this assignment is to teach teamwork skills, so individual projects will not be assigned. Since product design is not my area of expertise, I don't think that I can give more support for the project than I already do, which is feedback on their journal entries such as asking students to elaborate on certain points, to explain their ideas more clearly, and to point out other considerations about their concept. Needless to say, their writing is critiqued and corrected as well In the future, I will have them go to the senior project instructor of our department, as well as other members of my department, so the students can get more help with their design. It may also be helpful to have an outside expert such as another professor, an alumnus or a member of our IAB, critique their ideas.

OTHER ASSIGNMENTS

In addition to the product design contest, students were given other assignments that not only helped them improve their writing skills, but helped them improve their engineering skills as well. These assignments include: the design of an original experiment for which the students present a written and oral report; a paper on the ethical dilemmas faced by the engineers of the Space Shuttle Challenger; summarizing a talk given by an alumni who works in the electrical requirements of new office buildings and an engineering manager in a research in defence laboratory; an instruction manual; an oral presentation on a current topic in science and technology; resumes; and weekly reading assignments from the text. The following describes some of the features and pitfalls of these assignments.

The design of an original experiment

I have found that the design of an original experiment works best when done in class, where students can use me as well as other students as sounding boards for their ideas. I suggest to them that they take an experiment that they have worked on in a lab or perhaps as a research project and modify it or study another quantity that they had not looked at, and test a hypothesis about what they expect their results to be. Students have three weeks to work on this assignment. Students can often feel overwhelmed by this task, and the more feedback they get from the instructor early on, the better is the student's work. If the experiment cannot be demonstrated to the class, the student needs to provide proof such as pictures or a video, that the student actually performed the experiment.

Space Shuttle Challenger assignment

Students are shown a video featuring Roger Boisjoly, the engineer who tried to stop the Challenger launch and then suffered as a result of being a whistle blower, and are then asked to write a two-page paper on the ethical choices that the managers and engineers faced as well as how they think they would have acted had they been in the same situation. The main drawback of this assignment is that students may over rely on what's already been

written about the shuttle disaster and not do enough original work, but students usually do a fine job on it.

Alumni or representative from industry talk

Students particularly appreciate hearing from an alumnus of our department or some other person from industry. They often have many questions and get good advice on preparing for interviews and on what to expect from the working world. They are asked to write a one page summary of the talks, which cannot be plagiarized.

Instruction manual assignment

This manual assignment is the easiest one to plagiarize and no matter how many warnings I give about not looking at any other manuals to write their assignments, there usually are one or two students who plagiarize anyway. Those students receive a zero on the assignment and are made to redo them. I'm not sure what else to do about this issue except to be very vigilant about detecting it.

The other assignments

The oral presentation on a current topic in science and technology usually does not pose any significant problems in its execution except to make sure students cite all their sources. Students are eager to have their resumes screened by someone from industry, and to ensure that the weekly reading assignments from the text are done, students are required to answer questions about them

CONCLUSION

A technical writing class is a perfect vehicle for incorporating creative engineering endeavours such as participating in a design contest. Last fall teams of students spent four weeks working on a product design proposal for our business school's design contest competition. Generally students' experiences were positive and one team won second prize in the contest. Students were asked to write journal entries about each meeting, to submit for a grade their design product proposal, and to present to the class their design concept. The experience may be improved by asking outside sources to help them with their ideas and to review the students' proposals.

APPENDIX A

SUFFOLK UNIVERSITY
SAWYER BUSINESS SCHOOL

New Product Innovation Competition Submission Form 2008
For questions, please contact: Sushil Bhatia : sbhatia@suffolk.edu

Product Name: _ Kronos Healthlink
_____

Group: Ivan Echeverria(leader), Pelerge Charles, Raul Artigas, Fabrice Kabore

Innovative New Product Concept

Product Name and Product Description:
Product Name: Kronos Healthlink

Briefly describe (25 words or less) what the product is:
Revolutionary Health Monitoring Device that performs basic health information gathering for immediate analysis by the user's diagnostician.

Product Origin:
How did you come up with this idea? Briefly describe.
During my workout I experienced high levels of heart rate. When I informed my doctor he was unable to tell me the reason why my heart rate was too high. Likewise I was unable to recreate the exact conditions that placed my health in danger.
This device is capable of providing all the necessary information for any diagnostician to determine whether a patient's health was at danger due to a disease, environmental effects or to his own self-harm.

Patents:
Would you like to know more about patent and other methods of protecting your new product idea?
Yes

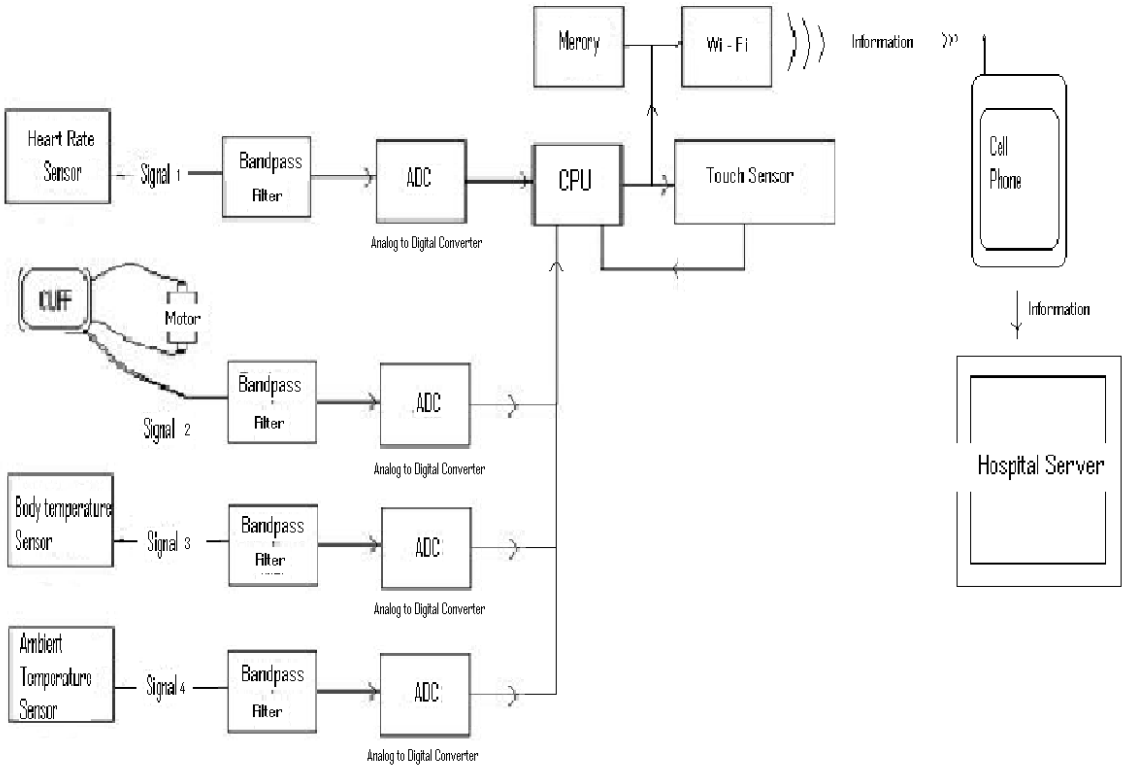
Value Proposition:
Product Sale Price: $300 - $450
Describe your product's primary function as clearly as possible.
What does it do? How does it do it?

The Kronos Healthlink is capable of:
- Monitoring blood pressure
- Monitoring heart rate
- Monitoring body temperature
- Monitoring environmental temperature
- Determining the user's current state of activity: either exercising, walking, jogging, or jumping
- Transferring securely the user's information to his doctor's server or a hospital server.
- Intercommunicating with the user's cell phone.

To achieve these functions the watch will have an advanced array of sensors and a user-friendly GUI (Graphic User Interface) with touch screen calibrated OS. This will give the user full access to the information being recorded.
To monitor heart rate we will make use of common standards by using a sensor that can sense slight changes of pressure throughout the median antibrachial vein. Furthermore the blood pressure can be determined in a similar way via the use of an inflating coating located at the inner belt that holds the watch to the wrist.
Temperature can be determined using thermistors (Resistor that varies with temperature); one located under the watch itself and the second one located at the top of the watch.
Bluetooth and Wi-Fi technology will allow the device to communicate with the hospital server, and all information will be sent with robust data encryption.
Furthermore, with the use of an accelerometer, and proper configuration, the watch will determine via the vigorous arm movement, whether the user is exercising or simply walking.
The accelerometer will also play a big part in the power management system as it will turn the touch screen "on", only when the user holds the watch horizontally to ground, thus saving power as much as it can via this sensing capability.
Moreover the watch will be powered by a rechargeable battery and will be able to charge using a dock set and "on-the-go" (I'm not sure what "on-the-go" refers to) via its solar panel coating.

Signal Processing and Information management.

The sensors register the different types of signals collected from the body and the environment. Then all the collected signals are passed through band pass filters. These filters reduce the "signal- to- noise" ratio and then send the analog information to a digital converter. Once the information is digitized a programmable microcontroller will further process the information and will display this information at the touch screen. The programmable microcontroller will also send the information to the WiFi chip for immediate data transmission.



Competitive Advantage

List your product's competitors by manufacturer, brand name and model number; describe how your product improves upon competitive products or technologies and describe the uniqueness of your product over the competition's product. Also describe here if your product has "green" features and benefits.

Product	**Features**	**Disadvantage**	**Cost**
The Exmocare BT2	Measure heart rate, blood pressure, skin temperature and skin conductance, Bluetooth	Only available for clinical researchers, academics and small home health care provider. Battery need to be recharge every 6 hours	$ 2500

Suunto X6HR Heart Rate Monitor Watch	Stopwatch Barometer Chronograph Thermometer Heart Rate Water proof	No blood pressure monitoring feature. Require battery maintenance every year	$ 398.85
Health Mark Body Tone Heart Rate Monitor Watch	Heart rate monitor watch HR transmitter continuous HR display Cardio Building program.	No blood pressure monitoring feature.	$ 89.00
MW705 Heart Rate Monitor Watch	Bluetooth transmission GPS signal, Water proof, reads NMEA data from GPS	No blood pressure monitor, short battery life	$ 200

The main functions of these products listed above are mostly monitoring a person heart rate or blood pressure but none of them come close to the Kronos Healthlink <-It's not clear to me how the Kronos is superior. There exists two actual products that perform the same functions as the Kronos Healthlink: The Exmocare BT2 which is the second generation of the BT1 and is mostly made for research companies and businesses. The BT2 is extremely expensive and contains half of the features of our product. The MW705 is a multifunctional sport watch but does not come with blood pressure monitoring functions. The MW705 is too vague and mostly made for athletes. The Kronos Healthlink is highly sophisticated, user friendly and costs about $ 300. With features such as Wi-Fi, and Bluetooth, our product is capable of streaming real time data to any physician's database. The Kronos Healthlink gives the user the ability for his physician or responsible caretaker to monitor his physiological data from virtually anywhere in the world.

Feasibility

Briefly describe "what will it take to launch the product".

Cover the risks and rewards of implementation and execution. (Production, marketing, sales etc.)

This revolutionary health monitoring system, uses the most advanced combination of sensors and communications technology on the market. It further introduces a novel power management system which uses an accelerometer as the central power management of the OLED touch screen, and it centralizes all its information with a robust encryption to be sent via WiFi or Bluetooth DUN (Dial-up Networking).

Most of these features can be found on top-of-the-line mobile phones, so we will not require new production practices and therefore production costs would be similar to that of mobile phones.
Keeping in mind that this device is aimed at health conscious people and disease-afflicted people, the price can be subsidized by most health insurance companies, thus, bringing the price to $100 or less. (Do you really know if health care companies will help pay for it?)

In the long run we could have a very successful product launch if we consider having medical insurance companies involved with it's marketing.

Summary:

State in layman's terms why you feel your product will be a success in the market...

Our product is an all-in-one portable device which gathers and monitors real-time information about basic human vital signs. Having the shape of a watch, it is discreet and can be worn without being bulky or cumbersome. It also has the advantage of transmitting instantaneously precise information to a physician or any health service provider. Being equipped with WiFi and Bluetooth technology, it can communicate the data wirelessly from any place with wireless internet access coverage or using cell phone and at any time.

Why is it important to have this product?

Having this product will reduce the number of medical visits for a patient who needs regular monitoring of heart and vascular functions and will improve the responsiveness of emergency services in case of heart failure or cardiac strokes.

What benefits will it provide?

The product will help reduce mortality rates due to heart failure and vascular accidents and improve the lives of patients who need permanent medical assistance.

APPENDIX B

Suffolk University
Sawyer Business School, Boston, MA
New Product Innovation Competition, 2008
Judging Scorecard

Judging Directions:
Imagine that you are a consultant and your job is to evaluate new concept plans proposed by innovators individually or as teams. Please circle points **1. (Low) & 5. (High)** that best describe how you feel about the submission.

Date:_____

Name of Innovator_____

1. Concept (Product Name):_____

A. How bold and fresh is the concept (please circle)?

Ordinary Seems old and familiar, not creative, and may be repackaged as "new and improved".	**1 2 3 4 5**	**Unique** A new concept invoking a "wow" response. May be a unique combination of old ideas.

B. How persuasive and coherent is the concept (please circle)?

Crude Not persuasive. Seems sloppy or Incomplete and is not presented in an understandable manner.	**1 2 3 4 5**	**Well-crafted** Clear, compelling, and refined to its highest possible level.

2. Value Proposition

How does the concept meet/create customer need (please circle)?

Low Value Disconnected from customer reality and doesn't add much value.	**1 2 3 4 5**	**High Value** Meets spoken or unspoken customer need, anchored in experience.

3. Bottom Line Results

How compelling are the concept's quantitative and qualitative benefits (please circle)?

Low Benefits Insubstantial or inadequate demonstration of quantitative and qualitative results.	**1 2 3 4 5**	**High Benefits** Significant and credible demonstration of quantitative and qualitative results.

4. Competitive advantage

How does the concept provide a unique and competitive advantage (please circle)?

No Advantage Does not provide significant competitive advantage for the company.	**1 2 3 4 5**	**Tremendous Advantage** Competitive advantage is significant and hard to mimic.

5. Feasibility

How easily can concept be implemented and are risks addressed (please circle)?

Low feasibility Does not seem feasible. Poor risk assessment.	**1 2 3 4 5**	**High feasibility** Seems feasible and risks are properly addressed.

6. Does this product have "green" features i. E. Is it environmentally friendly and safe (please circle)?

Low 1 2 3 4 5 High

7. Special Bonus Points (Between 1 and 5 points)

Total points =_____

8. Your comments/suggestions to the innovator

Name or the Innovator_____
Name of the Product_____

<u>Judge Information</u>: **Date completed:_____**

Name of Judge: _____

Company: _____

Address: _____

City: _____ State: _____ Zip Code: _____

Tel: _____: Email: _____

Signature: _____

APPENDIX C

1. “The design contest was an amazing way to bring together the class to work towards a project that could be very helpful for future generations. This competition also helped the engineering students match up to the business schools students. This competition was fun and exciting as it made us all think of various new technology that some had only thought of as a dream that would someday take shape to reality. The team work was awesome and helped us know each others potentials and specialties. The journals helped boost our grades and were a great way to keep track of ever step of progress towards our design.”
2. “The design contest was a great real life experience. We teamed up to go through a design process of a new product. The meeting reports were a good decision that kept track of what we were doing. Required a lot of research, which was great to get us familiar with new technology. Overall great task.”
3. “The design contest was a learning experience for me because I have never participated in such context. The good thing about it is that the context taught me how to be creative. Working on a team gave me the importance of being a team player. Two things I would change is the way they organized the proposal form, I think the contestant should have the freedom of writing it on our own format, and the instructor could also have the class compete among themselves.”
4. “The design contest brought team-work experience to the whole team. It has taught us what it's like to be in the real world where we have to come up with a design, prototype, and revision. Not everything were given to us; we had to research on our own and bring it up during our group meeting. Working in groups has it advantages where we all can come up with different solutions and pick the best one out of all. A disadvantage is we have all have different schedule therefore it is hard for us to meet outside of class time. I find it hard to contact other people because some of the member never reply to email or answer phone calls. I would recommend the instructor to have students work individually in the future. Student can come up with their own projects but they can seek each other for help on revision or new idea. This is fair for the rest of the students because each student can come up with their original idea and do their own work. Another recommendation is that the instructor should aid us more on the design and give us feedback.”
5. “I think that we did not have enough time to provide a well studied design product. Indeed there was a lot of theoretical assumption as part of the feasibility of the whole project. T he good point was the chance to think about innovation and the experience of a team work. I think our team worked well together and this is an experience worth doing.”
6. “Team work is very hard to accomplish unless a good leader is in the group. Sometimes the group leader does not have the energy and time to lead. Furthermore, a randomly picked group by the instructor adds to the problem of leadership. Thus, in order to save time and headache is better to have individual project.
   Another issue is time; I don't think that 3 weeks is enough time to summit a good proposal. Designing a good picture or diagram of the product takes time. The goal is to win the competition; hence a well elaborated proposal can accomplish this goal, and a good proposal takes time to put together.”
7. “The design contest was overall a good experience. It provided a good way to practice journal entries. However I wish that there was a little more structure, maybe to share the design with the class before writing the proposal. Our team worked together great, no problems at all.”

Biographical Information

Lisa Shatz is an assistant professor and chairman of the Electrical and Computer Engineering Department of Suffolk University in Boston, MA. Her research interests include understanding the relationship of shape and function of sensor hairs in such biological systems as vibrissae and inner ear hair cells.

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INFUSING PRINCIPLES OF LEARNER-CENTRED LEARNING INTO COURSEWARE DEVELOPMENT FOR THE TEACHING AND LEARNING OF ELECTRICAL TECHNOLOGY

Seah-Liang Shi Ping (School of Engineering, Electrical Engineering Div)

Ng Weng Choh (iMedia Centre)

Lim Ee-Lon (iMedia Centre)

Ngee Ann Polytechnic

Abstract

Various blends of pedagogical strategies and technological affordances have been proposed for the 21st century learners commonly known as the Net Gen, Gen Y, or Digital Natives. At Ngee Ann Polytechnic, we have approached Interactive and Digital Media (IDM) courseware development with a sound learning design that is infused with Learner-Centered-Learning features.

This paper reviews the major elements of our journey focusing on the development of learning design leveraging on technology to enhance teaching and learning with a specific focus and application on the teaching & learning of Electrical Technology for the School of Engineering. The paper also describes the courseware, virtual simulation and interactive game developed for this Electrical Technology module.

Keywords

e-learning courseware development, learner-centred learning, electrical technology

1. INTRODUCTION

This paper aims to discuss principles that form the foundation of the Learner-centred approach, and to describe an e-learning courseware project that was designed, custom developed and employed in Ngee Ann Polytechnic's School of Engineering, Electrical Engineering Division based on these principles.

In traditionalistic approaches to education, the responsibility of communicating course material is vested with the instructors. In recent times, more flexible, learner-centered teaching methods have been promulgated, inspired by the concepts of "discovery" learning (Bruner, 1966; Hermann,1969) and "active" or "autonomous" learning (e.g. Johnson & Smith, 1991). These instructional approaches advocate replacing or complementing traditional lectures with active experiential learning such as role-playing, simulations, self-paced or team-based exercises. While these methods have been successfully established in many educational settings, their benefits have not been automatic and have been realized only through substantial effort.

In tandem, the e-learning space has witnessed a correspondingly similar progression. Like traditional classroom instruction, e-learning derives from computer-based instruction paradigms that are geared to reflect passive training approaches. In recent times, more flexible, student-centred classroom teaching methods have been

advocated based on the precepts of 'participatory' and "active" learning; learner-centred approaches are likewise encouraged in the development of e-learning applications. Nevertheless, many e-learning courseware that employ sophisticated multimedia elements in which students interact with simulations, and animations still fail to fulfil their expected educational potential. Thus, adoption of IDM-based features may give the perception of engaging a learner in more active forms of learning, but its use per se does not necessarily ensure attainment of desired learning outcomes. As Michael Allen (2002) acutely observes in an article advocating discovery-based e-learning: "Lurking behind many of today's slick delivery systems are shop-worn, passive learning paradigms that Socrates spurned in the fifth century B.C."

2. LEARNER-CENTRED LEARNING

Learner-centred Learning appears to associate primarily to the constructivist view of learning in placing the importance on activity, discovery and independent learning.

This paper draws on the thinking of Weimer (2002) who is concerned with learner-centred teaching as an exercise in changing teaching practice. Specifically, Weimer identifies learner-centred teaching as encompassing the following five changes to practice:

- Shifting the balance of classroom power from teacher to student;
- Designing content as a means to building knowledge rather than a 'knowledge end' in itself;
- Positioning the teacher as a facilitator and contributor, rather than director and source of knowledge;
- Shifting responsibility for learning from teacher to learner; and
- Promoting learning through effective assessment

In approaching courseware development in Ngee Ann Polytechnic, we seek to evolve teaching practice as highlighted by Weiner (2002) by focusing on four key elements of the learning experience:

- **Reflective focus**

  Through reflective practice, our students are engaged to examine and interpret experiences to attain new understanding. Students will be encouraged to take ownership of their learning and be motivated to think deeper at their learning.

- **Collaborative focus**

  The collaborative focus aligns with constructivist and socio-cultural models of learning which recognize that students' perspectives and prior understandings are important, that context is essential, and that learning is a social activity. A collaborative approach to learning includes the ways in which IDM technologies enable our students to contribute in diverse ways to individual and shared learning goals. Through blogs, wikis, games, social networking sites and other platforms, our students are encouraged to participate in virtual communities where ideas are shared, discussed, cross-fertilized, peer-reviewed etc. The intent is to bring our students together to aggregate ideas, perspectives, insights, experiences.

- **Exploratory (Research) focus**

  Creating opportunities for our students to learn independently through research and self-discovery is fundamental to learner-centred constructivist pedagogy.

  For students to benefit from such opportunities, it is imperative to cultivate a culture of inductive learning and to equip them with suitable strategies. It is hoped that our students will be empowered as knowledge producers through meaningful research and discovery.

- **Doing/Producing focus**

  Doing/Producing relates to providing opportunities for our students to work on meaningful, realistic projects as well as implementing a variety of interactive problems for practice, exercises and tests that aid understanding. This is in recognition that students learn most effectively by doing and producing, rather than by being passive recipients.

  By putting students in control, it places the onus on them to actively engage in the tasks of searching, making the decisions, interacting with technology, contributing to discussion forums and tackling real world issues.

3. APPROACH

3.1 Focus on Learning Design

This phase focuses on articulating the existing learning design of the module and formulating a proposed learning design for development – which incorporates learner-centred learning principles. The front-end analysis will shape the instructional strategies and methods to be adopted, ranging from direct instruction, indirect instruction, experiential learning, independent study and interactive instruction. The outcome of the learning design review will inform decisions on the selection of multimedia and choice of courseware types.

It is reckoned that quality learning outcomes are best achieved with the considered application of pedagogy to the design of the e-learning courseware as well as to the management of the instructional process that revolves around the use of the courseware.

Courseware should not merely be used as an isolated teaching/learning resource; rather, it should also bring with it strategies for use. Consequently, we advocate that due attention be channelled not only to the design and development of content but also to the wider embedding context within which the courseware will be deployed.

3.2 Deepening the Learner-Centred Experience

Learning is often presented in the dualism of either learner-centred learning or teacher-centred learning. In the reality of practice, the situation is less distinct.

A more purposeful representation of learner-centred learning is to interpret these terms as either end of a continuum as shown below:

Learner-centred and Teacher-centred Continuum	
Teacher-centred Learning	**Learner-centred Learning**
Low levels of learner empowerment	High levels of learner empowerment
Learner is passive	Learner is active
Control and ownership with the teacher	Control and ownership with the learner
⟷	

In reviewing how we might look at this in practice, it is efficacious to reflect how far up the continuum we are able to move within contextual barriers in the teaching and learning situation. The following sections articulate possible instructional ideas and pedagogical methods to aid the progression towards a deeper Learner-centred Learning experience.

- **Implications for curriculum and lesson design**

  In relation to curriculum design, learner-centredness acknowledges the precept that students have an element of empowerment and choice in what to study and how to study. A popular learner-centred approach to curriculum design - Problem-Based Learning (PBL), allows for some scope of flexibility within a programme of areas that students may learn. As part of a learner-centred approach, it enables students to define a measure of their own learning parameters in terms of objectives/outcomes, dependent on prior knowledge (O'Neill, McMahon). This element of student choice or control aligns with the principles of learner-centred learning.

  An emergent practice in learning design is the 'democratic' negotiation and formulating of learning outcomes/objectives focusing on what a learner will be able to do (process and competence) vis-à-vis on the content being covered by the lecturer. Where possible, students also have the flexibility to adapt their own learning issues and context. This practice exemplifies the evolvement towards Learner-centred Learning in curriculum design and shifts the ownership of learning to the learner as opposed to a coverage model by the lecturer.

- **Implications for teaching and learning methods**

  To adopt a Learner-centred Learning approach, lecturers should endeavour to actively engage students in acquiring knowledge and skills through exercises in class, fieldwork and use of games and simulations. It is also crucial that students are made more aware of what they are doing and why they are doing it during the learning process. There should also be a strong focus on interaction, such as the use of simulations, discussion forums and synchronous virtual classrooms. Other approaches geared to Learner-centred Learning include devoting due consideration and discussion to prior learning i.e. addressing the needs of students who may be at different starting points. Negotiation regarding learning activities between lecturer and learners will further engage and challenge students.

- **Implications for student assessment practices**

  An important element of Learner-centred Learning is the concept of self and peer-assessment as an essential activity to help students 'take responsibility and ownership for their learning'. It is also advocated that formative assessments be utilized, which emphasizes feedback to students on their learning journeys. The inclusion of more formative assessment encourages a deeper learner-centred approach - whereby formative assessments are embedded in the learning design to help inject a sense of focus for students by highlighting learning gaps which could be addressed.

4. APPLICATION

4.1 Context

In this section, we present a reflective case study analysis of an attempt to develop IDM e-learning courseware with the introduction of learning design considerations and Learner-centred Learning focus for the Electrical Technology module from the School of Engineering's (SoE) Common Programme. The SoE Common Programme was identified as a pilot project under the polytechnic's institution-wide courseware development initiative. The pedagogical challenge was to leverage on courseware to re-orientate from a teacher centred didactic approach towards a Learner-centred Learning direction featuring collaborative, reflective and exploratory learning experiences.

4.2 Background on Engineering Common Programme

The Engineering Common Programme offered by SoE seeks to provide students with a firm foundation and an initial understanding of engineering and career options to assist them in identifying the engineering discipline with the right fit. The Electrical Technology module under the Engineering Common Programme aims to equip students with the necessary foundation for electrical circuit analysis, whereby they will learn electrical theorems and techniques for analysing and solving direct and alternating current circuit problems. Hands-on activities in laboratories will equip them with basic electrical measurement skills and reinforce concepts learnt in lectures and tutorials.

4.3 Review of Learning Design

Upon selection of the Electrical Technology module, an iterative consultation and review process was initiated between the iMedia Centre, Teaching and Learning Centre and module leader Mdm Liang Shi Ping. The intent is to articulate the existing learning design and formulate a proposed learning design for development. Excerpts are outlined as follows:

- **Current Learning Design**
  - Traditional learning design based on lectures, tutorials and lab sessions
  - Lecture notes are used to teach the basic concepts of content
  - During the tutorials, students apply the concept in solving questions

- During the lab sessions, circuits are connected and measurements are taken to validate the theories

- **Summary of Proposed Learning Design**

  - Designed to enable learners to do self-learning on selected topics. Learners will then form groups and undertake reflections and class presentation of applications that arise from concepts learnt
  - Interactive tutorials that help students understand the lecture content, followed by students setting their own questions for others to solve
  - Virtual lab that allows measurement of resistance and voltage. Students to also write their own lab sheets.

- **Proposed Courseware Design Features**

Courseware

Learning Activity	**Learner-centred Learning Features**
• Self learning on a media rich courseware platform for two topics, namely Electromagnetism and AC circuit analysis. The existing materials will be repurposed into a more attractive multimedia package with clear narration.	Engaging and interactive courseware for independent learning. Aligns with blended approach of e-learning and face-to-face lectures. A variety of different instructional media was incorporated and exploited for a more motivating and stimulating e-learning experience.
• Following completion of Electromagnetism topic, students will work in groups and propose applications in a class presentation to peer-learners	Reflective and collaborative learning as well as active knowledge acquisition. Group work helps students to understand different perspectives and think more critically and reflectively.
• Outstanding cases from students will be collated and incorporated into the courseware	Proliferate learner-generated knowledge

Tutorial Activities

Learning Activity	**Learner-centred Learning Features**
• For a specific tutorial session, students to attempt Multiple Choice Questions (MCQ) at home (anytime outside classroom tutorial session).	Learning not confined to traditional classroom tutorial - time, pace, place. Student access to range of learning resources other than tutor.

• Following which, students are grouped to play a 'tic tac toe' multimedia game projected by the lecturer, whereby they are challenged to select boxes containing hidden questions. Students will then be engaged to set questions (with solutions) for other groups to solve. • Challenge for developer is to develop multimedia game which facilitates lecturer to enter and refresh questions in an easy and flexible manner through use of XML technologies.	Learning as a fun, participative, highly social, active dynamic process. Encourages active learning which hinges on students' participation in the process of formulating questions and solutions with prompt feedback - 'Democratization of learning space'

Virtual Lab

Learning Activity	**Learner-centred Learning Features**
• Virtual Lab featuring virtual wires, digital multi-meter, breadboard and resistor components that allow students to conduct experiments anytime, anywhere. Virtual lab to augment physical lab sessions.	Interactive, multi-sensory virtual learning experience.
• During lab test week, students to submit a reflection on the learning experiences while using the Virtual Lab.	Reflection on learning experience, application, content, issues and concerns. Opportunity for students to explore their understanding of concepts and hypotheses, promoting reflective practices.
• Students to also submit an experiment (circuit) designed through the Virtual Lab.	Flexibility to design circuit schematics within topic parameters. Authentic tasks and a degree of choice enable students to take ownership of learning and be more active learners.

4.4 Intended Use of Courseware and Impact on Learner-Centred Learning

This section requires the module leader to articulate how the courseware will be deployed to drive his/her teaching practice (i.e. focus on how students are learning, what they experience, and how they engage in the learning context) based on the underpinning Learner-centred Learning concept. The plan for use of courseware should include:

- Topics to be covered
- Teaching delivery methods
- Learning activities
- Assessment activities

4.5 Module Scoping

The module scoping process outlines how the e-learning courseware will impact on the teaching approach of individual topics. With the emphasis on learner-centredness providing the orienting focus for learning design, highly positive learning outcomes is achieved through the *effective integration* of multimedia courseware, constructivist learning and elements of didactic teaching practice. An extract of the module scoping for the Electrical Technology module is presented below:

Topics/ Timetabled Hrs (weekly)	**Nature of product**	**Description of product needed**	**Explanation on how the product feature will enhance/ value add to learning**	**Indication of Learner-centred Learning (LcL) Feature**
Electromagnetism (3 hrs) AC theory (9 hrs)	X Courseware ☐ Training video ☐ Simulation ☐ Game ☐ Activity ☐ Others	An attractive eLearning courseware for 2 topics of Electrical Technology	The development of the courseware will help the students to understand the concept of electromagnetism. By assigning them to form groups and find application after studying courseware, they will reflect on it before making a choice. The sharing session in class will further challenge them as they have to face questionings.	X Collaborating X Reflecting X Exploring/ Researching X Doing/ Producing
Tutorial with gaming like features	☐ Courseware ☐ Training video ☐ Simulation X Game X Activity ☐ Others	Tutorial will allow students to set questions for others to solve.	The process of setting the questions will deepen students' understanding.	X Collaborating X Reflecting ☐ Exploring/ Researching X Doing/ Producing
Virtual Lab	☐ Courseware ☐ Training video X Simulation ☐ Game ☐ Activity ☐ Others	Simulation of real labs by using software to connect and test the circuits.	Students are not limited by physical lab to connect up circuits and take measurements. They can connect all sorts of circuit even those from their tutorials.	☐ Collaborating X Reflecting X Exploring/ Researching X Doing/ Producing

5. Module Leader's Reflections

5.1 Courseware

The topic selected for the courseware is topic 4 on Electromagnetism and Electromagnetic Induction. The reason for selection of this topic is that magnetic field is invisible but it plays an integral part in almost every electrical device used in industry or at home. There exists a magnetic field in the region surrounding a magnet. When a conductor is moved through a magnetic field, a voltage will be induced across the inductor. An attractive multimedia package will be able to show the induced voltage deflecting the pointer of an analogue voltmeter.

The courseware is incorporated with many examples and solutions. Students will be informed to go to the web-site and download the software one week before the time scheduled for this topic. They will access the courseware and solve some questions that test their understanding. During the lecture, they will discuss and clear any

doubts with the help of the lecturer. Students will then form groups of 2 to 4 to find a device that makes use of the application of the electromagnetism or inductor. They have to collaborate to do a class presentation during tutorial using power-point slides. In the presentation, they are required to:

1. name the device of their choice
2. list the main components in the device and
3. describe how it works

The courseware allows the students learn at their pace. The questions that they have to answer and submit will require them to understand the concepts. By searching for the application of electromagnetism through internet or books, students will see the theory applied in so many areas that affect their lives. Examples of the devices that employ magnetic effects are plentiful and some of these are generators, motors, transformers, circuit breakers, relays, computers, speakers. During the class presentations, they are sharing with the class the knowledge they have acquired as well as learning from their peers' findings.

The experience with students during the presentation was that the good students performed very well. However the weaker students (those that did not score well in common test) were able to share what they have learnt with confidence.

5.2 Tutorial

Most students enjoyed the 'tic tac toe' games. It is another way of learning, different from traditional tutorial where they solve questions from the notes. Through this approach, they are engaged to solve questions projected on the screen and learn while taking part in a competition. The set back is that in some classes, there are outspoken students who keep on shouting out the answers before the student assigned to answer has a chance to figure it out.

Suggestion from a lecturer for future consideration: *"**We can leverage on multi-player platform like the "King of the Hill" game where multiple players contest to reach the top of the hill first. They moved simultaneously towards the target by solving MCQ and their movements could be seen real time adding to the excitement of the game."***

After the first hour of the tic-tac toe game, students formed groups of 3 to 4 persons. They discussed and set a question for the other group to solve. The students tried to set challenging questions and provide solutions to give to the lecturer. Most of them put in a lot of effort and time to set one question so much as that there is insufficient class time for the other group to solve it.

5.3 Lab

Students were told to download the virtual lab software during the first lab session. They learn how to use the breadboard by doing series and parallel connections through the software at home before the next lab which will take place two weeks later. A lab sheet that required them to do reflection on the learning experience of virtual lab is to be completed and submitted. The software has five resistors, a multi-meter (for voltage and resistance measurement), a DC supply and a breadboard. When they come to the lab two weeks later fully prepared, they had a much easier time carrying out the experiments. They are ready to connect more complicated circuits and do measurement using real instruments.

6. Courseware Review

Following implementation of the courseware with revised learning design, a survey was administered to determine its impact on students' learning experience.

100 students were surveyed to rate the following statements on a scale of 1 to 5, with 1 being strongly disagree and 5 being strongly agree.

My Learning Experience

- The activities for this topic were interesting
- The online game helped me to develop a good understanding of the topic
- The e-learning courseware helped me to develop a good understanding of the topic
- I would like more topics/lessons to be taught in this way

Design Features of Courseware

- The animated illustrations, graphic images, text, learning games, audio narration and video demonstrate the concepts effectively
- The navigation (moving from one page/topic to another), functional features, interface within the courseware are friendly and intuitive
- The courseware is easy to access

The results of the survey were largely positive, with over 60% of respondents agreeing that the activities were interesting and helped them to deepen understanding of the electromagnetism topic. In terms of courseware design features, over 70% of respondents agreed that the well integrated use of multimedia elements and overall usability design help contribute to their enhanced understanding of key concepts.

The full results are presented as follows:

	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
My Learning experience				**(%)**	
The activities for this topic were interesting.	**4**	**10**	**12**	**66**	**8**
The online game helped me to develop a good understanding of the topic.	**2**	**9**	**23**	**60**	**6**
The e-learning courseware helped me in to develop a good understanding of the topic.	**3**	**6**	**28**	**59**	**4**
I would like more topics/lessons to be taught in this way.	**8**	**15**	**22**	**40**	**15**
The design features of the e-learning courseware					

The animated illustrations, graphic images, text, learning games, audio narration and video demonstrate the concepts effectively.	**4**	**6**	**19**	**61**	**10**
The navigation (moving from one page/topic to another), functional features, interface within the courseware are friendly and intuitive.	**4**	**4**	**19**	**60**	**12**
The courseware is easy to access.	**3**	**7**	**13**	**58**	**17**

7. CONCLUSION

This paper advocates that an effective e-learning courseware infused with learner-centred design principles and interactive multimedia will engender positive educational outcomes. The e-learning approach attempts to compel learners to construct knowledge with the lecturer as a facilitator of learning rather than a provider of knowledge. Learners will be challenged to organise and structure responses to problems, so as to develop a greater depth of understanding. One of the key strengths of the approach is that creative employment of Learner-centred Learning features throughout learning design and delivery will foster deeper understanding.

Ngee Ann Polytechnic's initiative to enhance the e-learning approach by infusing Learner-centred Learning principles into courseware has the potential to lead to an educational experience that is infinitely more interesting, engaging and effective.

8. ACKNOWLEDGEMENTS

Acknowledgement is given to Mrs Pee See Hua, Ms Shirley Williams, Director, Teaching and Learning Centre, Mr Andrew Sabaratnam, Director, School of Engineering, Multidisciplinary Engineering Division and Mr Koh Wee Hiong, Director, School of Engineering, Electrical Engineering Division for their invaluable contributions and support in the preparation of this paper.

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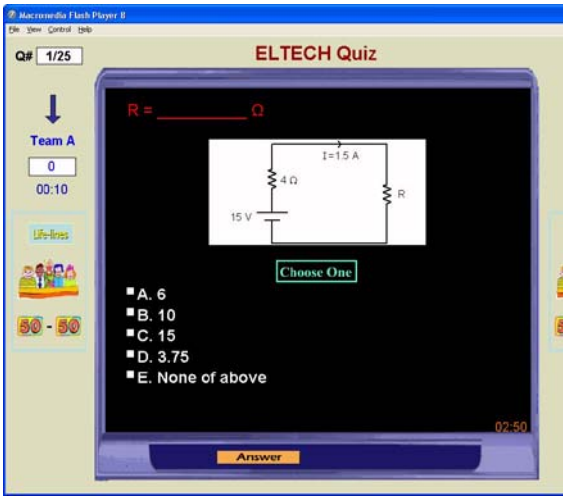
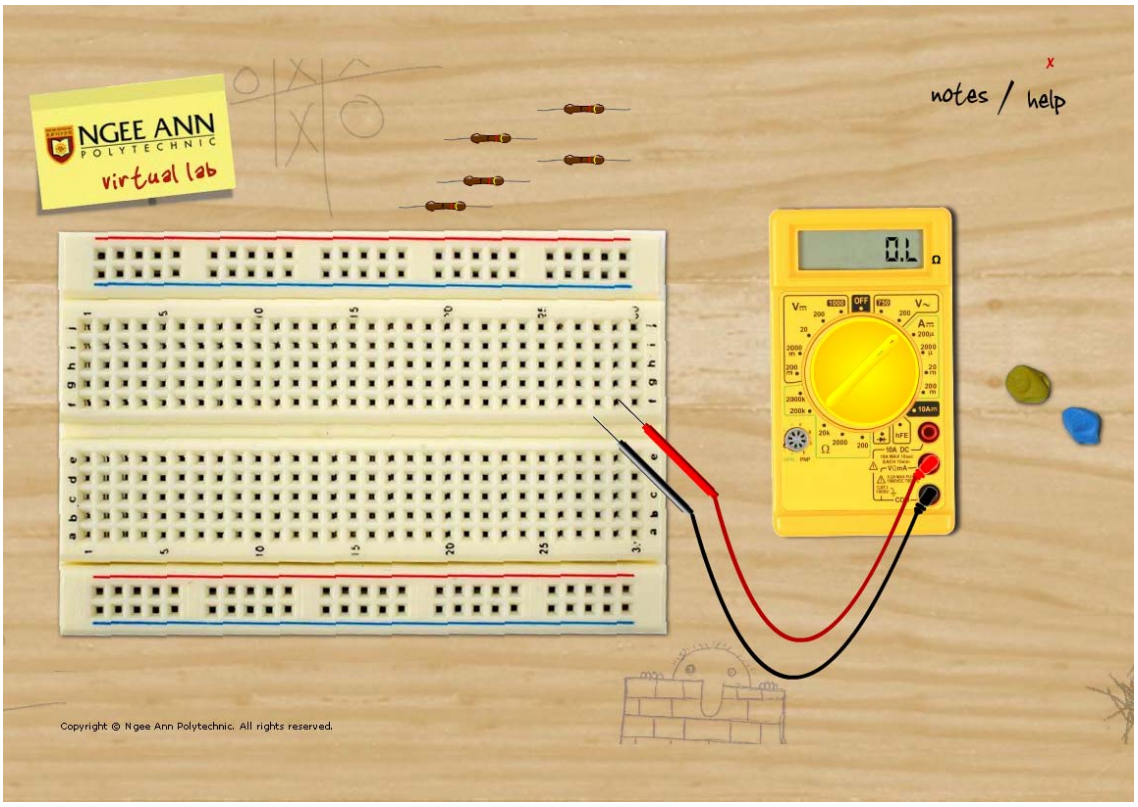
- *Teaching Research Method using a Student-Centred Approach : Critical Reflections on Practice, Jo Barraket*
- *Learner-centred Teaching : Five key changes to practice, Weimer, M*

Annex

Screen Shots of 'Tic Tac Toe' Multimedia Game



Screen Shots of the Virtual Lab



Integrated Learning for Engineering and Mathematics Modules

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ABSTRACT

The Department of Mathematics and Science (MS) and the School of Architecture and the Built Environment (ABE) in Singapore Polytechnic (SP) have adopted the CDIO educational framework in the Diploma in Civil Engineering and Management (DCEM) course. To meet CDIO standards, both MS and ABE have actively worked to integrate the learning of engineering and mathematics modules through the use of a common Engineering Formulae booklet.

The paper describes (a) the systematic approach which MS and ABE have taken, (b) the results of student perception feedback and (c) the recommendations for further refinements and improvements.

KEYWORDS

CDIO, mathematics, integrated learning, linkage, engineering, formulae booklet, reference module

INTRODUCTION

In this paper we focus on the CDIO Standard 3 — Integrated Curriculum [1]. To meet this standard, the curriculum must be designed with mutually supporting disciplinary modules, with an explicit plan to integrate them. Disciplinary modules make explicit connections among related and supporting content and learning outcomes. The course management team members play an important role in designing the integrated curriculum by suggesting appropriate disciplinary linkages, as well as opportunities to address specific CDIO learning outcomes in their respective teaching areas.

METHODOLOGY

MS and ABE formed a team to look into how engineering and mathematics modules could be integrated so as to enable students to relate better on how mathematics is applied to solve engineering problems. Module coordinators of engineering modules first compiled a list of formulae that are needed in the teaching and learning of their modules.

A total of 206 formulae from 16 engineering modules were gathered and compiled into a common Engineering Formulae booklet. In the booklet, each formula is indicated with a reference to the mathematics module that the students will be learning. The reference shows

the mathematics module code and the topic of the mathematics module notes where the details of the formula are being taught.

Similarly, in each mathematics module, references are also indicated. Each reference shows the formula and the page number of the Engineering Formulae booklet where the mathematics is applied to engineering modules. Hence, there are cross references of engineering and mathematic modules for integrated learning [2]. The Formulae booklet is given to all first year students. The students will use the Formulae booklet throughout the three-year DCEM course.

RATIONALE

In most engineering modules, formulae are given to students to solve engineering problems. The concepts and principles of these formulae are not explained to students as these involve enormous amounts of mathematical steps and manipulations. Hence, students do not have a good understanding of the formulae they have used. To bridge this gap, it is necessary to link these formulae to the relevant mathematics topics where the concepts and principles will be explained to promote their understanding of the engineering content [3]. It is important that students have a good understanding of engineering content for the future advancement of their careers and for further studies in the engineering field.

EXAMPLES ON LINKAGES FOR INTEGRATED LEARNING

To illustrate how the cross references of engineering and mathematic modules for integrated learning are carried out using the Formulae booklet, I shall use a simple example to explain my point. In this example, students are asked to find the area of a circle with a radius of 5 cm in an engineering module. Students will first obtain the formula from the Formula booklet which is given as $A = \pi r^2$. They will then substitute *r* = 5 *cm* into the formula as shown below: $A = \pi(5)^2 = 78.54\ cm^2$ .However, the students may not know how to solve the problem if they are asked to find the radius of the circle given that its area is $41\pi\ cm^2$. In the Formulae booklet, a formula like this is linked to the mathematics module where the manipulation of the formula is taught and explained. Hence students will have a better understanding and ability to solve engineering problems after learning the mathematics modules. (Please note that this problem seems easy as it is purely used for illustration purposes. Engineering formulae are usually much more complicated than this.)

Below is an example on how engineering formulae in the Formulae booklet are linked to the mathematics modules. Please take note of the explanation in the callout (in light blue) below.

Module Name: Structural Mechanics (Engineering Module)
Module Code: BE752Y
Module Coordinator: Rose Huang
Formulae used:

1. Direct stress $f = \dfrac{F}{A}$

2. Strain $\varepsilon = \dfrac{\Delta l}{l}$

Linkage to mathematics module is shown in the yellow box.

3. Hooke's law $E = \frac{f}{\varepsilon}$

4. Bending stress $f = \frac{M \cdot y}{I_{xx}}$ — **Integration (MS322Z, Chapter 4)**

5. Moment of inertia $I = I_{NA} + A \cdot h^2$ — **Integration (MS322Z, Chapter 3)**

6. Euler's buckling load $P_{cr} = \frac{\pi^2 EI}{l_e^{\,2}}$ — **Differential Equations (MS322Z, Chapter 8)**

Below is an example on how the working in a mathematics module is linked to the formula in the Formulae booklet. Please take note of the explanations in the callouts (in light blue) below.

From the mathematics module MS322Z Chapter 8, students learn how to find the deflection equation and the maximum deflection of a beam of length L. The beam has a uniform cross-section and is freely supported at both ends. It carries a uniformly distributed load (UDL), including its own weight, of w per unit length shown in Figure 1.

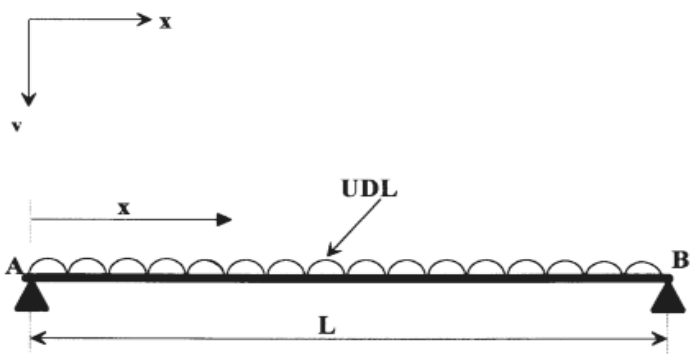
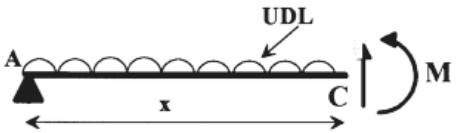


Figure 1. A Simply Supported Beam with Uniformly Distributed Load

Total load = wL

Reaction at each support = $\frac{wL}{2}$

Revision of engineering module (Structural Mechanics)



Revision of engineering module (Structural Mechanics)

To find M --- use the free body diagram above

Take moment about point C

$$M + (wx)(\frac{x}{2}) = \frac{wL}{2}(x)$$

$$M = \frac{wLx}{2} - \frac{wx^2}{2}$$

$$M = \frac{w}{2}(Lx - x^2)$$

Application of Mathematical Modelling

$$\boxed{\therefore \quad \frac{d^2v}{dx^2} = -\frac{M}{EI}}$$

$$\frac{d^2v}{dx^2} = -\frac{w}{2EI}(Lx - x^2) \text{ ------- it is of form } \frac{d^2y}{dx^2} = f(x) \qquad \text{Eqn (1)}$$

Integrate wrt x

Application of Integration

$$\frac{dv}{dx} = \frac{-w}{2EI}(\frac{Lx^2}{2} - \frac{x^3}{3} + A) \qquad \text{Eqn (2)}$$

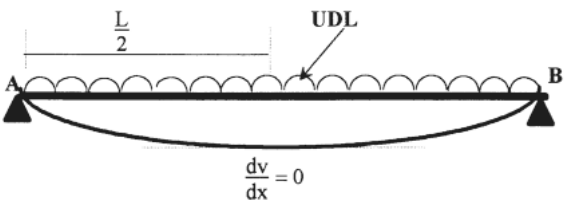
Integrate again wrt x

$$v = \frac{-w}{2EI}[\frac{Lx^3}{6} - \frac{x^4}{12} + Ax + B] \qquad \text{Eqn (3)}$$

To find the constant A, the boundary condition is:

when $x = \frac{L}{2}$, $\frac{dv}{dx} = 0$, as shown below.

Boundary conditions as applied to the deflection at the mid-span of a simply support beam



That is, the gradient is zero when the deflection is maximum.

Hence equation (2) $\frac{dv}{dx} = \frac{-w}{2EI}(\frac{Lx^2}{2} - \frac{x^3}{3} + A)$

Application of Differentiation

becomes $0 = -\frac{w}{2EI}[\frac{L}{2}(\frac{L}{2})^2 - \frac{1}{3}(\frac{L}{2})^3 + A]$

$$0 = -\frac{w}{2EI}(\frac{L^3}{8} - \frac{L^3}{24} + A)$$

$$0 = -\frac{w}{2EI}(\frac{2L^3}{24} + A)\text{, therefore} \quad A = -\frac{L^3}{12}$$

To find B, the boundary condition is:

when x = 0, v = 0 i.e. no deflection at the support.

Boundary conditions as applied to deflection at a support

Hence equation (3) $v = \frac{-w}{2EI}[\frac{Lx^3}{6} - \frac{x^4}{12} + Ax + B]$

becomes $0 = -\frac{w}{2EI}(0 - 0 - 0 + B)$, therefore B = 0

Hence the deflection equation is $v = -\frac{w}{2EI}(\frac{Lx^3}{6} - \frac{x^4}{12} - \frac{L^3}{12}x)$

Maximum deflection occurs at the mid span i.e. $x = \frac{L}{2}$

Hence, $v = -\frac{w}{2EI}(\frac{Lx^3}{6} - \frac{x^4}{12} - \frac{L^3}{12}x)$ becomes

$$v_{max} = -\frac{w}{2EI}(\frac{L^4}{48} - \frac{L^4}{192} - \frac{L^4}{24})$$

$$v_{max} = -\frac{w}{2EI}(\frac{8L^4 - 2L^4 - 16L^4}{384})$$

$$v_{max} = -\frac{w}{2EI}(-\frac{10L^4}{384})$$

$$v_{max} = \frac{5wL^4}{384EI}$$

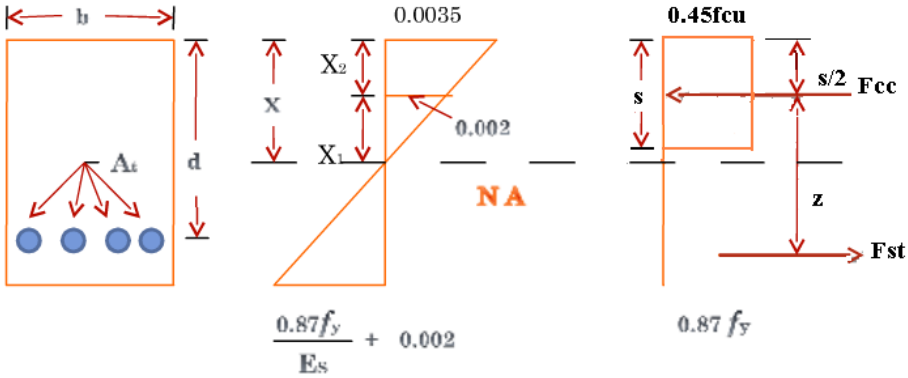
Linkage to the Formulae booklet Page 19, Equation No. 29 (b) of the engineering module: Steel Design & CAD

Refer to page 19 of Formulae Booklet, Equation No. 29 (b) (Steel Design & CAD)

Below is an example of how the contents in a mathematics module can be realigned to meet the needs of the engineering module.

In the mathematics module, students are taught how to solve for x in a quadratic equation of the form $a x^2 + b x + c = 0$. The equation can be solved by using factorisation or the quadratic formula $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$. The derivation of the quadratic formula is also shown and explained to students. Students are then taught how to solve simple quadratic equations such as $2x^2 + 4x + 1 = 0$. However, some of the quadratic equations encountered in engineering modules could be more complicated. Hence in the mathematics module, it is necessary to give examples or exercises on how to solve more complicated quadratic equations. Below is an example of a difficult quadratic equation encountered in an engineering module (Concrete Design) covering singly reinforced rectangular section in bending.

Bending of the section will induce a resultant tensile force F_{st} in the reinforcing steel, and a resultant compressive force in the concrete F_{cc} which acts through the centroid of the effective area of concrete in compression shown in Figure 2.



SECTION **STRAIN** **SIMPLIFIED STRESS**

Figure 2. Cross-Section of a Beam and its Strain and Stress Diagrams

For equilibrium, the ultimate design moment, M, must be balanced by the moment of resistance of the section so that

$$M = F_{cc} \text{ x } z = F_{st} \text{ x } z \qquad \text{Eqn (4)}$$

where *z* is the lever arm between the resultant forces F_{cc} and F_{st}.

$$F_{cc} = \text{stress x area of action}$$
$$= 0.45 f_{cu} \text{ x } bs$$

and

$$z = d - \frac{s}{2} \qquad \text{Eqn (5)}$$

So that substituting in Eqn (4)
$M = 0.45\, f_{cu}\, bs \times z$ and replacing *s* from Eqn (5) gives

$$M = 0.9\, f_{cu}\, b(d - z)\, z$$

Rearranging and substituting $K = \dfrac{M}{b\, d^2\, f_{cu}}$

$$\left(\frac{z}{d}\right)^2 - \left(\frac{z}{d}\right) + \frac{k}{0.9} = 0$$

More complicated quadratic equation is encountered in this engineering module. Mathematics module needs to include more complicated equations as well.

Solving this quadratic equation:

$$z = d\left(0.5 + \sqrt{0.25 - \frac{K}{0.9}}\right)$$

which is the equation in the code of practice BS 8110 for the lever arm, z, of a singly reinforced concrete section. …… the remaining calculations are omitted to save space.

In addition, if engineering and mathematics modules are not well integrated or coordinated, some of the important basic concepts could be left out from the entire course. For examples, the first moment of area and the second moment area, as illustrated below, were found to be missing from the DCEM course.

First moment of area is defined as area multiplied by perpendicular distance. Referring to the plane in the Figure 3, the first moment of the element of area dA about the x - axis is $y\, dA$.

Therefore the first moment of the whole figure is $\int_A y\, dA$ about the x - axis, the suffix A indicating summation over the whole area. The first moment of the whole figure about the y -axis is $\int_A x\, dA = \int_a^b x\,(y_u - y_l)\, dx$

Maths modules need to be realigned to include important basic concepts

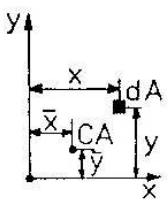


Figure 3. An Element of Area dA

Second moment of area is defined as area multiplied by the square of perpendicular distance. If the first moment of the element dA about an axis is multiplied again by the respective co-ordinate, we obtain the second moment of area, namely $y^2\, dA$ or $x^2\, dA$. The second moment of area of the whole figure: about the x -axis $I_{xx} = \int_A y^2\, dA$ and about the y -axis, $I_{yy} = \int_A x^2\, dA$. It is necessary that these two basic concepts are taught to the students in the mathematics modules and linked to engineering modules through the use of the Formulae booklet. However, sometimes it is not possible to keep adding content to existing mathematics modules. We can overcome this problem by removing non essential content

from the mathematic modules. However, with the reduction of curriculum hours for mathematics modules, we may ultimately need to create a separate mathematics module called **reference module** for students to learn outside their curriculum hours. The reference module will encourage students to learn additional concepts or to acquire a better understanding of the application of mathematics to engineering modules. For example, they may learn the derivation of the mathematical model $\frac{d^2v}{dx^2} = -\frac{M}{EI}$ used for finding the deflection of beam mentioned in one of the examples above.

SURVEY FINDINGS

A survey was carried out in Academic Year 2008/2009 Semester 2. Table 1 shows the responses to the five survey questions. The survey was conducted on 135 first, second and third year DCSE students. Each student was given a copy of the Formulae booklet.

- 90% of the students felt that the Formulae booklet helped them learn engineering modules better.
- 85% of the students felt that the booklet helped them understand or relate better how mathematical concepts are applied in engineering modules.
- 93% of the students felt that it was very convenient for them to refer to the booklet whenever they needed the formulae.
- 77% felt that, with the help of the booklet, they were motivated to learn engineering mathematics.
- 81% felt that they would use the booklet in their work or in their further studies after graduation.

Table 1
Responses of Student Survey

No.	Survey Questions	Disagree or Strongly disagree	Neutral	Agree or Strongly agree	Average score (out of 5)
1.	The Engineering Formulae booklet helps me learn engineering modules better.	1%	9%	90%	4.51
2.	The booklet helps me understand (relate) better how mathematical concepts are applied in engineering modules.	3%	12%	85%	4.36
3.	It is very convenient for me to refer to the booklet whenever I need the formulae.	0%	7%	93%	4.62
4.	With the help of the booklet, I am motivated to learn engineering mathematics.	2%	21%	77%	4.19
5.	I think I will use the booklet in my work or in my further studies after graduation.	2%	17%	81%	4.33

The findings based on general comments from these students are as follows:

- Many of the formulae for the modules on Geomatic and Structure Analysis have not been included in the Formulae booklet. They wondered why they still had to memorise formulae for these two modules.
- The Formulae booklet is particularly useful for weaker students.
- The compilation of the Formulae booklet is creative and a job well done.
- More details should be added in the Formulae booklet. The meaning of each term or symbol used in the booklet should be explained.
- Examples should be given for each formula.

DISCUSSIONS

The survey findings obtained from students have been positive. The majority of the respondents felt that the use of a common Formulae booklet in the integrated teaching and learning of engineering and mathematics modules was useful and effective. This Formulae booklet is a useful tool to help the students assimilate and apply the mathematics knowledge they have learnt, in the engineering modules. Hopefully, students will be more motivated to learn what they deem to be useful for their course of studies [4].

One problem we encountered is that some formulae in the Formulae booklet could not be linked directly to the mathematics modules, as additional content is needed. Our future work for further integration includes the streamlining of mathematics modules in order to provide most of the content to meet the requirements of the engineering modules and also to expand or enhance the reference module. In this way, the content of the mathematics modules will be even more aligned with that of the engineering modules.

More importantly the feedback given by the students will also be incorporated into the Formulae booklet. In addition, the following are some possible improvements which the team can make to this Formulae booklet project:

- Include an introduction to explain the rationale and purpose of the Formulae booklet.

- Have clear and standardised format in all the mathematics notes informing students of the connection with the Formulae booklet. It can be a box with a suitable heading plus a link to the page of the Formulae booklet. This must be standardised for all the mathematics modules so that the students are "trained" to identify such boxes as links to their course of studies.

- Create an online version hosted on Blackboard with hyperlinks to the mathematics notes for easy reference for the students.

CONCLUSION

The approach and specific innovation outlined in this paper conforms to the CDIO Standard 3, which advocates curriculum integration of disciplinary modules such as mathematics with engineering content and practices. From the survey findings in this pilot study, we found that majority of the students found this formulae booklet useful and effective. This gives the team the impetus to continue improving upon the Formulae booklet for the next few years.

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APPENDIX A

Survey Questionnaire on the Use of Formulae booklet.

Name: _____ (Optional)

Class: DCSE _____

(a) Please tick the appropriate boxes.
(b) 1 being strongly disagree and 5 being strongly agree

Strongly Disagree **to** Strongly Agree →

1 5

		1	2	3	4	5
Q1	The Engineering Formulae booklet helps me learn engineering modules better.					
Q2	The booklet helps me understand (relate) better how mathematical concepts are applied in engineering modules.					
Q3	It is very convenient for me to refer to the booklet whenever I need the formulae.					
Q4	With the help of the booklet, I am motivated to learn engineering mathematics.					
Q5	I think I will use the booklet in my work or in my further studies after graduation.					

Any other comments

_____

_____

_____

Thank You

INTEGRATING CDIO SKILLS IN A CORE CHEMICAL ENGINEERING MODULE: A CASE STUDY

Sin-Moh Cheah

SINGAPORE POLYTECHNIC

ABSTRACT

The Diploma in Chemical Engineering is one of the engineering programs in Singapore Polytechnic adopting the CDIO Framework as the basis of its curriculum revamp. This paper describes the work done on *Chemical Reaction Engineering*, one of the core modules in chemical engineering disciplines. Specifically, it detailed the work done on revamping of the laboratory experiments for the module, with the aim on integrating the topic with other chemical engineering disciplines as well as infusing three CDIO skills viz Teamwork, Communication, and Personal Skills and Attitudes, focusing on critical thinking skills, and ability to hold multiple perspectives. It described the rationale behind the redesign of laboratory experiments to contextualize the various soft skills so as to provide a learning environment that bear relevance to real-world work environment that students can appreciate. The design of assessment schemes to encourage both individual mastery and team collaboration was illustrated. This is followed by a discussion of student experience through blogs and survey questionnaire. Some points of reflections based on the lesson learnt were then presented, followed by an outline of follow-up actions and the challenges of implementing them.

KEYWORDS

CDIO, chemical engineering, chemical reaction engineering, assessment, evaluation

CDIO AND THE REVAMP OF THE DIPLOMA IN CHEMICAL ENGINEERING

Singapore Polytechnic had adopted the CDIO Framework as the basis for the design of all its engineering diplomas. All new engineering diplomas will need to be designed around the framework, and all existing diplomas will need to be revamped to integrate the various CDIO skills, guided by the 12 CDIO Standards and CDIO Syllabus. The revamp exercise for the Diploma in Chemical Engineering had been covered elsewhere by the author [1]. This paper focuses on the work done for a specific module, namely *Chemical Reaction Engineering*.

Chemical Reaction Engineering

The module is taught to Year 2 students from the Diploma in Chemical Engineering. Broadly speaking, the module aims to provide students with fundamentals of chemical kinetics and reactor design. In chemical kinetics, factors affecting the rate of reaction and the determination of rate equation are discussed. In reactor design, various types of industrial reactors are introduced and the development of design equations and sizing of reactors are covered. This is complemented by extensive practical work.

USING CDIO FOR MODULE REDESIGN

The revamp of the module focuses on the redesign of laboratory experiments for the module. From the onset, it is clear that our laboratory experiments, which are rich in hands-on experience, are the most conducive place to introduce various CDIO skills. This is because unlike lectures and tutorials, laboratory sessions deal with a much smaller number of students each time, roughly between 18-24 students, as opposed to lectures (60 or more students) or tutorials (around 40 students). By redesigning our laboratory activities in an innovative manner, they can be leveraged to provide the largest context on which infusion of CDIO skills can be initiated. Revamp of the laboratory activities follows the student-centred Triangle of Course Design [2] shown in Figure 1. The module coordinator together with a senior education advisor reviewed all the module learning objectives and recast them in terms of the intended learning outcomes.

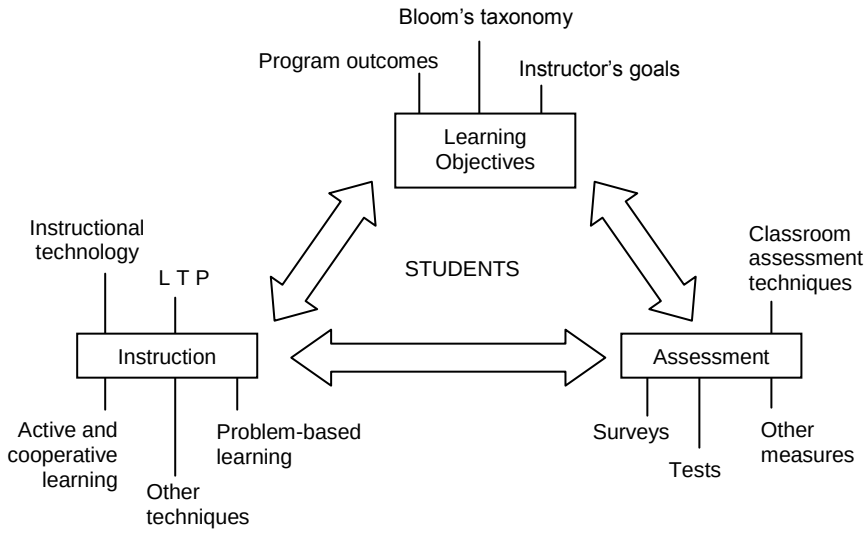

Figure 1. Student-centred approach to curriculum design

A sample of the learning objectives is provided in Figure 2. The details of this work had been covered in a separate paper by the team [3]. Suffice to say the various learning tasks in this module, be it communication skills, teamwork, etc were all contextualized to provide an active, experiential learning experience for the students. The module also included a mini design-build experience (DBE) where students are required to first determine the size of a reactor required for a given product conversion, and then proceed to fabricate one out of plastic tubing, and lastly evaluate its performance by carrying out a laboratory experiment. A comprehensive student guide was also developed to accompany the module, complete with explanation of the desired learning attitudes, underpinning knowledge of the selected CDIO skills, along with a complete set of rubrics for used in the assessment of the required demonstration of the CDIO skills.

The followings serve as the basis for the redesign of laboratory activities:

(a) Moved away from merely "laboratory" environment, but instead to towards a contextualized to reflect working environment in the chemical industry or chemical research institutes where our graduates eventually find employment.

(b) Moved away from merely proving theories, and towards integration of other related technical content, along with the desired CDIO skills.

For (a), all lab experiments were replaced by scenario-based activities, whereby for each activity, students were placed under simulated working environment that a chemical engineering graduate typically finds himself/herself in. This is achieved by re-writing the

entire laboratory manual, with a new section on “Task Scenario” placed at the beginning of each activity (See Figure 3), while the usual “Experimental Procedures” were “relegated” to the Appendix, where it is referenced from the Scenario. A special section on underpinning technical knowledge required was also added and was placed in the Appendix as well. This is to address one of the challenges inherently faced in the teaching of any chemical engineering module that contains a laboratory component: that of mismatch between learning underpinning knowledge in lecture and practice sessions in the laboratory.

AFTER

2 Obtain the Rate Law for specific chemical reactions

2.1 Describe the steps involved for determining the rate law parameters.
2.2 Use Arrhenius Law to determine the effect of temperature on the rate of chemical reactions.
2.3 Infer and interpret experimental data on the effect of temperature on the rate of chemical reactions.
2.4 Compare and contrast the integral and differential methods of analysis in rate law determination.
2.5 Use integral and differentiated methods of analysis to determine the rate law for a liquid reaction.
2.6 Calculate and interpret the results for the integral and differential methods of analysis using graphical solution and linear regression.
2.7 Identify the components of an effective team
2.8 Identify team roles and their impact on team performance
2.9 Apply team ground-rules and display teamwork (including leadership) in a range of team role situations when conducting experiments
2.10 Identify contradictory perspectives relating to modifications of a chemical reactor.
2.11 Design appropriate communication strategies and deliver effective oral communication to a given audience.

BEFORE

2 Understand the fundamentals of chemical kinetics

2.1 Distinguish between elementary and non-elementary reactions.
2.2 Explain the rate law and rate constant for elementary reactions.
2.3 Describe the temperature dependence of the rate constant using Arrhenius Equation.
2.4 Explain the molecularity and order of reaction.
2.5 Discuss the factors affecting the rate of reaction.
2.6 Determine the frequency factor and activation energy of a reaction.

3 Understand the methods for determining the rate law for liquid reactions

3.1 Describe the steps involved for determining the rate law parameters.
3.2 Compare and contrast the integral and differential methods of analysis in rate law determination.

Figure 2. Comparison between Learning Objectives before and after revamp

For (b), again a complete review of all the laboratory experiments was carried out. It was clearly evident that one of the five experiments do not serves much purpose other than confirming what were already taught in class. In the original design of the particular experiment, students carry out measurements of conversion of a chemical reaction at various points along the length of a chemical reactor, and hence verify that the concentration of feed materials decreases as it progressed down the reactor. This is rightly so, as the feed materials got consumed and formed products in the reactor. This experiment was therefore replaced with one that incorporates a mini design-built experience (DBE), as well as exposing students to some degree of design ambiguity that requires them to make sound engineering decision by making reasoned choices. This is a deliberate move to create the awareness that at times more than one acceptable design are possible and that trade-offs between different designs must be considered.

Integration of desired CDIO skills is based on the rationale soft skills and disciplinary knowledge are largely interdependent, and they should therefore be learnt and assessed together. To this end, all the activities in the laboratory require students to practice various soft skills in the technical context, based on the situation described in the task scenario. The

underpinning knowledge for these CDIO skills were briefed to students and also made available in the student guide. Figure 4 provides the underpinning knowledge on Managing Learning.

You are the Engineering Assistant in Tokkong Engineering Pte Ltd, a local chemical engineering company specializing in engineering design and integration of chemical pilot plants. The company's major clients include the universities and polytechnics, research institutions and laboratories. You report to Mr. Pow Kah Leow, the Project Engineer who designed pilot plants according to client requirements. You are in charge of performing test run on the pilot plants. The purpose of performing the test run is to ensure that the pilot plant is capable of performing according to its design specifications. You have a team of 3 – 4 technicians under your supervision.

A major customer, the Singapore Institute of Technical Studies (SITS), had ordered a chemical reactor test rig consisting of 2 types of reactor, namely the continuous stirred tank reactor (CSTR) and the plug flow tubular reactor (PFTR). A brief description of the system is shown in Appendix 1, and Appendix 2 is a set of experimental procedure developed by the Project Engineer for achieving the following stated objective:

"*To compare the performance of a CSTR and a PFTR*"

The Project Engineer informed you that the reactor test rig has been delivered to Institute of Technical Studies, and your team will be required to perform a test run in presence of a group of lecturers led by the Lecturer-in-Charge, Dr. Chin Khan Khor, for the site acceptance test. At the completion of the test run, you will be required to draft a written memo on behalf of the Project Engineer, to the lecturer-in-charge, detailing preliminary findings from the test run, concluding if the reactor test rig is functioning as expected.

Figure 3. Sample Task Scenario

- What is a learning approach and how does it impact on personal learning. Typical differences in the way people approach their learning (e.g., visual, auditory, kinaesthetic; holistic, serialist, etc)
- Different ways in which self improvement can be achieved (e.g., lifelong learning, creating positive beliefs and psychological states, etc).
- The challenges that lifelong learning entails and its implications (continual re-skilling, job changes, professional and personal flexibility, etc)
- What are positive beliefs and psychological states. How these can be developed and maintained (e.g., reframing, visualizing, self-motivation, etc)
- What is meant by dispositions and how they impact on human behaviour. How certain dispositions (e.g., initiative, perseverance, flexibility, etc) contribute to high performance and success in work projects and in life goals.
- What is meant by 'learning strategies and skills' and how they can help to make learning more effective and efficient. Different types of learning strategies and skills and how they contribute to improved learning (e.g., goal setting, learning plans, monitoring learning, organizing/summarizing information, receiving feedback, etc)
- Ways to manage time and resources (e.g., schedules, monitoring and review, etc)

Figure 4. Underpinning Knowledge for "Managing Learning"

ASSESSMENT DESIGN

Assessment is the most powerful tool to guide and support student learning (Edstrom et al, 2005). Detailed planning went into the design of assessment questions. Coverage of assessment is comprehensive, ranging from the underpinning technical knowledge to various CDIO skills. A complete breakdown of the assessment scheme for each activity was provided in the student guide. A sample of this is shown in Figure 5.

This Activity will be assessed based on the following components:

S/N	Components	Weightage	Individual	Group
1	Punctuality and Attire	4%	✓	
2	Laboratory Safety: (a). Safety Practice (b). Explaining safety precautions	 4% 4%	 ✓ ✓	
3	Attitude, Responsibility and Diligence in Conducting Experiments	8%	✓	
4	Pre-Experiment Assessment of Underpinning Knowledge: (a). Key Concepts, Principles, Procedures (b). Oral Presentation	 4% 6%	 ✓	 ✓ ✓
5	Teamwork	10%		✓
6	Post-Experiment Assessment: Questions for the Practical	10%	✓	✓
7	Report Assessment	50%		✓

Figure 5. Sample Assessment Scheme for an Activity

To balance between fostering teamwork and collaboration among students on one hand, and encouraging personal skills and attitudes of each individual student on the other, a mixed approach in assessment to reward both efforts were designed. Broadly speaking, the assessment questions can fall into one of three categories:

(a) Single questions for which each student has to answer – students typically choose from a pool of questions
(b) Group questions requiring everyone to answer – the same question requiring different answers from everyone in the group
(c) Group questions requiring a joint answer – questions requiring group discussion and a member of the group to provide the answer

Assessments can be broadly classified as In-Class Assessment and Report Assessment. The In-Class Assessments were carried out at two points in time: first at the beginning of class (the so-called “Pre-Experiment Assessments”; and later during debrief at the end of class – “Post-Experiment Assessments”. As what gets assessed gets learnt, pre-experiment assessments are introduced based on the information made available in the namely the underpinning knowledge and experimental procedures. A set of questions were carefully designed and used to test students understanding prior to allowing them to start the experiment.

Post-assessment questions do not just centre around the work being done in the lab, but serve to stretch student understanding beyond what they learnt in the lab. For the work done in the lab, questions are designed to test their observations of the way the steps are sequenced, test assumptions made in performing the subsequent calculations, and ways to improve the experiment. Questions were also designed for students to integrate what they learnt in other modules into what they learnt in chemical reaction engineering, for example to suggest ways to overcome the hazards posed by a very exothermic chemical reactions, i.e. reactions releasing a large amount of heat, or the impact of their design on pumping requirement if a long reactor with small tube diameter is used versus a shorter one with a larger tube diameter. See Figure 6 which showed samples of the three types of questions that form part of the Pre-Experiment Assessment.

Common questions for the group:

1. Explain your choice of the tube ID selected for your design.
   (Choose 1 member to answer. Common score for the group: 3 marks)
2. Briefly explain what other factors that you would take into consideration in the design of a chemical reactor.
   (1 from each member, 2 marks each)

Each member to choose one of the questions to answer: (3 marks each)

1. Explain what is meant by "plug flow".
2. Briefly explain, how, in a practical application, a deviation from "plug flow" may occur.
3. Name three assumptions that you made in carrying out the reactor design.
4. Should the analysis of possible sources of error be carried out before or after the experiment? Explain.
5. Explain how the conversion of NaOH will vary along the length of the PFTR.

Figure 6. Sample Pre-Experiment Assessment Questions: Key Concepts

Other than assessing the underpinning knowledge and integration with other technical knowledge, to complement the pre-experiment effort in inculcating greater appreciation of various CDIO skills, assessments were carried out in these areas, such as, (i) team roles; (ii) holding multiple perspectives; (iii) communication – oral presentation and memo; (iv) managing learning. Figure 7 provided some examples on the questions asked for items (i) and (ii) respectively.

<u>Pre-Experiment Preparation</u>: Forming a Team and Allocation of Roles

Divide the workload among your team members to take on the following roles:

1. Supervisor – overall coordination to ensure that procedures are being followed, proper safety precautions are taken
2. Panelman (or Boardman) – monitor the progress of the experiment via PC
3. Senior Technician – monitor proper functioning of conductivity meter and level control system
4. Technician Grade I – perform plant line-up, waste disposal (as and when needed), washing.

<u>Post-Experiment Assessment</u>: Teamwork

Discuss among your team members and answer the following questions:
(All members receive the team mark)

1. Explain the importance of the role of the Supervisor. (3 marks)
2. How do you decide on the allocation of roles? (3 marks)
3. Explain how a failure in the role of (a) Boardman, (b) Senior Technician, would impact the team performance. (4 marks)

<u>Post-Experiment Assessment</u>: Identifying different perspectives

1. Assume you come from one of the following departments, explain your view if the Plant Engineer proposes that an additional high temperature alarm be added to the CSTR pilot plant: (a) Finance (b) Operation (c) Safety
   (d) Maintenance (e) Senior Management
   (1 from each member, 2 marks each)

Figure 7. Sample Activity Design and Assessment

Assessment on critical thinking is achieved via hazard identification and prescription of preventive/control measures, especially in the context of working in the chemical processing industry. In this regards, students are stretched in their thinking process by requiring them to first look for hazard(s) associated with materials and equipment used as well as the process itself under normal and emergency situation. With these, students are required to then

explain the necessary safety precautions to be taken to protect themselves, their co-workers and the plant and equipment.

The intended outcome is for students to develop a generic skill on how to properly take a precautionary action against a hazard identified, regardless of what type of chemical plant or work situation they are in. For example, a chemical can pose multiple hazards, e.g. fire/explosion hazard as well as various health hazards. A grinding process poses a different hazard compared to a drying process. Likewise, operating a compressor is different from operating a boiler. By going through the critical thinking process linking causes and effects of a potential hazardous situation, students come to understand the importance that any safety precautionary measure to be taken must match the hazard that is present, as the incorrect measure(s) adopted may convey a false sense of security.

Rubrics were extensively used to aid the assessment of CDIO skills. Figure 8 showed a sample rubric for the assessment on Explaining Safety Precautions.

CATEGORY	LEVEL OF OUTCOME			
	4	3	2	1
Laboratory Safety: **Explaining Safety Precautions**	Clearly identified a hazard, satisfactorily explained how it may arise, and able to link it to the proper safety precaution to take.	Identified a hazard, attempted to explain how it may arise, some attempt to come up with proper safety precaution.	Identified a hazard but unable explain how it may arise, or to link it to a proper safety precaution. Sign of guessing the answers.	Inability to identify a hazard, or attempt to go straight into safety precaution without associating it with a hazard.

Figure 8. Sample Scoring Rubric for Explaining Safety Precautions

All expectations and assessment requirements were communicated to students on the first week at the beginning of the semester. All the materials were also made available electronically in the school's e-Learning platform. Another important feature of the assessment system is that of feedback. Instant feedback was given to students on their performance in the laboratory. Both positive and 'negative' (areas for improvement) ones were conveyed to students during the post-experiment assessment. Feedback on report submission was given 2 week later, after the report was marked.

EVALUATION

To obtain feedback on how well the revised laboratory activities are being received by students, a multiple approach to obtain feedback from students. A group of students was selected to take part in entering into an online journal of their experience as they worked through all the 5 activities. The students were also periodically interviewed by an impartial third-party staff member, namely an education advisor from the Polytechnic. Upon the conclusion of the activities, a survey was conducted for all 60 students in the program.

Overall, over 80% of respondents indicated that they understand the usefulness of teamwork, communication and thinking skills in their profession. 63% of respondents found the lessons

more interesting with the re-designed activities, and likewise 61% respondents indicated they participated more actively in their lessons. 81% of respondents also replied that they now better understand the relationship between this module and other modules. This is broadly supported by the students' journal entries who commented that critical thinking skills were being explicitly assessed. Others reported on the benefits of role-playing in shaping understanding of teamwork, and usefulness of integrative-type of questions in linking chemical reaction engineering to other modules.

Lastly is the observation made by the author on his interactions with the students during the laboratory sessions. Overall, it is observed that all students are more forthcoming in "volunteering" an answer, and that is most cases, all members of the group will actively participate during debrief. Free-riding among students were nearly non-existent as all members are forced to take part in the group discussions. Complaints about group members not participating in the pre-experiment discussions were drastically reduced. There were still occasionally but rare (like one in 25 groups) that some free-riding exists in post-experiment report writing effort, and the team is now considering utilizing peer-assessment to discourage such behaviour.

SOME PERSONAL REFLECTIONS

The use of a pilot module like *Chemical Reaction Engineering* is important as it provided the author with first-hand experience how to go about executing the necessary revamp. The result can serve as a useful template to illustrate how the infusion of various soft skills, in the polytechnic's context, can be achieved in practice. Through numerous reworking of the design of the student guide and laboratory manual, the author was able to internalize the CDIO requirements and it serves to allay the initial fear of an increased curriculum hours that followed such revamp. It also helped to build confidence in how to effectively assess effectiveness of non-technical skills such as communication and teamwork.

Through the revamp effort, the author is convinced that it is not adequate to cover the learning of soft skills such as oral communication, report writing and presentation, only in standalone modules. Students still communicated poorly or wrote badly despite the numerous assignments to hand in. Others, such as teamwork and critical thinking, although stressed in the curriculum, were not effectively covered in the various core chemical engineering modules. Often students are assumed to somehow "get it"; for example, how to think critically after working through several tutorial questions, or able to work in teams after assigning them in groups for a given assignment or laboratory experiment.

Next is the mindset change that occurred on the use of pilot plants and workspaces. It was initially thought that new pilot plants as well as workspaces may be required to train students in these "new" skills of teamwork, communication, etc. On deeper analysis, such doubts were build on the traditional approach to teaching and training in which many experiments and laboratory activities were designed pretty much to prove the theories taught in classrooms. With the revamp effort calling for a "new" approach to teaching and training, it becomes a natural extension of the thinking process that there needs to have new facilities for new training. The result from the revamp of *Chemical Reaction Engineering* demonstrated conclusively that no additional workspaces are required. What is more important is how to weave into the existing laboratory sessions the application of the various soft skills.

The author also finds that working one-to-one with an education advisor is very effective at eliciting the 'hidden' or implied learning objectives desired by the module coordinator but not verbalised satisfactorily in written form in the specific learning objectives. Probing questions from the education advisor can help the module coordinator crystallize the rationale behind a

stated learning objective, the revision of which can lead to a much clearer learning outcome. It becomes apparent that one should write learning outcomes in clear and appropriate terms.

Lastly, using a competency-based approach in assessment of intended learning outcome can help promote clearer and creative thinking in curriculum redesign, especially in terms of integrating various other CDIO skills as well as new developments such as green engineering, biofuels, etc. This will be elaborated in greater detail in next section.

FOLLOW-UP ACTIONS AND CHALLENGES

While one can discern from the above that integration of soft skills can be added onto existing laboratory sessions without incurring additional curriculum hours, more time is indeed required to conduct a more comprehensive assessment. There is also a very real increase in manpower: each of the *Chemical Reaction Engineering* experiments requires two lecturers to be deployed full-time for the entire 3-hour duration of the session.

On the assessment design, it can be contemplated that assessment of individual contribution to report submission be carried out. The current practice was based on a group effort with everyone in the group given the same report marks. It is a common practice among students that, to “optimize” the available time (real or perceived), they are inclined to share out the workload, say by dividing among 4 students 8 questions, each attempting 2 questions and then merely join together each other’s contribution for the submission. There is no attempt on their part to understand what the others had put together. Apart from that, the issue of “free-riding” can still arise. There can be a member of the group who had decided to take a back seat now that report writing is not being assessed on an individual basis. The author would like to consider introducing peer assessment into report assessment. Thus, another challenge is to encourage team-working in preparing the written report. Peer assessment would probably be the method of choice to assess individual contribution.

With the experience gained, the author will be proceeding to share his learning experiences with other lecturers with a view of helping them integrate the relevant CDIO skills into their respective modules. Several sharing sessions and a workshop had been conducted, as well as one-to-one coaching sessions. Work is in progress to roll out additional ‘CDIO-enabled’ modules covering at least 5-6 more modules from Year-1 through to Year-3.

Lastly, there remained the challenge of how to integrate more such soft skills into other instruction medium such as lectures, tutorials and assignments. More demanding are the lectures and/or tutorials, due to the large class sizes (60 or more students in the case of lectures and up to 40 students during tutorials). The team is contemplating to use the Bhopal tragedy as a case study to illustrate the impact of engineering design on society and the environment, and to touch on the questions of ethics as well. The Bhopal case study is also useful to in introducing the concept of green engineering as part of sustainable development, whereby an alternative synthesis pathway can avoid the production of harmful chemical intermediate altogether. The recent debate on biofuels is another topic rich in context for incorporation into the module to actively engage students in appreciating contradictory perspectives and understanding the responsibilities of chemical engineers to society.

CONCLUSIONS

At the time of this paper, two cohorts of students had completed the modules. Preliminary data for the second cohort indicate similar learning experience compared to the firs cohort, although the data for the second cohort seemed to reveal less satisfaction with the curriculum revamp. A small portion of these students do not appear to appreciate the

importance of soft skills despite having completed the module. This could be due to the lower academic achievement of the second cohort, who adopted a rather indifferent attitude during lessons. This observation points to the difficulty of comparing the same laboratory design and assessment across cohorts of differing academic ability. Nonetheless, the results are encouraging enough for the team to continue fine-tuning the laboratory activities and their related assessment schemes for the benefit of the majority of students.

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Biographical Information

Sin-Moh Cheah is a chemical engineer turned academic. He is the current Course Chairman for the Diploma in Chemical Engineering. His current scholarly interests are curriculum re-design and program evaluation. He has lectured on various topics including chemical engineering principles, separation processes, heat transfer and equipment, and chemical reaction engineering. He held various positions in Mobil Oil Singapore Pte Ltd prior to joining Singapore Polytechnic.

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INTERNATIONAL REQUIREMENTS IN CDIO PROGRAMS

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ABSTRACT

Engineers are today involved in many ways in international projects. This may involve, for example, having various components of a large and complex engineering system produced in different countries, these components then being brought together at some location where the system is assembled. Another way in which international interaction in engineering occurs is where the design of a system is done in one country and the manufacture and assembly of the system is done in other countries and the whole process is planned and monitored in yet another country. There are many other ways in which engineering tasks are undertaken in an international environment and the practise of engineering in such an environment is becoming more and more common. Some preparation for working in an international environment, therefore, should be included in engineering programs. In this paper some of the ways in which engineers work in an international environment are reviewed and discussed and methods for including consideration of working in an international environment in an engineering program are discussed. The fact that the CDIO Syllabus clearly mentions international considerations only in 3.2 COMMUNICATION IN FOREIGN LANGUAGES is discussed. CDIO, with its international membership and commitment to the development of curricula that consider all aspects of engineering, would seem to be an ideal organization to develop methods for bringing such international considerations into engineering curricula and this is also discussed.

KEYWORDS

Internationalization, Syllabus, University Engineering Programs, Engineering Education, CDIO.

INTRODUCTION

Large numbers of engineers are today involved in many different ways in projects that require them to work in an international environment. Some of the ways in which engineers work in an international environment are:

1. By working on international development projects in or with workers from developing countries, the work usually being supported by governmental or non-governmental aid agencies. This work is often concerned with water supply, housing or medical related problems.

2. By working on projects in foreign countries on behalf of a home based company under contract to some level of government in the foreign country or to companies, either local or foreign, operating in these countries. Examples of the type of work involved in this area are the design and construction of hydroelectric plants, dams, bridges, transportation systems, and processing plants that support local mining operations.

3. In opening new manufacturing plants in foreign countries, these plants being designed to meet a demand in the home country, and in the training of local workers for these plants. In some cases this will involve the engineer spending significant periods of time in the foreign country while in other cases it will only involve a number of relatively short visits to the foreign country.

4. Implementing modifications to existing products designed for and previously only sold in the home country that will make them acceptable for sale in foreign countries. This may involve modifications to meet differing government regulations and modifications that ensure that the product is socially acceptable in these countries. Work in this area often involves interacting with people in the foreign country who will be selling and in some cases manufacturing the modified product.

5. Working on projects in the home country in which part of the design process will be subcontracted to engineers in foreign countries. Examples of this are the subcontracting of cfd studies to workers in India and the subcontracting of significant portions of the design of new automobiles to engineers in Eastern Europe.

6. In working on complex engineering systems in which large parts of the system are manufactured and in many cases largely designed in a number of different foreign countries around the world. Modern commercial aircraft are examples of this type of activity. Both Boeing and Airbus now have large parts of their new aircraft produced and designed in various different foreign countries.

7. In working for home based companies whose work is largely undertaken in foreign companies. Examples are exploration and mining companies who operate mainly in foreign countries.

This is by no means a complete list of the ways in which engineers undertake work in an international environment. It will also be noted that there is overlap between some of the areas listed above. Of course, work of this nature has long existed but has not involved the majority of practicing engineers as is the case today in many countries.

To illustrate how great the number of companies involved in producing a complex modern system, consider the Boeing 787 Dreamliner. Some of the companies involved in this project include:

- the flight deck and fuselage will be manufactured by Boeing at Wichita,
- the wings and the fuselage fairings will be manufactured by Boeing in Winnipeg, Canada,
- the fin will be manufactured at Frederickson
- the moving leading and trailing edges of the wings will be manufactured by Boeing at Tulsa and at Boeing Australia.
- manufacture of the centre wing box and installation of the wells will be undertaken by Japan's Fuji Heavy Industries.
- the mid-forward section of the fuselage and the fixed section of the wings will be manufactured by Kawasaki Heavy Industries
- the wing box will be manufactured by Mitsubishi Heavy Industries .
- the all-composite nose section will be built by Spirit Aerosystems of Wichita.
- the main and nose landing gear will be supplied by Messier-Dowty of Velizy, France
- the landing gear actuation systems will be provided by Smiths Aerospace
- the electric braking system will be supplied by Goodrich and Messier-Bugatti.
- the pilot controls will be provided by Kaiser Electroprecision
- the common core system (CCS) will be supplied by Smiths Aerospace UK
- the integrated standby flight display.will be supplied by Thales
- the flight control electronics, autopilot and the navigation package will be provided by

Honeywell, of Phoenix, Arizona,

- the mid-section and rear-section of the fuselage including the tailplane will be manufactured by a joint venture company, Global Aeronautica, set up by Vought Aircraft Industries and Alenia Aeronautica
- the cabin lighting, which will include a 'simulated sky' ceiling effect produced by arrays of light-emitting diodes (LEDs) which can change in colour and brightness will be supplied by Diehl Luftfahrt Elektronik
- the passenger doors will be provided by the French company Latecoere
- the nacelles and thrust reverser will be provided by Goodrich
- the primary power distribution system, auxiliary power unit, environmental control system, primary and remote power distribution system and the electrical power generating and start system will be supplied by Hamilton Sundstrand of Windsor Locks Connecticut

Another recent example is the Siemens' share of a contract to supply 100 high-speed trains to China. They will supply a number of components such as various pieces of electrical equipment and the chassis. The Siemens work will be undertaken in Krefeld-Uerdingen, Germany, in Nuremberg, Germany, in Graz, Austria, and in Shanghai, Tianjin and Jinan, China.

There have been a number of studies of methods of bringing international considerations into engineering education, references [1] to [7] being a small sample of typical such studies. Unfortunately many of these existing studies limit themselves to considering only one possible approach. References [8] and [9] discuss various possible approaches.

When discussing the internationalization of engineering education programs other forms of internationalization are often implied. An example is the attempts that are being made to find internationally acceptable evaluation criteria for engineering programs that when implemented would ensure that an engineering graduate from one country would be accepted as having being educated to a standard that allows them to work anywhere in the world without having to take further professional examinations. Considerations such as these are not part of the present discussion.

IMPLICATIONS FOR ENGINEERING EDUCATION

In order to work effectively in an international environment the graduate engineer needs to be able work effectively and productively in international teams. The graduate engineer needs to appreciate and respect the fact that there are cultural differences between countries and that these differences need to be recognized and taken into account when developing and working in international teams. The graduate engineer needs to recognize that engineers in different countries may have somewhat different approaches to engineering and that they may have somewhat different engineering skills. In addition, the engineer must clearly recognize that having a different approach and somewhat different skills does not make these engineers from other countries inferior in any way and, depending upon the job being undertaken, they may in some areas provide an advantage. The engineer should also realize that when working in international teams communication problems can arise that are not connected with language problems but arise from different social behaviour. In working on international projects the engineer should also realize that differing societal needs and differing governmental regulations must be taken into account. It is also important for the engineer to realize that they may have to deal with societies in which the use of bribes and other forms of 'behind the scenes' payments are part of the conventional process of doing business. Dealing with such situations requires the application of high ethical standards but with an understanding of how such situations have arisen. These considerations indicate that some preparation for working in an international environment should be included in

engineering programs.

Engineering programs should, therefore, introduce students to the reasons why engineering projects, in so many cases, have become international and also introduce students to the need to be able to work effectively in international situations. Engineering programs should introduce students to the importance of being aware of societal differences that while very important are often very subtle, and should lead to awareness of the problems that may arise when working internationally.

INTRODUCING INTERNATIONAL CONSIDERATIONS INTO ENGINEERING PROGRAMS

There are a number of possible ways of introducing engineering students to the skills and personal outlooks required to work effectively and productively in foreign countries and with engineers and other professionals from other countries. Among these potential approaches are:

1. Have class discussions and student prepared brief reports on the reasons why engineering has become such an international activity.

2. Have students work in project teams that have members from institutions in other countries. While it is desirable for team members to meet in person, much can also be learned from having the team members communicate by e-mail.

3. Arrange to have students spend a period of study or work in a foreign country and arrange to have these students share their experiences with other students upon their return.

4. Have students undertake international development type projects. Projects that require that local societal needs be taken into account are particularly important.

5. Have engineers with experience working internationally address the students and discuss their experiences.

6. Have class discussions of the ethical and other problems that can arise when working internationally.

7. Introduce case studies of problems that have arisen in international engineering projects. Problems experienced by Airbus and Boeing in the development of their newer projects and of the legal problems experienced by a Canadian engineering consulting company in undertaking international projects are examples of the types of cases that can be considered. Case studies of this type can be introduced in a special course on working internationally and/or they can be introduced at appropriate points in standard engineering courses.

The introduction of a course that is concerned with the practice of engineering in an international environment and with the skills required to work effectively in such an environment into the curriculum is one approach to introducing the methods discussed above into an engineering program. This course could include topics such as international cultural differences and their influence on the success of international teams and international ventures. The course could involve a combination of project work, class discussions, case studies and talks by experienced engineers. However, the introduction of such a course should not exclude the discussion of aspects of the practice of engineering in an international environment in conventional courses in the program.

There are a number of potential ethical issues that can arise in the practice of engineering in

an international environment. Some of these have already been discussed but others do exist. For example, in times of economic downturn should every effort be made to maintain the operations in the home country if this is at the expense of the international operations that have been established to support the home operation? The ethical aspects of government regulations that favour home operations over international operations in these times can also be considered.

Whatever procedures are adopted to develop student awareness of the practice of engineering in an international environment, the end result should be graduate engineers who are comfortable when working in an international environment, who understand that there are societal and regulatory differences between countries that need to be accounted for in undertaking work of this type, and who are accepting of the fact that different groups may have different strengths and weaknesses.

INTERNATIONAL CONSIDERATIONS IN A CDIO PROGRAM

CDIO, with its international membership and commitment to the development of curricula that consider all aspects of engineering, would seem to be an ideal organization to develop sound methods for bringing international considerations into engineering curricula. Of course, as mentioned before, a number of universities have adopted various approaches to try to internationalize their programs and have achieved varying degrees of success. However, none of these universities has had the benefit of working within an international initiative of the CDIO type which has collaborators from so many different parts of the world

At present the CDIO Syllabus only clearly mentions international considerations in *3.2 COMMUNICATION IN FOREIGN LANGUAGES* and today, this does not by itself seem to be an adequate way of bringing international considerations into the curriculum. Instead it would appear that this area of the Syllabus needs to be updated. It is suggested therefore that CDIO should establish a group that would evaluate what has been done in the area of trying to bring international considerations into engineering curricula and have this group also gather the views of CDIO member institutions on how this should be done. Based on this, the group should produce a set of recommendations as to how best to bring international considerations into CDIO curricula. They should also recommend how the CDIO Syllabus should be modified to more completely reflect the need to bring these considerations into the curriculum.

CONCLUSIONS

With engineering activities being increasingly undertaken on an international stage it appears that it is important to provide exposure to this in engineering educational programs. Some possible methods of doing this have been discussed here. A brief discussion of the need for CDIO to take an active role in developing improved methodologies for bringing international considerations into engineering curricula has also been given.

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INTRODUCTORY COURSE OF ELECTRONIC CONTROL ENGINEERING WITH EXPERIMENTAL LEARNING

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ABSTRACT

In this report, the development of the introductory course of engineering for a first grade student of electronic control engineering department in Kumamoto National College of Technology is discussed. The objective of this course is a cultivation of creativity and the abilities of both cooperation and communication. In special, the development, practice and effect of “falling egg” program is described.

KEYWORDS

Experimental learning, introductory course, creativity development, competition

INTRODUCTION

In Japan, the higher educational organizations of Engineering consist of a university, a junior college, and a college of technology. While the former two types of organization accept a student who graduates a high school over the 18 years old to enter, a graduator of junior high school aged 15 years can enter the college of technology. So such younger students do not have enough basic knowledge for general educations, such as the mathematics, the physics and etc. Therefore, till the first term of third grade, students should learn such basic subjects selectively. As a result, the remaining two and half years, namely after the second term of third grade to the end of the 5th grade, are jam packed with the basic and applied engineering subjects and practices. However, the industrial circles of Japan evaluate the abilities of the graduators of colleges of technology as considerably high. The reasons of that are considered that the college of technology has both the small capacity and the well-furnished environments for experiments and practices [1].

On the other hand, there existed the problem on the learning along the courses during this short period that students can’t hold the enough understandings of the relations between the different subjects. As a faculty development activity, we have modified the basic subjects concerning to engineering for first and second grade students in 2003 [2]. The “Basics of Engineering” is a one of them for first grade student, which is an introductory course of engineering. While the about 160 students are divided by 4 classes without a relativity of their original department, the classes for the lecture and practices of Basics of Engineering are organized depending on their original department in order to press the students for recognition of the significance of the creativity, the ability of cooperation, and one of the communication based upon the each policy and the suitable method of the department. In

this report, the development of the lecture and practices of “Basics of Engineering” of Electronic Control Department are described.
Basics of Engineering is consists of the lectures of the techniques of drawing up of technical document, the introduction of manufacturing and an outline of electronic control system. To develop the creativity, this subject involves several practices such as the “falling egg”, “robot scavenger”, “Line tracer” and etc. The “falling egg” is a name of the experimental learning activity with making a shock-resistance tool for egg, made by using only one sheet of a thick paper (almost A2 size), so as to protect a egg from the shock caused by the fall from the 5th floor of the school building. It can regarded as one of the practice based on PBL method [3]. Students can recognize the significance of the invention for realization of own idea. The objective of the practice of “robot scavenger” is almost same as one of the “falling egg” but brought close to the electronic control system. Furthermore, in this course, the practice of line-trace robot controlled by simple logic circuit is also involved in order to introduce the concept of feedback control system.
Effectiveness of this course was evaluated through the questionnaire survey for student. Then, we consider that such course is much effective for development the first step of engineer’s attitude.

INTRODUCTORY COURSE OF “BASIC ENGIEERING”

Basics of Engineering is consists of the lectures of the techniques of drawing up of technical document, the introduction of manufacturing and an outline of electronic control system. To develop the creativity, this subject involves several practices such as the “falling egg”, “robot scavenger”, “Line tracer” and etc. The syllabus of this course is shown in Table 1. The “falling egg” is a name of the practice to make a shock-resistance tool for egg, made by using only one sheet of a thick paper (almost B3 size), so as to protect a egg from the shock caused by the fall from the 5th floor of the school building. Students can recognize the significance of the invention for realization of own idea. The objective of the practice of “robot scavenger” is almost same as one of the “falling egg” but brought close to the electronic control system.
Furthermore, in this course, the practice of line-trace robot controlled by simple logic circuit is also involved in order to introduce the concept of feedback control system.

Lectures

Lectures use the 40 % of the total hours for this course. First, we explain about the outlines and the relationships between the each subject, and the summary of control system using some examples such as the robot, the elevator, the air conditioner and etc. In special, the difference between the feedback control and sequential control and the relationships between mechanical engineering, electronics, computer engineering are considered as the important points to teach. These contents need 6 hours including a guidance of this course.

Next, we lecture how to make the technical reports. Namely, it involves a structure of the technical documents, a usage of the technical terms and phrases, a description of references, and etc Drawing is significantly lectured. The drawing method of solid body, namely a projection, is lectured in detail for 10 hours including the practices. Achievement is evaluated by examination and its results normally become 75% in average.
In advance of electronic circuit work, the basic theory and techniques of a soldering. And the introduction of logic circuit is lectured before making the simple line-tracer. These lectures require 2 hours for each.

Experimental Study

The “falling egg” is a one of the practice to develop the creativity. Students try to make a shock-resistance tool for egg, made by using only one sheet of a thick paper (almost A2 size),

Table 1
Syllabus of “Basics of Engineering”

Name of Subject	Code	Name of Lecturer	Code	Class	Term	Credit	Type
Basics of Engineering	L111	Hirofumi Ohtsuka Kosei Nojiri	C02 C15	C1	Whole year	2	Compulsory
Text	Printed original synopsis						
Study aid book	“handy book of mechatronics”, Hirofumi Miura, OHM-sya						
Abstract	In this course, students can understand the outline of control system, the basics of the drawing techniques for making a technical report, and the significance of the creativity required for engineer, and etc. In the practice of “Training for creativity”, students will try to solve the simple craft problem with many solutions under the several limitations. And, through the “Line tracer”, students can learn about the significances of both the hardware and the software.						
Objective	Students can 1. Understand the basic structure of control systems and explain it. 2. Make the technical report with the figure based on drawing techniques and the simple electric circuit. 3. Learn an enterprising spirit for solving a problem under some limitations.						

Contents	Hour	Objective of achievement	Evaluation
Guidance	2		Based on the result of the examination, the report, and the work of manufacturing.
Basics of Control System	6	Understanding of the construction of control system and the roles and relationships of its components.	
Basics of Drawing	10	Getting an ability of drawing. (Understanding the projection methods.)	
How to make a technical report	6	Getting an ability of Making the technical report of simple manufacturing problem, using the figures.	Based on the result of the examination, the report, and the work of manufacturing.
Training for creativity 1	10	Getting an enterprising spirit for solving a problem under some limitations through the simple paper craft practice.	
Training for creativity 2	14	Getting an enterprising spirit for solving a problem under some limitations through the practice of simple robot.	Based on the result of the examination, the report, and the work of manufacturing.
Line Trace robot	14	Through the making of Line Trace robot, understanding the outline of the feedback control system and the significance of the collaboration between the hardware and the software to the successfully works.	

Total evaluation	Evaluated from the results of the examinations (50%), the report evaluation (40%), and the work of the manufacturing (10%).
Course Style	Lecture : 40 %, Experimental Practice : 50 %, others : 10 %

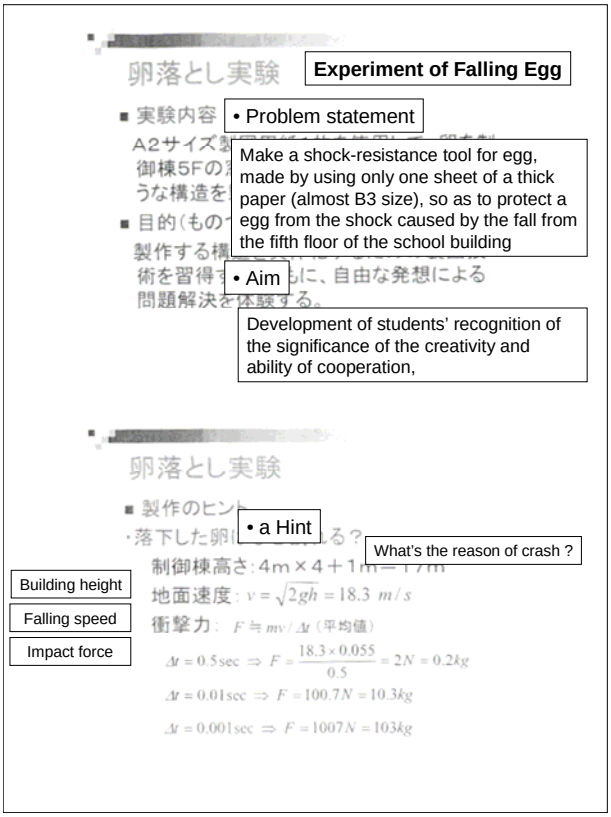

Figure 3. Instruction document

Figure 1. Work example for "falling egg"

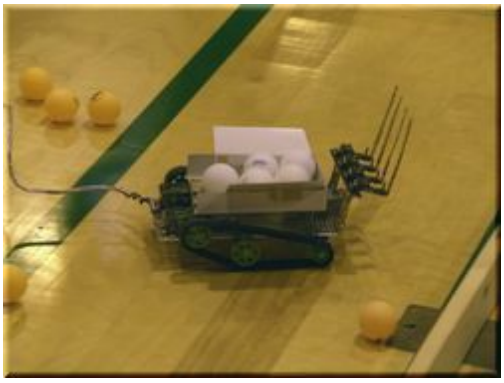

Figure 2 Work example of "robot scavenger"

so as to protect a egg from the shock caused by the fall from the fifth floor of the school building (see figure .1). Details will be described in the next section.
The other practice aiming at the development of creativity is the "robot scavenger"(see figure 3). We have also obtained the effective educational result.
The practice of a simple "line-tracer" using a gate circuit is located as the final practice of this course. From the result of questionnaire for fifth grade student, we have confirmed that this practice is very helpful for student to understand the relationship between the subjects and its contents and improve their motivation.

EXPERIMENTAL STUDY "FALLING EGG"

As Mentioned above section, "Falling Egg" is a title of "Training for creativity 1" shown in the table 1. Its objective of achievement is settled that students get an enterprising spirit for solving a problem under some limitations through the simple paper craft practice. Similar efforts have been done as shown in reference [4]. But the program was finished in a lecture for only 150 min and the problem setting was not so impressive. This program requires 10 hours involving the experiment.

Guidance

At first, we distribute the simple document in which the problem statement and a few hints were given as shown in Figure 3, and white A4 paper in order to make notes of original ideas. And we give the following significant advice in advance:
(1) Never make an imitation.
(2) Never be bound by preconceptions.
(3) Failure is a stepping-stone to success.

Figure 4. Now thinking

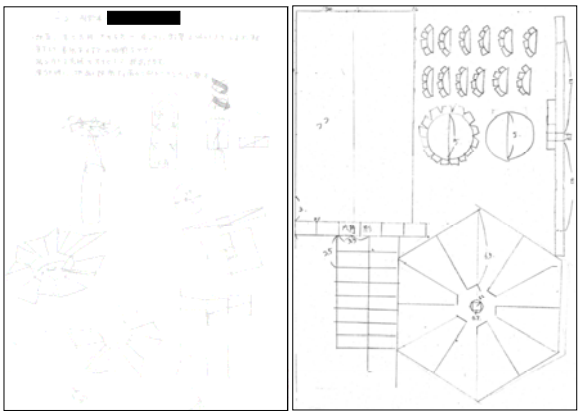

Figure 5. Conceptive illustrations

Figure 6. Making a paper craft

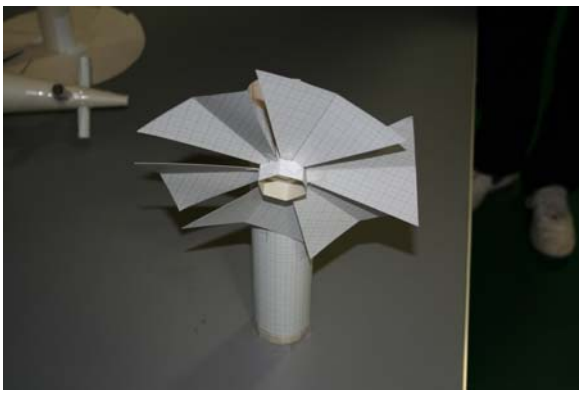

Figure 7 Finished good

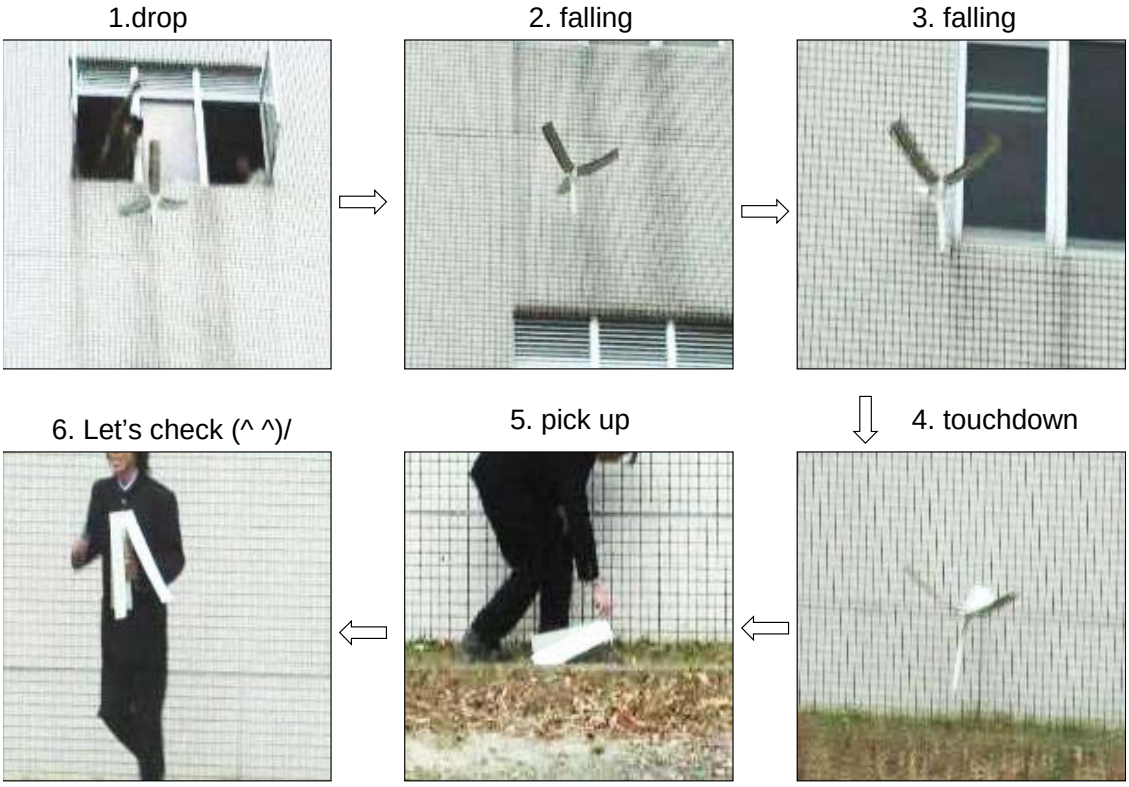

Figure 8 A Sample View of Experiment

Activities

Students make a shock-resistance tool for egg individually. They start activity by prediction of the shock force caused by the collision to the ground, and try to enumerate several concepts. So, in the initial hour, they devoted themselves solely to thinking on a solution to the problem. Then, they gradually start an argument about candidates for solution (See Figure 4), We do not disturb rather than encourage them to discuss about each other's ideas, because they can smoothly find a weak point of own idea and sort a better/best idea from several candidates. Figure 5 shows an example of conceptive illustrations and its cutting plan.
After the lecture's check about the cutting plan, they can start making a paper craft (See Figure 6). There exists some restriction for production, such that student never uses a spare paper, and never use anything else of the specified materials: string (1m), glue, and adhesive tape. Furthermore, usage of the glue and adhesive tape must be accord with original aim. And, student must take into account the way of loading the tool with egg at the final stage of production. It was required about 3 hours for production on the average. Figure 7 shows an example of finished good.

Experiment

Experiment has been executed on January 9th in 2009. Weather condition was almost fine and there was almost gentle north wind but sometimes changed. Figure 8 is a sample view of experiment. Lecturer drops the shock resistant tools from the fifth floor of school building (height is almost 17m). Student must fix his eyes on falling tool (in order to give consideration to a result in later). The experimental results are shown in Table 2.

Table 2
Experimental Results

Success	Cracked	Broken	Total
22	2	20	44
50%	5%	45%	

Making a Report

Lecturer asked each student to submit a report of the "Falling Egg" till 2 week after the experiment. As shown in Table 1, the report evaluation point was accounted for 40% of the total evaluation point. The instruction for making a report is given as follows:

(1) Report must be composed of the following items: Problem Statement, Concept, Structure of the tool, Experiment (method and result), Considerations, Impression
(2) Use Table and Figure adaptively to make the description easy to understand. Figures should be drawn based on the projection methods.
(3) Considerations about experimental results have to include not only own result but also colleagues' results. It is necessary required that reasons of such results are considered.
(4) Report should be more than 5 pages.

Figure 9 shows an example of student's report. Reports were evaluated based on the grading method according to five ranks by two lecturers. Average evaluation points resulted in 4.18 and 4.14, respectively.
According to the part of "impression" in the student's report and the direct hearing, we can see that experimental study program "Falling Egg" was supported by an overwhelming majority. Some typical comments are the follows.

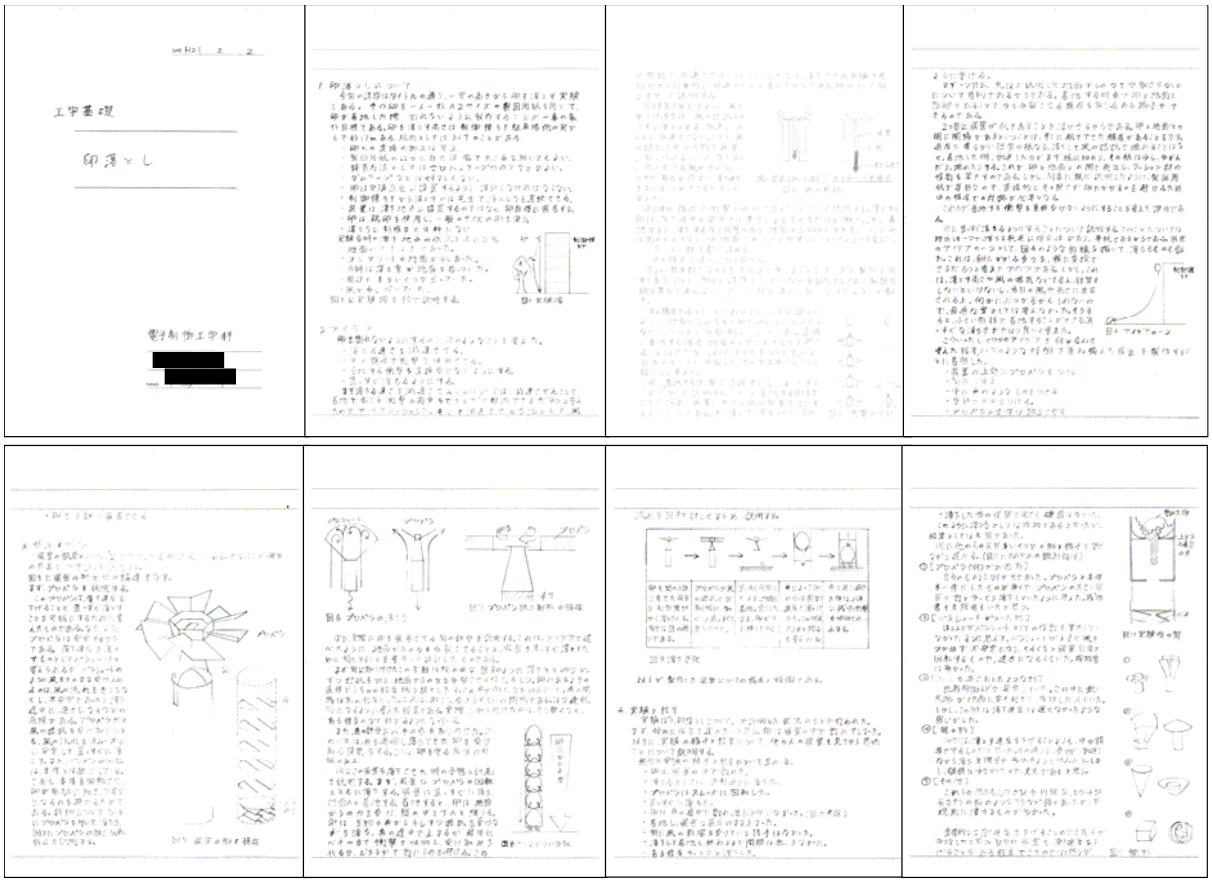

Figure 9 Example of Student's Report (an extract)

- "My tool failed to protect. The experimental result was different from my prediction. But, I have a sense of fulfilment because I really felt and studied the significance of analysis of the cause and effect through this project."
- "However I got unexpected results, I have recognized that repetition of Trial and Error is very important."
- "As the production of tool progressed, I came to enjoy this project."
- "I was very surprised at the unexpected experimental result. I recognized that a production is very difficult under such a hard situation to estimate. But, in such difficulty, there exists a pleasure. I didn't feel a pain. I thought an enjoyment of difficulty is required to get a success."
- "I was very enjoyed because there are several types of tools and there exists different form tools even if their ideas are essentially same.
- " I want to try again with another idea."
- " I tackled such a unique project with fun."

CONCLUSIONS

In this report, the development and the practices of "Basics of Engineering" of Electronic Control Department are introduced. This course involves many practices aiming at the development of student's creativity and the lectures of the basics of control system and of the drawing and writing techniques for technical document. Its evaluation has been done based on the activity and the report describing the own idea and developed tool (with figures), analysis of the experimental result and consideration (finding the point to be improved).
Students have eagerly tackled this difficult problem and over the 90 % of them have evaluated every year that it can successfully develop their motivations and assist to

understand the aim of this subject. In special, the features of the program “Falling Egg” are considered as follows. The problem setting gives impact for students such that it is an impossible problem because of many restrictions. But it gives an impulse for student to challenge. Finally, students become to recognize “That is only a surface impression”. As shown in Table 2, namely almost 50% success rate, we can note that its difficulty is attractively adjusted as exquisite level. Furthermore, because there exists many solution candidates and students are allowed plenty of scope for their imagination, they can examine many solution candidates through other students’ experimental results. Students’ impressions prove that both the success and the fail motivate them to study engineering. At the end of this program, students can share the recognition about an important responsibility of engineers by imaging the egg as human. We consider that this course is a effective for development the first step of engineer’s attitude.

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LEARNING THROUGH OVERSEAS INDUSTRIAL TRAINING PROGRAMME CUM COMMUNITY SERVICE PROJECT

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ABSTRACT

This paper describes the experiences of learning through an overseas community service project carried out, over 18 days, in February/March 2008, in Makassar, Indonesia. As part of their second year curriculum, Singapore Polytechnic (SP) students are required to attend an industrial training programme (ITP) of seven weeks duration at the end of the year. Those who opt for ITP overseas do a shorter stint to reduce cost. In the School of Architecture & the Built Environment (ABE), every year, about 30 – 35 % of the cohort go overseas for 3 – 4 week stint on an overseas ITP and/or community service project. In the paper we discuss how students and staff from ABE collaborated with the Department of Civil Engineering, State Polytechnic of Ujung Pandang, Makassar, on the construction of a pedestrian cum light vehicular bridge at a fishing village in Nelayan Untia, Makassar. Feedback from students, during and after the trip, showed that they benefitted greatly from this unique from of out-of-classroom learning. They developed a global perspective by recognizing the similarities and differences in the social, cultural, economic, environmental and technical conditions of the two countries.

KEYWORDS: Community service, Global perspective, economic, environmental, social.

INTRODUCTION

The purpose of the overseas industrial training programme (OITP) in Makassar is to expose Singapore Polytechnic (SP) students from the School of Architecture & the Built Environment (ABE) to the economic conditions of the less well-known but important island of Sulawesi in neighbouring Indonesia with a population exceeding 230 million. Makassar is the capital city of South Sulawesi. Collaboration with the State Polytechnic of Ujung Pandang (SPUP) on OITP started following the signing of a Memorandum of Cooperation between SP and SPUP on 1 July 2006.

The first community service project from 26 February – 16 March 2007, involved the renovation of the Central Library at SPUP. The second community service project from 18 February – 7

March 2008, consisted of the construction of a reinforced concrete bridge to replace an old dilapidated wooden bridge at Nelayan Village. The community service projects are conceived with the active participation of the staff of the Department of Civil Engineering at SPUP. The rapport and network established between SP and SPUP students will give SP students first hand knowledge of working with international students of another culture.

As many infrastructure works by Singapore companies are carried out in ASEAN, China, India and the Middle East, the overseas ITP and community service project experience acquired by the students will enrich them with a broader mindset and the ability to venture outside Singapore soil when needed.

COMMUNITY SERVICE PROJECT

In February 2008, 18 second year students accompanied by 2 academic staff from ABE, left for Makassar, Indonesia for their overseas ITP. The ITP is compulsory for all SP students and a pass grade is required before the award of a diploma. The majority of the students do their ITP through attachment to local companies. However, increasingly more and more students are encouraged to go for overseas industrial attachment and carry out community service projects. The aims are to train students in acquiring a global perspective, learn habits such as resourcefulness, compassion, graciousness and develop skills such as teamwork and communication. The community service project that was proposed was the construction of a concrete bridge to replace an old timber bridge at a fishing village. Its implementation followed the key steps: Conceive – Design – Implement – Operate.

Conceive

The fishing village of Nelayan is located on the eastern side of Makassar, the capital of South Sulawesi (Figure 1). It is about 16 km from the city with the main livelihood of the villages being fishing. The village is surrounded by small canals which provide easy access to the sea. Timber bridges were constructed across these canals to provide access for humans and light vehicular traffic. However, in the long-term, timber bridges are not considered feasible what with the more frequent use and heavier vehicle loads in the future. Thus a community service project was conceived to replace the main access timber bridge (Figure 2) with a concrete bridge.

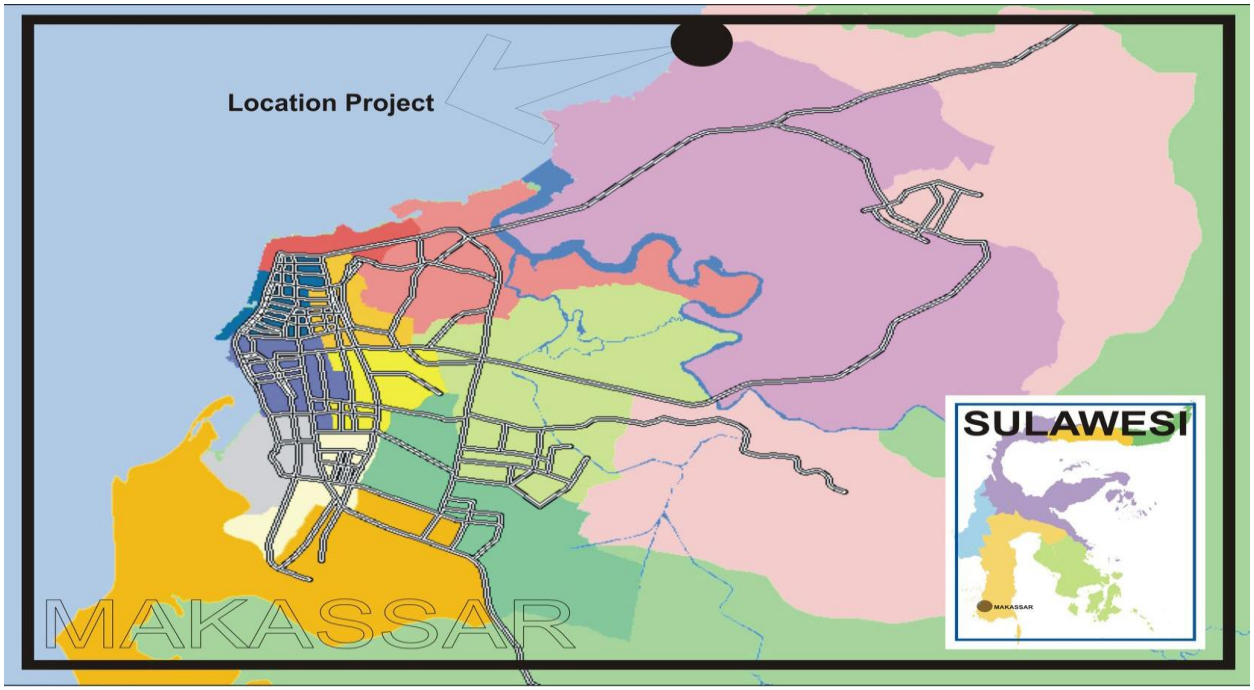

Figure 1: Location of Nelayan Village in Makassar

Figure 2: View of Existing Timber Bridge in Nelayan Village

Design

The type of bridge design was decided through discussions between SP's OITP team and SPUP when they visited the fishing village during the first OITP in February/March 2007. Main factors that were considered in arriving at the design were its function, structural strength, ease of construction and cost. Eventually the final design consisted of a reinforced concrete bridge, 8 m long and 1.8 m wide, standing 2 m above the high tide level.(Figure 3)

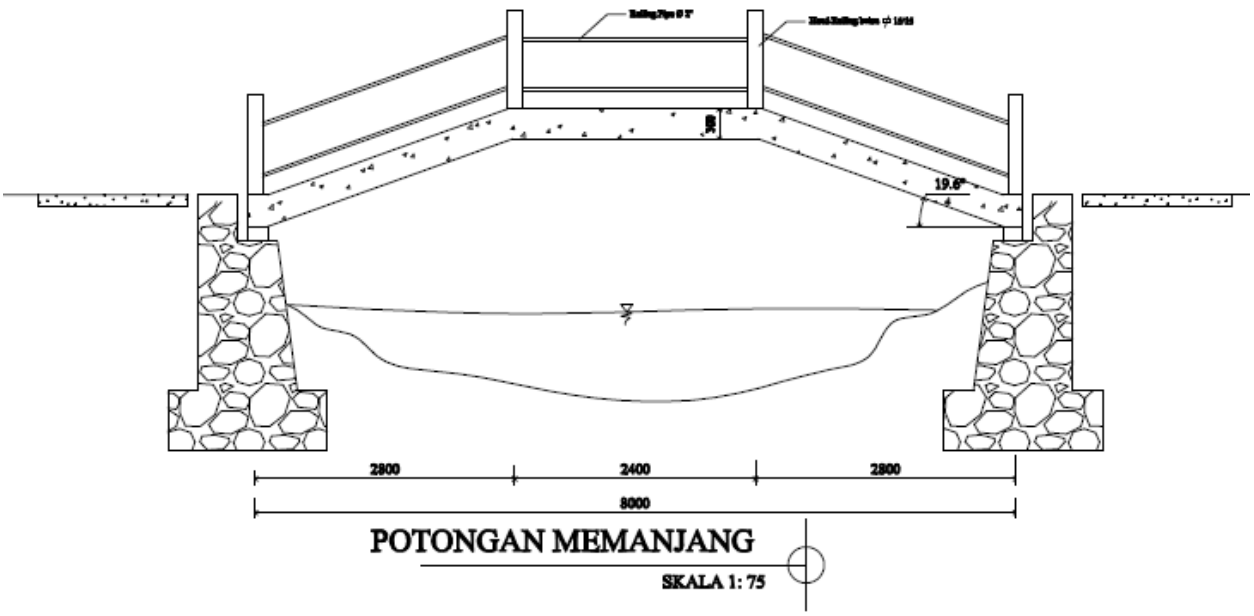

Figure 3: Proposed Design of Bridge

Implement

Construction of the bridge started on 19 February 2008 with a grand project launching ceremony graced by the Mayor of Makassar, Mr Ilham Arief Sirajuddin. The sponsors of the project were Singapore Polytechnic, State Polytechnic of Ujung Pandang and a major local contractor, Bosowa Corporation. The new concrete bridge was constructed next to the existing timber bridge which served to transport building materials during the construction phase as well as served to facilitate movement of the villagers. Work on the bridge was divided into two main parts:

- Substructure consisting of wing walls and abutment constructed using stone masonry
- Bridge deck consisting of beams, slab and handrailings

Construction materials were sourced locally from Makassar. Staff from SPUP served as the project management team. SP and SPUP students worked intermittently alongside the contractor during the construction stage. SP students assisted with tasks such as cutting and bending of steel bars, sawing and nailing of timber for formwork (Figure 4), wheel barrowing sand and aggregates for mixing of concrete and lifting of logs to support the bridge deck (Figure 5). The construction schedule is shown in Table 1.

Table 1: Bridge Construction Schedule

No	Work Item	Duration (week)		
1	Wing Walls & Abutments			
2	Girder Beams			
3	Slab			
4	Handrailing			
Overall Construction Work		**3 weeks**		

The cost of construction was around Rp 83,000,000 (S$12,969). Singapore Polytechnic contributed S$5000 to fund the project.

Figure 4: Nailing of formwork

Figure 5: Lifting of logs for propping of bridge deck

The students found this stage to be exciting as it gave them the opportunity to put into practice some of the civil & structural engineering knowledge that they had learned over two years in the Diploma in Civil & Structural Engineering course. Especially relevant were construction technology and reinforced concrete design. The students were also able to differentiate between the method of construction adopted on this project, in a rural setting, versus similar projects in Singapore especially in areas such as the use of machinery, manpower and safety. As the students were working alongside the contractor's workers and other SPUP students, there were also occasional frustrating moments due to the language barrier although this did not pose much of a problem as they were, by then, sensitized to their working environment. Further the close guidance and encouragement from the staff served to motivate the students.

Operate

This was the most rewarding part of the project marking the successful completion of the construction work. The handover ceremony of the completed bridge (Figure 6) was again officiated by the Mayor of Makassar and carried out on 7 March 2008 – that same afternoon the SP students and staff left for Singapore.

Figure 6: Completed reinforced concrete bridge

Students' Reflection on the OITP cum Community Service Project

All student participants were asked to reflect on their trip to South Sulawesi so as to gauge whether they found it to be interesting and meaningful. Sample students' reflections, edited for grammar, are shown below each learning behaviour:

Flexibility in Thinking

The project offered students with many opportunities for creative thinking during the implementation stage. They had to adapt to the environment and accommodate each others views.

As one student noted: "Upon reflecting on this wonderful trip, I have learnt that it is very important to adapt and accommodate in order to enjoy the stay in any foreign countries or even in Singapore. There is a saying that a person should change to suit his surrounding and not expect his surrounding to change to suit him. In short, it was a wonderful and enriching stay in Makassar and I have really enjoyed myself. It was an experience like nothing else on earth."

Teamwork

In order to successfully complete the project over a short duration, teamwork across cross-cultural lines was paramount. As a student opined:

"This trip has provided me a great opportunity to get along with other polymates and bond with them. I am also happy and like to show my appreciations to the local helpers who assisted and the guided us throughout the whole trip. Their sincerity and commitment really warmed my heart."

Appreciation of different social and economic conditions

Living and participating in various activities in South Sulawesi also allowed students to think positively about their fortunate lot in Singapore. As a student reminisced:

"After staying for three weeks in Indonesia, I have come to realized that I was born with an advantaged background. I have much more than other people in Indonesia on comparison, the things I do day-to-day are so different from them. I bury myself with studies and computer games, while failing to appreciate the simple walks of life the Indonesian spent their day with. I have actually become more understanding about the surroundings and I am more appreciative towards the things I have, hence not to take things for granted. Time to me, is more precious than ever before."

Discipline & Time Management

Students appreciated the value of discipline and time management to make a success of the trip.

According to one participant: "Certainly, I have no regrets about choosing this Makassar trip for my ITP. We really put our hearts and minds together to make sure it was a successful one. This ITP also made me realize the importance of discipline by becoming more responsible and dedicated to the duty that was given to us. When there are any problems between our team mates, we try to sort things out by having calm talks and give each other encouragement. Time management is another important lesson that I've learnt in this ITP. It's been a good and fun experience for me because I've learnt lots of things during this period and I hope I can have the honor to take part again in the future."

Communication

Students saw the value and benefit of mixing and working with total strangers. Appreciating the importance of as such a life skill for their future, a student commented:

" I believe that it is more important to learn about different country's culture and learn about how to communicate well among people. Before this trip, I was actually a complete stranger to the other 17 students who we traveled together and also strangers to the students of SPUP. However, during the 18 days, we got to communicate and learn about how to care for each other. Though we had some communication problems with the students of SPUP, however we tried our best to converse with them. The students of SPUP learnt some English we also learnt as much Indonesian language so to minimize the language barriers between us. Thus, I suppose that if I do not know how to communicate well among people, I will sure suffer in a working world."

Besides the above reflections, a survey of the participants confirmed that this mode of learning was found to be refreshing, fun and enriching. They rated it at 4.3 out of 5 points.

CONCLUSION

In the implementation of the Community Service Project in Makassar, CDIO concepts were adopted. The approach was found to be very effective in encouraging students to acquire domain knowledge, problem solving skills, teamwork and communication, compassion, graciousness and a global perspective.

Feedback from participants has shown that they find the annual OITP cum Community Service Project a meaningful and enriching learning approach and would like to see it expanded to other countries. In fact another group of 19 students and 2 staff were in Makassar in March 2009 to work on a Footpath Construction Project which would benefit around 400 village folks.

Both SP and SPUP are already in discussion to identify the next Community Service Project for 2010.

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LESSONS LEARNED FROM DEVELOPING AND OPERATING A LARGE-SCALE PROJECT COURSE

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ABSTRACT

In 2004, Chalmers University of Technology in Göteborg, Sweden, decided to develop a project-based course for third-year students enrolled in its five-year engineering programmes. The motives were (a) that many of these programmes lacked a project course aimed at developing skills in project planning, teamwork and communication prior to the fifth-year master thesis project, and (b) that the introduction of a Bologna framework-style 3+2 education required the introduction of a bachelor thesis project. The project course was offered for the first time in spring 2007.

The aims of the Chalmers project course are that the students should integrate, deepen and develop knowledge and competency acquired during the first three study years. The course also aims to give the students good competencies to participate in project teams, using a critical and reflecting way of addressing and solving the project task. The project course is a large-scale endeavour: The course is compulsory for the students of fourteen “Civilingenjör” (MSc in Engineering) programmes and the Architecture programme. Each year, around 900 students are enrolled, working on 200 projects in many different areas, ranging from fundamental physics to architecture. The course size is 15 ECTS credits. A large number of faculty and staff are involved – teachers, administrative staff, librarians, linguistic staff etc. The course is very complex with all its different course elements that need to be coordinated.

The aim of the paper is to describe the development process of the project course, account for the course design, including the intended learning outcomes, the teaching approach and the assessment schema and to evaluate the experience from running the courses focusing on challenges deriving from the scale of the course, and from assessment of team-based project courses.

The project course has been carefully evaluated during its first two years. The evaluation results show that there have been problems with to provide clear and consistent information to students and staff and to clarify roles and responsibilities. Despite these information issues the students have a highly positive attitude towards the project course. Also the teachers are very satisfied with the quality and conduct of the students project work.

KEYWORDS

Project course, large-scale, generic competencies, assessment, engineering education

INTRODUCTION

Chalmers University of Technology has started a project course for all third year engineering students. The motives for starting the course were that many of Chalmers engineering programmes lacked a project course aiming at develop skills in project planning, teamwork and communication prior to the master thesis project, and that the introduction of a Bologna framework-style 3+2 year education required the introduction of a bachelor thesis project.

The aims of the Chalmers project course are that the students should integrate, deepen and develop knowledge and skills within some part of the field of study. The course further aims to develop the students' abilities to work using a critical and reflecting way of addressing and solving the project task, and to give the students the competencies to work as engineers in a scientific way of working and finding solutions. The project course is also used to support the development of the students' "generic competencies", such as the abilities to communicate and to work in teams are trained. A certain project of their own choice is the main vehicle for developing these knowledge and skills.

This Chalmers project course was offered for the first time in spring 2007. Fifteen education programmes at Chalmers are involved in the project course and about 900 students enrolled in the course last spring (2008). The students could choose among more than 200 projects in many different areas. There is also a lot of staff involved in this very large course – programme chairs, teachers (supervisors and examiners), administrative staff, librarians, linguistic staff, etc. The course is complex with all its different moments that need to be coordinated

The aim of this paper is to explore the challenges involved with starting and executing a large-scale project course. More specifically, we aim to

- Describe the development process of the project course.
- Account for the course design, including intended learning outcomes, teaching approach and assessment. In particular the way in which learning of generic competencies is integrated is discussed.
- Evaluate the experience from running the courses focusing on challenges deriving from the scale of the course, and on assessment of team-based project courses.

The remainder of the paper is structured as follows: We start by accounting for some related work in order to position the current paper. This is followed by a brief account for the course development process and the major design issues involved. We then describe the course including aspects such as intended learning outcomes, the teaching approach and the assessment. This is followed by a discussion of the evaluations that have been conducted, including teacher, student and administrator perspectives. Finally, conclusions are listed.

RELATED WORK

Project-based courses have become increasingly popular in engineering education during the last decades. A well-known example is Stanford's ME210: Mechatronic System Design project course [1]. At some universities, such as Aalborg University in Denmark, project work accounts for as much as 50% of the study time [2]. For a CDIO-based programme, CDIO Standard Five suggests that an engineering curriculum should include at least two design-implement experiences [3].

Underlying this trend is the growing insight that projects are essential for students to develop the key engineering competences of developing, implementing and operating product, processes, and systems. In addition, team-based project-based courses provide a natural

setting in which to teach generic competencies, such as teamwork and communication skills. From the perspective of fundamentals, realistic projects strengthen the foundation upon which deeper conceptual understanding of disciplinary and multidisciplinary knowledge can be built [3].

There exists a multitude of publications describing single project-based courses, highlighting some innovative aspect, such as the use of an industry-style project control model [4], a virtual collaboration environment that supports multinational student teams [5], or peer-based assessment [6].

However, surveys of project courses [7, 8] point out some recurring challenges involved with organizing project-based education, including assessment schemes that consider the multitude of learning outcomes that often characterize project courses, design of projects, the need for different teaching practices and competence, cost-effectiveness and scalability for large student groups. The course described in the paper posed particular challenges with respect to assessment and scalability.

DEVELOPMENT PROCESS AND DESIGN ISSUES

In this section, we discuss the development process of the course and some of the design issues that were particularly challenging to resolve. As stated above, the project course was given for the first time in spring 2007. The motives for starting the course were that many of Chalmers' engineering programmes lacked a project course aiming at develop skills in project planning, teamwork and communication prior to the fifth-year master thesis project, and that the introduction of a Bologna framework-style 3+2 education required the introduction of a bachelor thesis project.

These new needs motivated a common approach, despite the fact that Chalmers programmes have varying goals and pre-knowledge in project work and generic competencies. Thus, the development team was mainly composed by the programme chairs for Chalmers "Civilingenjör" and Architecture programmes, at times complemented by staff from the Centre for Language and Communication. The project leader was the dean of education for the "Civilingenjör" programmes. The development team met bi-weekly during the Fall of 2006.

The development considered in a fundamental way many aspects of a project course, including aims, intended learning outcomes, teaching and learning experiences, assessment, administrative procedures etc. This said, the development was not done entirely from scratch; it was possible to re-use certain elements from programmes that had recently introduced new project courses. Such elements included the notion of a "contract" between the students in a project group, regulating their aims, roles and responsibilities, the requirement for a relatively extensive planning report and parts of the assessment approach.

Let us now consider a few of the design issues that led to most discussion:

Common set of learning outcomes. As indicated above, a project-based course typically aims to develop disciplinary knowledge as well as generic competencies. Some project courses have very extensive sets of learning outcomes. Kovacevic [9] reports on a project course with ca 15 defined learning outcomes including "classic" generic competencies such as written and oral communication and teamwork skills but also creativity, business knowledge awareness, intellectual property rights, use of communication technology, decision-making etc. Some teachers may still feel that they need to address even more issues; the role of technology in society, entrepreneurship, a tendency which is strengthened if there is only one team-based project course in the curriculum. However, it became clear that in the present context - the large number and differing profile of programmes - a few

select generic competencies should be focused. They were chosen to be problem formulation, information search, planning, teamwork, and written and oral communication. The selection reflected both the basic requirements on Bachelor of Science/Engineering degrees in the Swedish Higher Education Ordinance [10] and the common denominator amongst the programmes. Some programmes have included a few additional learning outcomes in the project course, as discussed below. However, Chalmers programmes with higher ambitions with respect to generic competencies generally need to adapt a programme-level perspective, allocating generic competencies that are not addressed in the current course to other courses.

Assessment. The intended learning outcomes thus could start from a platform provided by the Swedish Higher Education Ordinance [10]. However, the Ordinance does not state how to teach or assess a particular learning outcome. It proved very challenging to identify the connection between the learning outcomes and various components of the assessment. The discussion was conducted on multiple levels: Should there be "graded" grades of or only pass/fail? What assessment methods were relevant for each learning outcome and how should they be weighted? How should the individual contributions be assessed and weighted? Resolving these issues and developing the assessment scheme was a major part of the course development.

Dual goals: Team-based project work and independent work. The course further had to meet two goals: The course was not only going to be a team-based project as part of a five-year engineering degree programme. It was also going to serve as the 15 ECTS credits independent work that demonstrates that the student has the skills required to work independently in the field, which is part of the requirements for a Bachelor of Science degree according to the Swedish Higher Education Ordinance [10]. Thus, the project and its documentation had to be designed in such a way that the individual's contribution to the project result could be identified. The project group size was discussed: what is the minimal group size for training teamwork, what is the maximum group size if individual contributions are to be distinguishable? The assessment scheme was designed to enable this distinction. In the end, groups with 3-6 students were permitted.

Project selection and team composition. It was debated whether to let students form teams themselves which would then select a project, or if students should individually choose a project, and then the team be composed by a teacher (the course administrator). The latter approach was chosen in order to force students to work in project groups with students that they had not worked with before, potentially from another programme. The aim was to strengthen the multidisciplinary collaboration dimension of the project course.

The nature and extent of generic competencies training. The issue was here the programme's differing starting points. Some of Chalmers' programmes have ambitious approaches for integrating training of generic competencies in several courses during the first three years, whereas other programmes have very few such elements. The resolution was the agreement on a common set of generic competencies that are trained in the project course, including problem formulation, planning, teamwork and oral and written communication. The circumstance that students from some programmes have a stronger background in generic competencies was addressed by making some generic competency learning experiences voluntary, and by enabling programmes to define additional generic competency learning that build on the common set. Examples include scientific methodology and group dynamics.

Language. It was discussed whether it should be compulsory to write the project report in Swedish or if also English would be permitted, reflecting that many of Chalmers faculty are international, and that a bachelor thesis written in English might be used as a merit when applying for graduate education abroad. However, it was decided to stick strictly to Swedish, partly to ensure that each student writes at least one long report in Swedish during his/her

education (of which the last two years are taught entirely in English), partly due to the resources needed to provide linguistic consultation in English for such a large student group.

COURSE DESIGN

Introduction

The project course is a large-scale endeavour: Fourteen "Civilingenjör" (MSc in Engineering) programmes and the Architecture programme at Chalmers offer the project course. The programmes are Architecture, Architecture and Engineering, Automation and Mechatronics Engineering, Bioengineering, Chemical Engineering, Chemical Engineering with Engineering Physics, Civil Engineering, Computer Science and Engineering, Electrical Engineering, Engineering Mathematics, Engineering Physics, Industrial Design Engineering, Industrial Engineering and Management, Mechanical Engineering, and Software Engineering.

The projects are proposed by all of Chalmers 16 departments. The number of students is approximately 900, working on 200 projects in many different areas. The course size is 15 ECTS credits.

A large number of faculty and staff are involved – teachers, administrative staff, librarians, linguistic staff etc. The roles and responsibilities include:

- The persons responsible for Chalmers education programmes (the programme chairs) are responsible for the intended learning outcomes and contents, for coordination, and for selection of projects for the individual programme. In some programmes, a dedicated person coordinates the programme's projects.
- The supervisors give instructions to and guide the project groups and judge the quality of the projects. The supervisors have a very central role during the whole project course.
- The examiners and the supervisors are in cooperation responsible for the course assessment.
- The teachers, supervisors and librarians from Chalmers library and Centre for Language and Communication are responsible for the generic competencies course elements. The language department also offers new supervisors at Chalmers to join a supervision course as a help to guide the students in the project work.
- The educational administrators at each programme act as examiners of the generic competency learning experiences. They also initiate and collect the course evaluations at the various programmes.
- Administrative staff at Chalmers' student centres are involved during the whole project course concerning admission, information, selection of projects, allocation of projects, documentation of compulsory course elements in the course.

More information about the course (in Swedish) can be found at [11].

Course aim and intended learning outcomes

As stated above, the aims of the Chalmers project course are that the students should integrate, deepen and develop knowledge and skills within some part of the field of study. The course further aims to develop the student's abilities to work using a critical and reflecting way of formulating, creating, evaluating, documenting, presenting and defending the solution to the project task. A certain project of their own choice is the main vehicle for developing these knowledge and skills.

More specifically, the intended learning outcomes for the course suggests that when a student has passed the Chalmers project course she/he should be able to:

- Identify, formulate and delimit a problem or task statement within the field of study.
- Plan the work to solve and report on the problem/task within a given time frame.
- Seek for, gather and critically interpret relevant literature and background information that is relevant to a problem-
- Integrate and develop knowledge relevant to solve the problem, and use that knowledge to solve the problem.
- Contribute to a project team that solves a complex problem.
- Engage in teamwork and cooperation in a project group.
- Use a diary to document the whole project process.
- Orally present and defend the problem solution.
- Document the result in a written report of good scientific quality.
- Evaluate the project outcomes with respect to the project's goals.
- Critically read and evaluate another project work with respect to problem formulation, project execution and results.

Course timeline

The work with the course starts in October, when the departments are invited to submit project proposals. Confer the course timeline (figure 1). The programme chairs then review the proposals in order to ensure their quality and relevance for their particular programme. The programme chair then decides which of the proposals that are eligible for selection by the programme students. The proposals are then posted on the course website. Students select and prioritize projects. They are then assigned to a particular project and project group. The outcome of the project selection phase is announced in early December.

The project work starts in the middle of January. A major first milestone is the planning report, as discussed below. At half time in the project course, in the beginning of April, the supervisor arranges a meeting together with the project group. At this meeting the students should give a status report and the supervisor will give feedback to the students concerning if the project meets the requirements for passing the course. The final presentation takes place in early June.

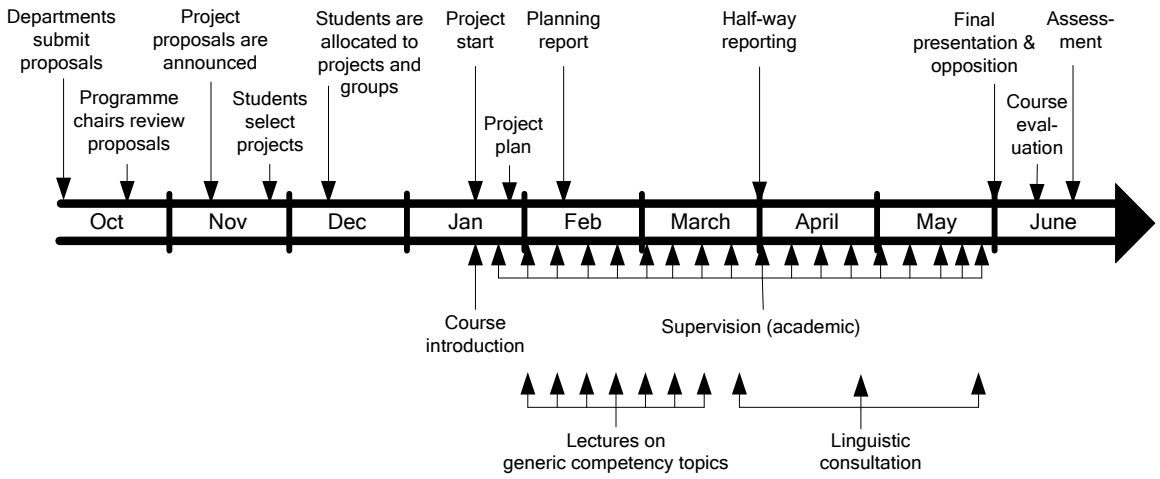

Figure 1: Course timeline.

Project examples

Examples of projects and their proposing departments include:

- Function and state assessment of building designs (Civil and Environmental Engineering)
- Autonomous model aircraft (Computer Science and Engineering)
- Electric bicycle (Energy and Environment)
- Prototypes for future detector systems (Fundamental Physics)
- Sucralose and DNA (Chemical and Biological Engineering)
- Bio-MEMS: Future medical instruments? (Microtechnology and Nanoscience)
- Shaping of wood (Materials and Manufacturing Technology)
- Stochastical modelling of economical time series (Mathematical Sciences)
- Lean family car (Product and Production Development)
- Ozone layer model (Radio and Space Sciences)
- New ferry concept (Shipping and Marine Technology)
- Automated music recognition (Signals and Systems)
- Change management strategies when introducing new working methods in children's hospital emergency unit (Technology Management and Economics)
- Vigor Wave Energy Converter (Applied Physics)
- Composite aircraft landing gear (Applied Mechanics)
- Lithographic thermometer (Student proposal)

The wide range of programmes that offer the course is clearly reflected in the different characters of the projects, even in this limited sample of projects. Many can be described as system design projects (Electric bicycle, Lean family car, New ferry concept), but there are also economic simulation projects (Stochastical modelling of economical time series) and organizational change projects (Change management strategies when introducing new working methods in children's hospital emergency unit).

Teaching and learning experiences

The teaching in the course includes lectures and practical exercises that train generic competence skills, as well as tutoring sessions for subject matter and linguistic consultation.

As indicated in figure 1, the teaching experiences aimed at giving the students the necessary generic competencies - project working competencies, information literacy and communication skills - to carry out the project, are run early in the term. These include lectures, practical sessions and workshops.

Tutoring sessions are arranged throughout the term: The supervisor arranges a start-up meeting with their project groups. The supervisor and the students discuss the project idea, about how the supervision will be carried out and how the presentation and opposition should be done. They also discuss the assessment of the project. The supervisor also introduces at start a "contract" between the project group's members – 3-6 students in each project group - in which the students are encouraged to decide how to work together in the group. They should decide about rules for the group when working with the project and they should document it and show it to the supervisor. The students are also encouraged to tell each other in the group what ambitions they have when carrying out the project course. This part is not shown to the supervisor but is an internal agreement in the group. The supervisor should tell the group about the extent of the supervision and make agreements of when to

meet with the group. Most of the supervisors meet their group once a week or even more frequently.

The students are also offered three linguistic consultation sessions. In these sessions, their emerging reports are reviewed and discussed by staff from Chalmers centre for Language and Communication.

Written reporting

During the project, the students document their work in a project plan, a planning report, a final report, and as continuous reporting. They also write an opposition report that analyzes and critics another group's final report.

Project plan. Initially in the project, the students should write a project plan containing

- A description of the aim, goals and scope of the project,
- Resource needs in the project
- The project time schedule
- Distribution of roles and responsibilities in the project

Planning report. However, the first major milestone in hand-in of a planning report in the middle of February. This planning report expands the project plan into a more detailed problem description and analysis. The programme chair decides about the method and time to hand-in the report. The planning report should contain the following headlines and information:

- Title
- Background
- Aim(s)
- Problem/issue/subject
- Limitations
- Method(s)/performance

Final report. The final report should be delivered in the end of May. The suggested disposition is:

- Title page
- Abstract/summary
- Table of contents
- Introduction/background
- Project description - main part
- Discussion
- Conclusions
- References
- Attachments

The design of the final report can differ depending on the character of the project chosen. A literature study has for example not the same disposition as design-build-test project. As a help the students are offered special writing instructions. Plagiarism is of course not accepted and all sources and references should be given in a correct way.

Continuous (individual) reporting. The first three reports are written by the project group in collaboration. In order to support the students' reflection on the project progress and to enable assessment of the individual contribution to the project result, they are also required to continuously document their work efforts. This continuous reporting consists of a time log that should be updated daily during the project work, and a diary that should be written at least once a week. In the diary the students should, in chronological order, describe the different project working phases. It should describe who did what, it should contain discussions and reflections on solutions chosen and it is recommended that it also tells about meetings in the group, planning, milestones etc. The supervisor should have the possibility to read in the diary and the time log before the meetings between the group and the supervisor.

A summary report of individual contributions from each project participant should be added to the final report. The report should tell account for distribution of roles and responsibilities in the project, including contributions to:

- Planning
- Information/literature search and analysis of collected information
- Selection of methods of research/development
- Problem solving, analysis and synthesis including contributions like creativity, active contribution in reflecting, project discussions and conclusions
- Main author of certain parts of the project report

Oral project presentations

Project presentations

Oral project presentations are carried out in beginning of June. Examiner, supervisor and opponents should be present at the presentations and oppositions. It is also recommended that the supervisor of the opposition group is present. The presentations are limited to 30 minutes including presentation, opposition and questions from examiner. At the oral presentations the following parameters are evaluated:

- Content
- Structure
- Presentation techniques/skills
- Visualization
- Time management
- Handling of questions

The content is judged from the point of view if the project participants have made a good choice of material from the final report for the presentation and if the material presented is adjusted to the audience and to the specific presentation situation. The structure is judged from the point of view if the presentation is well structured and easy to follow. All speakers should introduce and keep good (eye) contact with the audience during the presentation and should speak freely with only some support for the memory. Material used for visualization at the presentation (graphics, images, text etc) should be clear and easy to understand, and not contain too much detailed information. The speakers should tell about the material in a clear and comprehensible way. The project group should keep to the time offered (30 minutes). Questions from the audience ought to be handled and answered in a good way.

Opposition

After the project group's presentation there is an opposition. The opposition aims to clarify and question the content in the report. The opponent group has 10 minutes to present their discussion of the examined report.

The opposition group should also hand-in a written opposition report (400-600 words). In addition, each student should write an individual opposition report. The written opposition report should examine the report looking for strengths as well as weaknesses. It should illuminate and discuss the content. The following parameters should be judged:

- The structure of the report and other formal aspects
- Problem formulation
- Theory background and literature assessment
- Method/realization of the project
- Results, reflections, discussion, conclusions

The assessment of the opposition includes both the written and oral contributions from the group giving the opposition. A well performed opposition is characterized by relevant questions and ability to create context to the audience. The opposition should start and end in a planned way. Only constructive criticism is accepted.

Assessment

The assessment in the Chalmers project course involves several steps. The assessment concerning the result from the project group work is based on the following components:

- Planning report
- Final report
- Result from the project work
- Project working process

A 10-level scale is used to assess the different components. Each component is also assigned a weighting of importance on a scale 1-5. The highest score that a group can get is 100. The points allocated to each project group are then converted to a grade on the scale fail, 3, 4 or 5. 40 points or more are required to pass, 40-59 points yields the grade 3, 60-79 a grade 4, 80 or more a grade 5. The decision to initially judge each course element with respect to a 1-10 scale was taken in order to get a less rough and more flexible scale, when adding the points for all components to get the total sum. The components and weightings are summarized in table 1.

The final report is assessed with respect to a common set of criteria developed by Chalmers Centre for Communication and Languages. These so-called HISS criteria consider the holistic appearance of the report, contents and understanding, structure and language. These criteria are in turn sub-divided into sub-criteria that are connected to characterizations describing reports on various grade levels. The results from the project work (a "design", "simulation results" etc) are assessed in a subject-dependent fashion. The diaries and time logs are used along with the supervisor's impressions of his/her contacts with the group, to inform the assessment of project working process.

To be able to give individual grades basic data and methods to judge each students´ contribution to the different parts of the project and to the result are needed. The grade of the project group is the baseline grade for the individual grade.

Table 1: Project group grade components and weights

Component	Assessment basis	Grade scale	Weight	Assessor
Planning report	Planning report instructions	0-10	1	Examiner
Final report	HISS criteria	0-10	5	Examiner
Result	Subject-dependent	0-10	2	Examiner
Project working process	Project diary Time log Supervisor's contact with group	0-10	2	Supervisor

A student's individual grade may, however, be raised as well as lowered from that baseline. The diary, time log and summary report are the formal bases for the individual assessment. Contacts and meetings between the supervisor and the students during the project process are also very important in this process. The individual student's contribution to the project presentation and opposition is also considered. The supervisors also have the possibility to utilize peer assessment, specifically to let the members in each group assess each others contribution to the project group result.

An individual student who is assessed to not have contributed sufficiently may be failed on the course. Students that do not pass have to re-do the entire course the following year.

The supervisor should at meeting tell the project group the basic assessment of their work and give each student a written evaluation of her/his contribution to the project. The examiner should also offer each student a discussion about the individual grading.

EVALUATION OF THE PROJECT COURSE

The project course has been carefully evaluated during its first two years. Below, we account for the methodology used to evaluate the course and the main findings.

Evaluation method and process

The main aims have been to evaluate the experience from running the course focusing on challenges deriving from the scale of the course, and from the team-based assessment. The evaluation has collected information from all categories involved in the course. Interviews and have been carried out with programme chairs, examiners, supervisors, administrative staff, librarians and staff at the language department. In addition, students have been interviewed and course evaluations from all programmes have been examined.

The course evaluation the first year focused on:

- Quality of the final project reports in comparison with the learning outcomes formulated in the course plan.
- The "double" role of the projects as both an individual work and a teamwork in the project group
- Grading
- Generic competencies
- Information given to the different actors involved
- The involved actors roles and responsibilities
- Planning and administration

The course evaluation the second year focused on:

- Information given to all actors before and during the course
- The course memo with its course information to students
- Allocation of different tasks to involved actors in the course
- The connection between the learning outcomes stated in the course plan and the course elements
- Assessment instructions and criteria
- The "double" role of the projects as both an individual work and a teamwork in the project group – how can the individual contribution from each student be judged in a fair way

Interviews with the actors

Supervisors

Generally the supervisors were very positive to the role of being supervisors in the course. They seemed to really appreciate the students' way of working. The students were described as very interested, responsible, mature, skilled in cooperating and reflecting on their projects, and capable of giving constructive criticism to other project groups. Most supervisors were of the opinion that the generic competencies learning experiences have been a good help to the students. The planning report, time log and diary used to follow the project work were regarded as helpful tools to monitor the project progress.

The positive impression can also be seen in the assessment and grading of the students' project work. Most of the project groups got the highest (5) or the second highest (4) grade. In most cases all students in the same project group got the same grade.

On questions regarding the course learning outcomes and if they are met most of the supervisors considered them as fulfilled. Regarding the students writing skills, most supervisors regarded as them as acceptable. The supervisors also described the students' oral presentations and oppositions as well performed. However, they also reported that they think that the course goals are not very obvious to the students. The supervisors maintained that the intended learning outcomes are too numerous and not easy to keep in mind.

Many of the supervisors found it difficult to distinguish between the individuals in a project group. Several supervisors expressed wishes for more clear assessment criteria, for the whole group as well as for the individual students. Several supervisors asked the question if it is meaningful at all to try to distinguish between the students in a group – the Chalmers project course should offer training and practice in how to cooperate in a real way close to reality. In society, in the reality, it is the result of the group that is interesting, not the contribution from each individual. It should therefore be the result from the whole project group that is assessed. Some supervisors further argued that the individual grading adds an unnecessary element of worry which is not in agreement with the course's aims of learning to work together effectively in a group. However, the job split between the supervisors as the main teachers in the course and the examiners as assessors is reported to have functioned very well, with few conflicts regarding assessment and grades given to the project groups and the individuals.

When we asked about the amount of time (hours) spent on supervising the project groups the answers were vague from the supervisors – almost none keep record on how much time that was spent on supervising. However, many teachers stated that the supervision was more time demanding than expected and that they were not allocated a sufficient amount of hours for this task before the start of the projects.

While most of the supervisors met their group once a week some meet the students even more frequently – especially projects with laboratory elements in close proximity to the supervisor's office. In these cases, the supervisor sometimes experienced the frequent questions and interruptions as disturbing and stressing.

When the supervisors were asked if they needed any additional support in their role as supervisors the answer was no and they did not wish for any particular type of support. Many of the supervisors stated that they have had the opportunity to talk to and get advice from other supervisors/colleagues at their own department and that this is satisfactory. In some cases, there has also been a second supervisor present – for example a doctoral student.

Concerning information given before and during the course also the supervisors asked for better information published in a common webpage giving a clear overview of all course activities and clarifying roles and responsibilities in the course.

Language department and library staff

Also the teachers/supervisor/librarians at the language department and Chalmers library were very positive to the students' projects. Most of the students were described as very active and interested and capable of working effectively together in groups and writing good project reports. However, these actors also argue that the students could gain a lot by learning more/get more skilled concerning the generic competencies and information literacy. The language department staff and the library staff both wished for a closer contact with the supervisors.

The project group size has varied. The recommended group size is 4-6 participants. However there are also smaller groups with only 2-3 participants. This has normally not seen as a problem from the supervisors' point of view but the teachers/staff at the library and language department regarded this as a problem because it demands more resources and takes more time. A comment is also that the group-dynamic experience disappears if the groups have few participants.

Concerning information before and during the course also the language department staff and the librarians expressed wishes for a webpage with information that is easy to grasp for all actors involved in the course. There was also a wish for a better notification system connected to schedule system so that changes to the schedule for generic competency learning experiences can be easily visible and transparent to everyone. Documentation of the compulsory course elements was also problematic to some degree. It is a time consuming job to sign all the students' attendance cards.

Administrative staff

The administrative staff has very important and comprehensive tasks before and during the Chalmers project course. Also the administrative staff reported information problems and wishes to have one webpage where all course information can be published and accessed. The administrative staff also requested a clearer overview of who does what and when.

Students

The data from course evaluations showed that the course is appreciated by a large majority of students as a very engaging and interesting course although the students also indicated that the course demands a lot of work. Almost all students were very positive to the project group work, and to learn about and practice group dynamics.

The course evaluations from the first year (2007), showed rather heavy criticism regarding the information in the course. Students at all programs were very critical to how and where

the information was given before and during the course. The information was reported to be unclear, sometimes wrong, given too late and was changed during the course. This situation caused confusion and extra work. But there were also several innovative suggestions on how to make the information situation better: The students asked very clearly for **one common** webpage giving all necessary information in a clear way concerning the whole course. They also asked for a possibility to carry out the project selection on the web to facilitate the process for both students and staff thus saving a lot of time. It was not only the students but also the staff that asked for better information before and during the course. Sometimes the staff could not give correct information and answer the students' questions and this was obviously frustrating and led to some criticism.

The course evaluations have also shown that about half of the students are satisfied with the assessment and the individual grading, and the other half is not. It should also be noted that the encouragement to the students to write a mutual contract/agreement in the beginning of the project telling of their individual ambitions does actually not seem to have a function to fill. The fact is that almost all students decide for the ambition on the highest level – they want the highest grade.

Discussion

The students have a very positive attitude regarding the project course. Also the supervisors/teachers are very satisfied with the quality and conduct of the students' project work.

The setup of the development process and team proved to be very effective in terms of creating the new course design. The programme chairs that constituted the development team also had the authority to make decisions about the intended learning outcomes, the assessment scheme etc. In Kotter's terms, they had established a sense of urgency, had a common vision, and formed a powerful guiding coalition [12] that was able to overcome Chalmers' tradition of "silo-style" programme development, and instead, work out a common solution. However, administrative staff was poorly represented on the development team. This omission may partly have caused the information flow issues discussed below.

The major difficulty in running such a large-scale project course have thus been the problems connected to obtaining a clear and consistent information flow to students and staff, along with an clarification of each actors roles and responsibilities. The first year evaluation, in 2007, manifested an obvious need for a coordinating person taking responsibility for all common information activities and tasks concerning the Chalmers project course. This was acutely arranged by engaging a person for these tasks for a period of 3 months in autumn 2007 before the start of the 2008 project course. The coordinator concentrated his work on planning a process for giving clear and consistent information to all actors involved in the project course. A communication plan for the course was also presented pointing out what should happen and when before and during the course. There were also efforts to show and decide about different roles and tasks for the actors involved.

Also in the course evaluations from the second-year course, 2008, it was still the information flow that rendered most disappointment, although the criticism is somewhat milder, probably due to the improvements that had been made. There has been a large effort, involving many persons, to improve the administrative aspects of the course during its first two years. The information has gradually become better and the project selection can now be carried out on the web, which is highly appreciated by the students.

The generic competencies learning experiences are taught by staff at the language department and the library. The various educational programmes at Chalmers do not offer the students generic competencies during the students first to years in the same way. The

result of this is that the students' skills concerning generic competencies and information literacy differs when they reach the third year. From a project work point of view, this is not regarded as a problem since the students work together in groups and can help each other, can learn from each other, and can supplement each others knowledge and skills. Lectures in certain generic competencies were compulsory the first year. However this resulted in some criticism, due to the varying background of the students. Because of this, the lectures are no longer compulsory. However, the supervising meetings at the language department are still compulsory and are appreciated by the students. The project groups do themselves book the meetings when they feel it is suitable in time. There are suggestions to further investigate the role of the generic competencies learning experiences and how these experiences are connected to the subject part in the projects. It is also suggested to investigate which generic competencies the students are offered at the various educational programmes during their first two years in order to get an overview of their skills they are expected to have when starting the Chalmers project course. There is also a need for an even clearer explanation of the importance of the aims and importance of the generic competencies in connection with the project work.

The assessment in the Chalmers project course involves multiple steps and components. When looking at the statistics (for both the first and the second year the course was given) concerning the grades, both for the group and the individual participants, we find that most projects and students have got a high mark 4 or 5 (on a scale of 5) so the differentiation is small. It has been discussed if this is a problem or not. Maybe it is very natural because the students have high ambitions and state these before the course starts. The observation of the small grade variation is also in agreement with the difficulties reported from the supervisors on giving individual grades in the project group work. However, there are also some significant differences in the average grades awarded by different departments, which might imply that they are interpreting and applying the assessment scale differently. It may also be caused by variation in quality of students and their project work. It is apparent from the evaluation of the course that the assessment criteria, and how they are practiced by examiner and supervisors, need further discussion.

CONCLUSIONS

The start of the large-scale project course at Chalmers shows that it is possible to run such a large project course with positive results: The teachers are very satisfied with the quality of the students project work, as well as by the process skills that the students demonstrate. The course is a very popular course among students.

The design of such a course poses course design challenges related to agreement on intended learning outcomes and assessment, handling of varying pre-generic competence skills and project group selection. A development team composed of the programme chairs for each program was effective in resolving these issues in a timely manner.

The large scale poses communication challenges: There have been problems with obtaining a clear, complete and consistent information flow to students and staff and there have been problems to get all involved to understand all other roles and responsibilities. To address these issues, a university-wide coordination function has been developed to organise and follow this project course during the coming years.

Assessment and grading is a challenge in project courses which is even more emphasized in the large scale. The assessment is inherently complex with many factors to consider, and many teachers perform the assessment. There have been some signs of systematic grade differences between departments, which may be considered by students as unfair. There is a need for continued evaluation and refinement of the assessment scheme.

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MODIFICATION TO THE CDIO SYLLABUS: UPDATES AND EXPANSIONS TO INCLUDE LEADERSHIP AND ENTREPRENEURSHIP

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ABSTRACT

CDIO is a generalized model for the enhancement of engineering education. CDIO programs impart to the student a broad base of knowledge, skills, and attitudes necessary to become successful young engineers. This array of abilities is represented in the CDIO Syllabus. This paper examines the role of the Syllabus in the design of CDIO programs, and in meeting CDIO Standard 2. It compares the CDIO Syllabus with the UNESCO four pillars of learning, and finds them to be highly aligned. The Syllabus is then compared with the national accreditation and evaluation standards of several nations, and found to be consistent, but more detailed and comprehensive than any of the individual standards. Based on these comparisons, as well as other input received over the last decade, it is proposed that the CDIO Syllabus be modified, in part to add missing skills and in part to clarify labels, to make the Syllabus more explicit and more consistent with national standards. The result is called the *CDIO Syllabus, Version 2.0.* In modern society, engineers are increasingly expected to move to positions of leadership, and often take on an additional role as an entrepreneur. This paper also explores the degree to which the CDIO Syllabus already covers these topics, and the extensions that might be necessary to more adequately cover these two important roles of engineers. The CDIO Syllabus is compared with modern models of leadership and entrepreneurship, and extensions to the Syllabus are proposed. The proposed outcome is an extended version of the Syllabus, called the *CDIO+LE Syllabus*.

KEYWORDS

CDIO Syllabus, CDIO Standard 2, knowledge taxonomies, engineering leadership, entrepreneurship

INTRODUCTION

CDIO is a generalized model for enhancing engineering education. It moves engineering education from a model built on the abstractions of engineering science, toward one based on engineering science integrated into the context of practice. It responds to the needs expressed by program graduates, industry, governments, and national accreditation and evaluation bodies around the world.

These needs have been expressed in many ways. We summarize it by stating that every graduating engineer should be able to: "Conceive-Design-Implement-Operate complex value-added engineering products, processes and systems in modern team-based environments." [1] CDIO explicitly prepares students to enter careers as effective members of engineering teams, and they should leave the university "Ready to Engineer."

The CDIO approach strives to prepare students with the knowledge, skills and attitudes to be *leading engineers*. The approach has three overall goals: *To educate students who are able to:*

- *Master a deeper working knowledge of technical fundamentals*
- *Lead in the creation and operation of new products, processes, and systems*
- *Understand the importance and strategic impact of research and technological development on society* [1]

A CDIO education stresses the fundamentals, and is set in the *context* of conceiving, designing, implementing, and operating products, processes, and systems. We seek to develop programs that are educationally effective *and* more exciting to students, attracting them to engineering, retaining them in the program and in the profession.

One of the early and key documents developed by the CDIO Initiative was the CDIO Syllabus, which outlines the knowledge, skills and attributes expected of a graduating engineer. The objective of this paper is to review the CDIO Syllabus, nearly ten years after its drafting, for its applicability and continued relevance. We propose some minor changes in the document to increase its contemporary relevance and broaden its coverage.

Premises of the CDIO Approach

Three premises -- capturing the vision, goals, and pedagogical foundation -- are fundamental to the CDIO approach:

1. The underlying need is best met by setting goals that stress the fundamentals, while at the same time making the process of conceiving-designing-implementing-operating products, processes, and systems the *context* of engineering education
2. Learning outcomes for students should be set through stakeholder involvement, and met by constructing a sequence of integrated learning experiences, some of which are experiential, that is, they expose students to the situations that engineers encounter in their profession
3. Proper construction of these integrated learning activities will cause the activities to have dual impact, facilitating student learning of critical personal and interpersonal skills; and strengthening product, process, and system building skills, while simultaneously enhancing the learning of the fundamentals [1]

Premise #1

The need to make conceiving-designing-implementing-operating the context of engineering education is so fundamental to the CDIO approach that it is captured in the first CDIO Standard, or principle of effective practice.

Standard 1 – The Context
Adoption of the principle that product, process, and system lifecycle development and deployment -- Conceiving-Designing-Implementing-Operating -- are the context for engineering education

A learning context is the set of cultural surroundings and environments that contribute to understanding, and in which knowledge and skills are learned. We believe that the product, process, or system lifecycle (conceiving-designing-implementing-operating), should be the *context*, but not the *content*, of engineering education. The setting of the education, the skills we teach, and the attitudes we convey should all indicate that conceiving-designing-implementing-operating is the role of engineers in their service to society. Note that the standard requires that engineering education should provide a general framework of product, process, and system lifecycle development and deployment, of which conceiving-designing-implementing-operating is an example. This idea was more fully developed in the keynote address of the 2008 CDIO International Conference. [2]

Premise #2

The second premise suggests setting learning outcomes that impart to the students the broad base of knowledge, skills, and attitudes necessary to be a successful young engineer. These are enumerated within the framework document entitled *CDIO Syllabus – A Statement of Goals for Undergraduate Engineering Education*. [3] The *CDIO Syllabus* was developed through discussions with focus groups comprised of various stakeholders, and by reference to other documentation of the time. As shown in Table 1, the CDIO Syllabus classifies learning outcomes into four high-level categories: technical knowledge, personal attributes, interpersonal skills, and the skills specific to the engineering profession. The content of each section was expanded in the CDIO Syllabus to a second level (also shown in Table 1), to a third level (see Appendix A), and to a fourth level (available at http://www.cdio.org). To ensure comprehensiveness, the Syllabus was explicitly correlated with key documents listing engineering education requirements and desired attributes. As a result of this development process, the CDIO Syllabus emerged in 2001 as a rational and consistent set of skills, derived from an understanding of needs, that stakeholders would expect from graduating students. We will call this version of the CDIO Syllabus developed and published in 2001 the *CDIO Syllabus Version 1.0*.

CDIO Syllabus v1.0 has proven to be a useful reference for those developing engineering programs, planning curricula, and evaluating student learning. It has now been translated into Swedish (see Appendix B), French (see Appendix C), Spanish (see Appendix D) and Chinese (see Appendix E). Of course, the CDIO Syllabus is just a reference document, and it is not prescriptive. If programs feel that the CDIO Syllabus is not appropriate for their programs, or needs to be expanded, they can modify it in any way desirable to them.

Table 1
CDIO Syllabus v. 1.0 at the Second Level of Detail

1 TECHNICAL KNOWLEDGE AND REASONING 1.1 KNOWLEDGE OF UNDERLYING SCIENCE 1.1 CORE ENGINEERING FUNDAMENTAL KNOWLEDGE 1.2 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE **2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES** 2.1 ENGINEERING REASONING AND PROBLEM SOLVING 2.2 EXPERIMENTATION AND KNOWLEDGE DISCOVERY 2.3 SYSTEM THINKING 2.4 PERSONAL SKILLS AND ATTITUDES 2.5 PROFESSIONAL SKILLS AND ATTITUDES	**3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION** 3.1 MULTI-DISCIPLINARY TEAMWORK 3.2 COMMUNICATIONS 3.3 COMMUNICATIONS IN FOREIGN LANGUAGES **4 CONCEIVING, DESIGNING, IMPLEMENTING, AND OPERATING SYSTEMS IN THE ENTERPRISE AND SOCIETAL CONTEXT** 4.1 EXTERNAL AND SOCIETAL CONTEXT 4.2 ENTERPRISE AND BUSINESS CONTEXT 4.3 CONCEIVING AND ENGINEERING SYSTEMS 4.4 DESIGNING 4.5 IMPLEMENTING 4.6 OPERATING

CDIO Standard 2 emphasizes the importance of setting a comprehensive set of learning outcomes, aided by the CDIO Syllabus. Note the Syllabus is named in the shorthand title for the Standard, but not in the text of the Standard; it is a reference, not a prescription.

STANDARD 2 -- CDIO SYLLABUS OUTCOMES
Specific, detailed learning outcomes for personal, interpersonal, and product, process and system building skills, consistent with program goals and validated by program stakeholders

An engineering program should set learning outcomes for the knowledge, skills, and attitudes intended as a result of engineering education. The CDIO Syllabus is intended as an aid in this process. Also a part of Standard 2 is that learning outcomes are reviewed and validated by key stakeholders, that is, groups who share an interest in the graduates of engineering programs, for consistency with program goals and relevance to engineering practice. In addition, stakeholders help to determine the expected levels of proficiency, or standards of achievement, for each learning outcome. [1]

Premise #3

Having discussed CDIO Standards 1 and 2 in some detail, it is worth mentioning the remaining ten CDIO Standards that are implicitly referenced in the third premise. These standards cover the effective practices that allow us to reach the learning outcomes (Standard 2) within the context of engineering practice (Standard 1). They include curriculum design (Standard 3), first-year engineering courses (Standard 4), design-implement experiences (Standard 5), learning workspaces (Standard 6), teaching and learning (Standards 7 and 8), the development of faculty competence (Standards 9 and 10), student learning assessment (Standard 11), and program evaluation (Standard 12). Further discussion of these effective practices and examples of their implementation within CDIO programs is provided in *Rethinking Engineering Education: The CDIO Approach*. [1]

Objective of This Paper

With this background, the specific objective of this paper is to review the content and applicability of the CDIO Syllabus ten years after its drafting, and recommend updates and evolution. Discussion touches on the following points:

- The historical development of the CDIO Syllabus
- The use of the Syllabus in aligning curriculum, teaching and learning, and assessment
- Proposed modifications in the core Syllabus to respond to broad-based input
- Proposed extension of the Syllabus to include entrepreneurship and leadership

THE DEVELOPMENT OF THE CDIO SYLLABUS

The CDIO approach has its origins in an attempt to understand the needs of industry, and use them to inform the design of engineering education. Over a period of about one year, interviews and focus groups were conducted with engineering faculty, students, industry representatives, university review committees, alumni, and senior academics. The focus groups were asked, "*What is the full set of knowledge, skills, and attitudes that engineering students should possess as they leave university?"* We then sought to organize these outcomes in such a way that it would be easy to adapt to the needs of a local program and engineering disciplinary field, while explicitly recognizing the skills and abilities that are common to all engineers, and the specific characteristic of a CDIO-based education, that is, to be firmly rooted in the Conceive-Design-Implement-Operate context.

Organization of the CDIO Syllabus

Results of the focus groups and topics extracted from reference documents were organized into a list that evolved into the CDIO Syllabus, which is shown at the second level of detail in Table 1. At the highest level of organization, the Syllabus is divided into four sections:

1. Technical knowledge and reasoning
2. Personal and professional skills and attributes
3. Interpersonal skills: teamwork and communication
4. Conceiving, designing, implementing, and operating systems in the enterprise and societal context

These four headings were arrived at by a logical clustering of the over one hundred topics that emerged from the interview process. The organization reflects cognitive knowledge, how to think, how to work with others, and how to engineer. It also maps directly to the underlying need identified above, that is, to educate students who can:

Understand how to conceive, design, implement, and operate (Section 4)
Complex value-added engineering products, processes, and systems (Section 1)
In modern team-based engineering environments (Section 3), and
Are mature and thoughtful individuals (Section 2). [1]

The last phrase, "are mature and thoughtful individuals," acknowledges that within a university context, students grow psychologically and socially, as well as intellectually. The first section, *Technical Knowledge and Reasoning*, is program-specific, that is, it outlines major concepts of a specific engineering discipline. Sections 2, 3, and 4 are applicable to any engineering program.

Alignment of the CDIO Syllabus

The first draft of the Syllabus was compared with existing lists of criteria and standards, including ABET 2000 [4], and lists provided by several professional societies and corporations. In all cases, the CDIO Syllabus was found to be more comprehensive. The document was also peer reviewed by specialists in the many fields represented, for example, communications, ethics, system thinking, in order to ensure that the document would be consistent with the organization of knowledge used by professionals in the various fields.

One of the most important aspects of the CDIO Syllabus is its internal organization. A syllabus, or template for learning outcomes, can be organized in many ways: the ABET accreditation criteria [4] are not subdivided into categories at all. The EQF characteristics [5] are categorized as Knowledge, Skills and Competences. The EUR-ACE accreditation criteria [6] are subdivided into Knowledge and Understanding, Engineering Analysis, Engineering Design, Investigations, Engineering Practice, and Transferable Skills.

The UNESCO Framework and the CDIO Syllabus

UNESCO [7] has proposed that all education should be organized around four fundamental types of learning:

- Learning to Know, that is, acquiring the instruments of understanding
- Learning to Do, so as to be able to act creatively on one's environment
- Learning to Live Together, so as to co-operate with other people
- Learning to Be, an essential progression that proceeds from the previous three

These four types of knowledge form a whole, because there are many points of contact, intersection and exchange among them. The UNESCO framework recognizes that a syllabus should elaborate the activities of a profession (Learning to do).

The organization of the CDIO Syllabus can be described as an adaptation of the UNESCO framework to the context of engineering education. At the first level, the CDIO Syllabus is divided into four categories:

1. *Technical Knowledge and Reasoning (or Learning to Know)*
   Section 1 of the CDIO Syllabus defines the mathematical, scientific and technical knowledge that an engineering graduate should have developed. This section is inherently specific to programs and disciplines. For example, the knowledge content of a chemical engineering education is different from that of a mechanical engineering education.
2. *Personal and Professional Skills and Attributes (or Learning to Be)*
   Section 2 of the Syllabus deals with individual skills, including problem solving, ability to think creatively, critically, and systemically, and professional ethics. In contrast to Section 1, Sections 2, 3, and 4 of the Syllabus define skills and abilities that are common to all engineering disciplines. All engineers solve problems, work with others, and contribute to the lifecycle of a product, process, or system.
3. *Interpersonal Skills: Teamwork and Communication (or Learning to Live Together)*
   Section 3 of the Syllabus lists skills that are needed in order to be able to work in groups and communicate effectively.

4. Conceiving, Designing, Implementing and Operating Systems in the Enterprise and Societal Context (or Learning to Do)
   Finally, Section 4 of the CDIO Syllabus is about what engineers do, that is, conceive-design-implement-operate products, processes and systems within an enterprise and societal context.

Although the UNESCO framework precedes the first draft of the CDIO Syllabus by several years, the original drafters of the Syllabus did not know of its existence. Thus, UNESCO and CDIO independently arrived at the same fundamental structure.

Levels of Detail

Another feature that distinguishes the CDIO Syllabus from other taxonomies of knowledge and skills is that it is far more detailed. The second level of the Syllabus, shown in Table 1, is comparable to the level of detail shown in most other documents. This is acceptable as a general guide to learning outcomes, but is far too little information to define detailed learning outcomes, design a curriculum or individual courses, or assess student learning. The two to three additional levels of details in the full CDIO Syllabus provide this information. (see Appendix A)

THE ROLE OF THE CDIO SYLLABUS IN EDUCATION

The CDIO Syllabus plays a central role in the design of an engineering education. As the formal statement of the intended learning outcomes of an engineering program, the Syllabus

- Captures the expressed needs of program stakeholders
- Highlights the overall goals of the program
- Provides a guide for the design of curriculum
- Suggests appropriate teaching and learning methods
- Provides the targets for student learning assessment, and
- Serves as a framework for overall program evaluation

In the curriculum and instructional design process, the CDIO Syllabus is adapted to a local engineering program in order to ensure that intended learning outcomes are aligned with institutional mission and vision, program objectives, and institutional and program values. (see Figure 1) This sometimes means that a program omits a few of the personal, interpersonal, and product, process, and system building skills found in the CDIO Syllabus, or add a few to highlight specific values of its institution.

The list of intended learning outcomes, adapted from the CDIO Syllabus, then serves as the basis for instructional decisions about curriculum, teaching and learning methods, and the assessment of student learning. In the curriculum design process at the program level, intended learning outcomes are detailed, sequenced from basic to complex, and mapped to appropriate levels and courses in the overall curriculum. For example, an intended learning outcome related to oral and written communication would be further defined into enabling steps and learning activities that would be integrated into courses at all levels of the curriculum so that by graduation, students would be able to demonstrate their competence in oral and written communication.

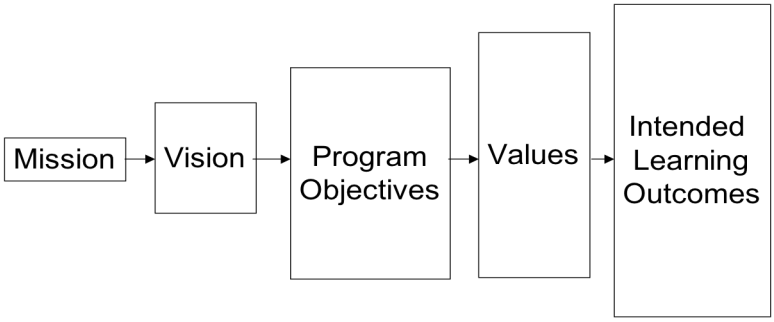

Figure 1. Alignment of intended learning outcomes with program mission

In the instructional design process at the course level, intended learning outcomes guide decisions about appropriate teaching, learning, and assessment methods. The appropriateness of teaching and assessment methods depends on the nature and level of the learning outcomes. Using the same example of communication, appropriate teaching and assessment methods would be those that would allow students to practice their skills, get feedback on their performance, and in an assessment situation, demonstrate their achievements. Biggs refers to this purposeful relationship between the intended learning outcomes, teaching and learning activities, and assessment of student learning as *constructive alignment*. [8] (see Figure 2) Wiggins and McTighe refer to the outcomes, teaching and learning, and assessment sequence as *backward design*. [9] With or without a specific name, all models of instructional design highlight the centrality of learning outcomes and the importance of the alignment of curriculum, teaching, and assessment. The CDIO Syllabus is a starting point for defining these learning outcomes.

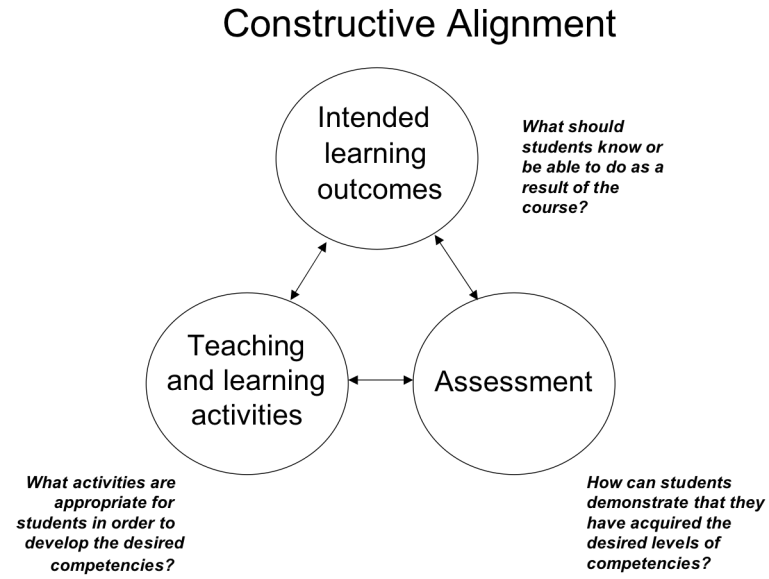

Figure 2. Alignment of intended learning outcomes with teaching and assessment

PROPOSED MODIFICATIONS TO THE CDIO SYLLABUS

Since the CDIO Syllabus was first drafted more than ten years ago, it has been a remarkably stable document, serving programs in all domains of engineering in educational institutions of all types throughout the world. However, there have been pressures to change the Syllabus. These pressures have two primary sources. The first pressure arises from the development of new taxonomies of knowledge that surface new issues or organizations that we should consider. The second pressure comes from questions from users of the Syllabus looking for clarification or for knowledge and skill areas that seem to be missing. In this section, we review the correlation of the CDIO Syllabus with other emerging documents, and then summarize the most frequently heard user concerns. The comparison with the UNESCO framework is discussed in the previous section.

Comparisons with National Accreditation and Evaluation Documents

The most common comparison documents for the CDIO Syllabus are those of national accreditation or evaluation bodies, usually produced by governments or professional societies. CDIO programs at different universities worldwide usually need to meet their respective national or accreditation standards, for example, ABET in the United States [4] or the National Agency for Higher Education in Sweden [10]. This need brings the correlation of the CDIO Syllabus with national outcomes requirements into focus. During the development of the first version of the CDIO Syllabus, it was correlated with the outcomes criteria of ABET EC2000. [3]. The most relevant section of ABET EC2000 is Criterion 3 on *Program Outcomes and Assessment*:

> Engineering programs must demonstrate that their graduates have
>
> (a) an ability to apply knowledge of mathematics, science, and engineering
> (b) an ability to design and conduct experiments, as well as to analyze and interpret data
> (c) an ability to design a system, component, or process to meet desired needs
> (d) an ability to function on multi-disciplinary teams
> (e) an ability to identify, formulate, and solve engineering problems
> (f) an understanding of professional and ethical responsibility
> (g) an ability to communicate effectively
> (h) the broad education necessary to understand the impact of engineering solutions in a global and societal context
> (i) a recognition of the need for, and an ability to engage in, life-long learning
> (j) a knowledge of contemporary issues
> (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

The correlation of the CDIO Syllabus with ABET EC2000 Criterion 3 is shown in Figure 3. One should note that this comparison generously interprets the ABET EC2000 criteria. The CDIO Syllabus reflects a more encompassing view of engineering than does ABET EC2000, by considering the full product/system/process lifecycle, including the implementing and operating life phases, whereas the ABET EC2000 criteria focus

solely on the design phase. For example, Criterion 3(c) calls for “the ability to *design* a system, component or process to meet a desired need.” However, since the word *process* was included in the definition, Figure 3 interprets the criterion to include the design of implementation and operation processes. In practice, a program could show satisfaction of Criterion 3(c) solely by demonstrating design of a part of the product. Overall, the CDIO Syllabus is well aligned with the ABET EC2000 criteria. The major advantage of the CDIO Syllabus is that it is more detailed, containing two or three more levels of detail than do the ABET EC2000 criteria. The increased levels of detail facilitate the interpretation of general statements, such as “communicate effectively”, that are common in national outcomes requirements.

	ABET EC2000 Criterion 3										
CDIO Syllabus	a	b	c	d	e	f	g	h	i	j	k
1.1 Knowledge of Underlying Science	■										
1.2 Core Engineering Fundamentals	■										
1.3 Advanced Eng. Fundamental Knowledge	▒										■
2.1 Engineering Reasoning and Problem Solving					■						▒
2.2 Experimentation and Knowledge Discovery		■									
2.3 System Thinking			▒								
2.4 Personal Skills and Attitudes									■		
2.5 Professional Skills and Attitudes						■					▒
3.1 Multi-disciplinary Teamwork				■							
3.2 Communications							■				
3.3 Communication in a Foreign Language											
4.1 External and Societal Context								■		■	
4.2 Enterprise and Business Context											
4.3 Conceiving and Engineering Systems			■								
4.4 Designing			■								
4.5 Implementing			▒								
4.6 Operating			▒								
	■	Strong Correlation					▒	Good Correlation			

Figure 3. The CDIO Syllabus correlated with ABET EC2000 Criterion 3

In September 2008*, Engineers Canada,* through its Canadian Engineering Accreditation Board (CEAB), published a new set of accreditation criteria and procedures.[11] The criteria include 12 graduate attributes that are well correlated with the CDIO Syllabus:

3.1.1. Knowledge Base
3.1.2. Problem Analysis
3.1.3. Investigation
3.1.4. Design
3.1.5. Engineering Tools
3.1.6. Individual/Team Work
3.1.7. Communication
3.1.8. Professionalism
3.1.9. Society/Environment
3.1.10. Ethics and Equity
3.1.11. Economics and Project Management
3.1.12. Life-Long Learning

For example, *environmental issues* and *engineering tools* are a combination of *modeling* and *fundamental skills* in the CDIO Syllabus. The CDIO Syllabus at the third level of detail provides a more refined definition of the 12 graduate attributes specified in the new CEAB document, and can certainly help institutions to meet these new criteria. The correlation of the CDIO Syllabus with the CEAB criteria is illustrated in Figure 4.

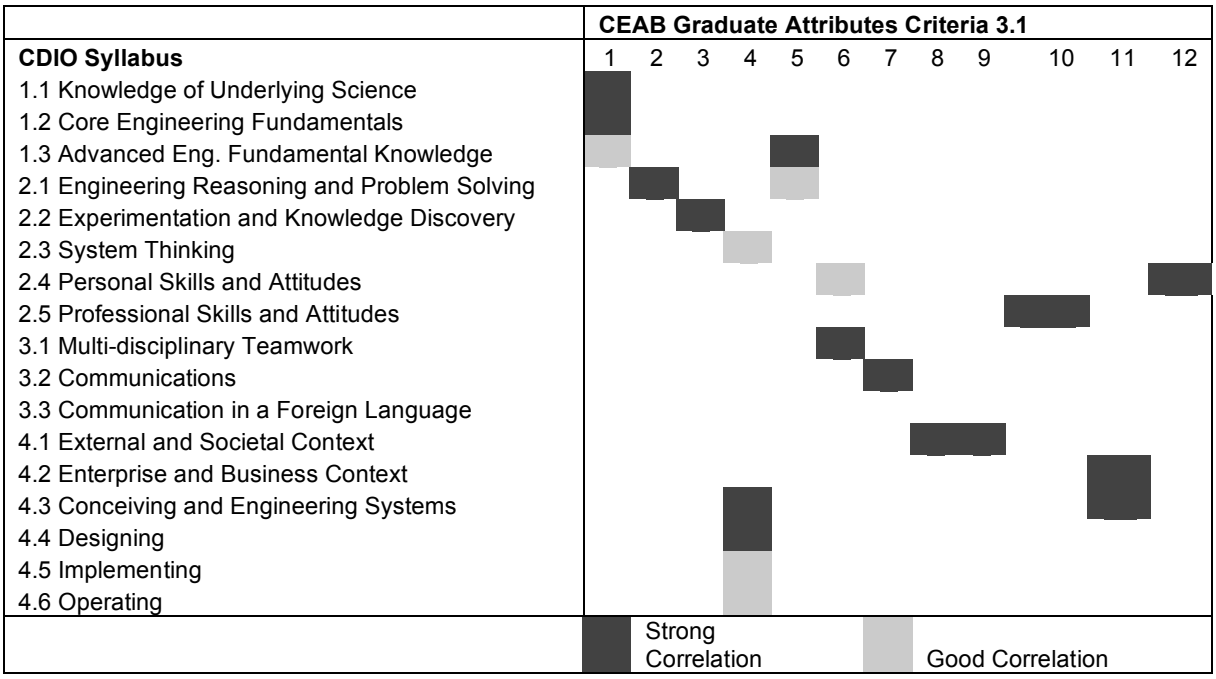

Figure 4. The CDIO Syllabus correlated with the CEAB Graduate Attributes

Subsequent analyses compared the CDIO Syllabus with national and international standards, such as the British UK-SPEC, the Dublin Descriptors, and the Swedish national engineering degree requirements [12], as well as the European EUR-ACE framework standards for accreditation of engineering programs [13]. Across all these comparisons, a similar pattern re-appears: The CDIO Syllabus states outcomes for engineering education that reflect a broader view of the engineering profession, and its greater levels of detail facilitate program and course development. A program whose design is based on the CDIO Syllabus will also fulfill its national requirements.

The principal modifications in the CDIO Syllabus that would be indicated by comparisons with national accreditation and evaluation documents might be clarifications of some of the topics so that the correspondence is more explicit. We proposed the following modifications to the CDIO Syllabus (see Appendix F):

- 1.0 -- Change to *Disciplinary or Subject-Based Knowledge and Reasoning* (Swedish Ordinance and EUR-ACE)
- 1.1 -- Add *Mathematics* (ABET)
- 1.3 -- Add *Methods and Tools* (ABET and CEAB)
- 2.1 -- Change to *Analytical Reasoning and Problem Solving* (ABET and CEAB)
- 2.2 -- Add *Investigation* to the title (CEAB)
- 2.5.1 -- Change to *Ethics, Integrity, and Social Responsibility* (ABET and CEAB)
- 2.5.2 -- Add *Professional Responsibility* (ABET)
- 2.5.5 – Add *Equity and Diversity* (CEAB)

- 3.1.5 -- Add *Multidisciplinary Teaming* (ABET and CEAB)
- 3.4.1 -- Add *Inquiry, Listening and Dialogue* (CEAB)
- 4.1 -- Add *Economic Context* (UK-SPEC)
- 4.2.5 -- Add part *Engineering Project Finance and Economics* (CEAB)
- 4.3.1 -- Add Understanding Needs (ABET and CEAB)
- 4.3.4 -- Add *Systems Engineering* (CEAB)
- 4.4.6 – Modify to indicate *safety* (CEAB)

Clarifications Based on User Feedback

Innovation and Invention

In the last decade, the concept of innovation as a role or purpose of engineering has become commonly accepted. However, there are several different understandings of the word *innovation*. The broader one is the development and exploitation of new ideas. A more specific understanding applicable to engineering is that innovation is *the development and introduction into the market of new goods and services*. If one accepts this latter definition, innovation is just the market-oriented view of what in the CDIO Syllabus defines in Sections 4.2 through 4.6 – Conceiving and Engineering Systems, Designing, Implementing, and Operating, within an enterprise. More emphasis may need to be placed on understanding the market and user needs as a basis for developing goals, but otherwise, the skills and knowledge necessary to foster innovation is completely covered in the CDIO Syllabus.

Invention refers to the development of new technologies that may enable innovations, including their incorporation into products and services that will be delivered. While invention is present in the CDIO Syllabus, it is made explicit only at the fourth level of detail, under 4.2.2 and 4.2.3. It may be better to raise the visibility of this important engineering function.

With respect to innovation and invention, the following modifications to the CDIO Syllabus are proposed (see Appendix F):

- 4.0 -- Add *Innovation* to the title
- 4.2.2 -- Change to *Enterprise Stakeholders, Strategy and Goals*
- 4.2.5 -- Add *Engineering Project Finance and Economics*
- 4.2.6 -- Add *New Technology Development, Assessment and Infusion*
- 4.3.1 -- Change to Understanding Needs and Setting Goals

Sustainability

During the last decade, the importance of sustainable development has become widely recognized. Future engineers need to be able to mitigate the negative environmental consequences of current energy and production systems, and create new ones that are essentially carbon neutral. It follows that engineering education must emphasize sustainability principles. In this context, the CDIO Syllabus, v.1, has received some criticism, as sustainability is mentioned in only one place, at the fourth level of detail, under 4.4.6. The low visibility has been interpreted as insufficient emphasis on this topic.

However, it can also be argued that CDIO is fundamentally aligned with the ideas of sustainability: Engineers are said to conceive, design, implement and operate complex technical systems with the entire product/process/system lifecycle in mind. Moreover,

sustainability is a complex concept. It includes the three main dimensions: economic, environmental, and social sustainability, including both subject matter and judgmental aspects, such as, ethics and decision-making [14]. There are many places in the CDIO Syllabus that emphasize the lifecycle perspective, for example, requirements should cover all phases of the lifecycle; analyses should be made of lifecycle values and costs; and product retirement should be planned ahead. With this broader perspective in mind, links between sustainability principles and CDIO Syllabus topics can be identified [15]. In essence, we conclude that the CDIO Syllabus does support the development of an engineering education that strongly considers sustainability. Nevertheless, the visibility of the concept of sustainability could be strengthened in the CDIO Syllabus, signaling its importance to students, industry, and program and course developers.

Based on these issues of *sustainability*, the following modifications to the CDIO Syllabus are proposed (see Appendix F):

- 4.0 -- Include *Environmental* in the title
- 4.1 -- Include *Environmental* in the title
- 4.1.7 -- Add Sustainability and the Need for Sustainable Development
- 4.4.6 -- Make *Design for Sustainability* more explicit
- 4.5.1 -- Change to *Designing a Sustainable Implementation Process*
- 4.6.1 -- Change to *Designing and Optimizing Sustainable and Safe Operations*

Other Critiques and Inputs

Over the years, several universities have observed that the CDIO Syllabus does not place sufficient emphasis on the topics of ethics, morality, and social responsibility. For example, The Pontifical Catholic University of Chile adapted the CDIO Syllabus to their program by adding to 2.4 the following (translated from the Spanish): *Commitment to Christian principles; Concern for those in great need*; and *Concern for the environment.*

Others have observed that, while the CDIO Syllabus covers aspects of formal communication well, that is, writing, oral presentations, and graphics, it could do better with informal and interpersonal communications. This would include topics such as social networking, negotiation, active listening, and persuading.

Another important critique is based on the work of Johan DeGraeve, which proposes a *Five-E Model* for engineering education. The model, developed at Group T International University College in Leuven, Belgium, describes five "*E*" terms around which their program of educating *integral engineers* is built. The first three *E*'s represent the roles engineers play in society.

- *ENGINEERING* -- making things
  Integral engineers create by making use of technology and the underlying sciences. They are familiar with a multidisciplinary approach.
- *ENTERPRISING* -- getting things done
  Integral engineers have vision. On this basis, they define a mission around which they gather others. Through innovation, daring and leadership they effectively get things done.
- *EDUCATING* -- developing oneself and others
  Integral engineers are capable of coaching themselves, others, and teams. Their ideal is the development of each and everyone.
- *ENVIRONMENTING* -- embracing all elements
  Integral engineers are conscious of the influence of technology on the world, and

vice versa. This is why they take into account the impact of their actions on ethics, ecology, aesthetics and economics within a globalizing and ever-evolving world.

- *ENSEMBLING* -- transcending and including
  Integral engineers see the coherence of things. By differentiating and integrating, and approaching all things from different angles, they achieve deeper insights and arrive at ever-richer experiences. [16]

These five *E*'s are not really an addition to the CDIO Syllabus, but rather an overlay or a view through a different lens.

Based on these critiques and inputs, we propose the following modificaitonsto the CDIO Syllabus (see Appendix F):

- 2.4.6 -- Add *Educating Others*
- 2.4.8 -- Add *Knowledge Integration (Ensembling)*
- 2.5.1 -- Change to *Ethics, Integrity, and Social Responsibility*
- 3.4 -- Add new listing *Informal Communication* to include:
  - 3.4.1 *Inquiry, Listening, and Dialogue*
  - 3.4.2 *Negotiation, Compromise and Conflict Resolution*
  - 3.4.3 *Advocacy*
  - 3.4.4 *Establishing diverse Connections (Grouping)*

LEADERSHIP AND ENTREPRENEURSHIP: CDIO+LE

In modern society, engineers are increasingly expected to move to positions of leadership and to take on additional roles as entrepreneurs. Leadership is not necessarily positional, that is, a leader need not be a boss, manager, director or president. *Leadership* refers to the role of helping to organize effort, create vision, and facilitate the work of others. In the context of engineering, senior engineers are the ones who most often lead. *Entrepreneurship* refers to the specific activity of creating and leading a new enterprise. Many, but not all, new enterprises are built around a product or technology, and involve entrepreneurial engineers. In this section, we explore the degree to which *leadership* and *entrepreneurship* are already included in the CDIO Syllabus, and the extensions that might be necessary to more adequately address these two important roles of engineers.

Engineering leadership and entrepreneurship are not orthogonal to the skills already contained in the CDIO Syllabus. After all, the goal of the CDIO approach, as described above, is "To educate students who are able to:

- Master a deeper working knowledge of technical fundamentals
- <u>*Lead*</u> in the creation and operation of new products, processes, and systems…"

The knowledge, skills, and attitudes needed in the creation and operation of new products, processes, and systems should, therefore, already be contained in the CDIO Syllabus. In fact, there is a broad overlap, both between leadership and entrepreneurship, and between the two of them and the skills already in the Syllabus. To a certain extent, the three are just different profiles of the same broader set of skills, as suggested in Figure 5. This Venn diagram suggests the organization of the discussion that follows. We have already reviewed the CDIO Syllabus, v. 1, with its proposed modifications. Here, we discuss what could be added to expand the topics in the Syllabus beyond the already proposed modifications, to include *Engineering*

Leadership. Finally, we examine what other topics are needed to embrace *Entrepreneurship.* We recognize that many programs are using the CDIO Syllabus, v.1 (or will use the proposed v. 2.0), and may not want to address leadership and entrepreneurship in their programs. For this reason, we propose a new, second-level document, the *CDIO+LE Syllabus*, with the additional content discussed below.

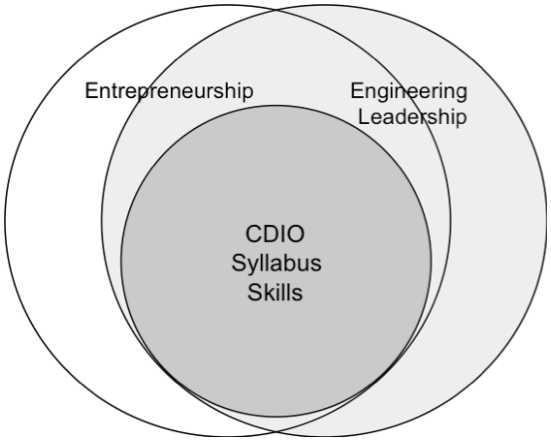

Figure 5. The overlapping relationship between the knowledge, skills and attitudes in the CDIO Syllabus v.1, engineering leadership, and entrepreneurship

The Expansion of the CDIO Syllabus to Include Engineering Leadership: CDIO+L

Some, if not all, engineers will move, at some point in their careers, to positions of technical or engineering leadership, ranging from being a leader of a small team, to being the technical leader of an entire enterprise. Leadership is explicitly discussed in Section 3.1.4 of the CDIO Syllabus, but this is really about leading small groups, and is only a placeholder for the wider set of skills that an engineering leader is required to have. These skills include character traits, such as loyalty and integrity, and abilities, such as the ability to make sense of complex contextual information, to relate and persuade, to create transformational visions, and to deliver on those visions. In this section, we discuss relevant contemporary models of leadership, and propose extensions to the CDIO Syllabus.

Leadership Models

Much has been written over the years about the qualities of a leader. In contemporary scholarship, organizational leadership is closely studied by those in organizational behavior groups, often at schools of business or management. Diverse fields, including business, government, and the military have adopted these organizational models, and customized them to their respective domains. Generic models of leadership, then, can be customized for engineering contexts.

Among the many views of leadership development, the general approaches that may best fit engineering contexts are those that function in environments of change, uncertainty, and the deliberate pursuit of invention. [17] One school of thought that stands out is *Transformational Leadership* because of its emphasis on a driving need to change and to mobilize resources in new ways, requiring new visions of the future. [18]

This model resonates with leaders of groups that are using applied science and engineering to generate new products that may require redefining markets and business models.

Contingency theory reminds leaders that over time no single approach to leadership will fit all situations, and one must continually assess one's environment to provide appropriate leadership. [19] This approach thus incorporates the importance of providing vision and strong direction in one circumstance, and also recognizes when one might lead best by creating a stable and supportive environment in which others might lead. This view suggests that engineering leadership in a change-driven environment is situational. [20] The complex and specialized nature of engineering requires that leadership be found everywhere. There are instances when one must be able to listen to the technician on the shop floor who might be the first to see the solution to a design-for-production problem. In advancing technical fields, the individuals looking outward from the company at new technologies, and those working in an organization's laboratories, provide a kind of technology leadership. Other who follow markets, and observe novel uses of products that are enhancing or eroding markets, must exert a kind of situational leadership as well. All of these leaders need first to recognize that change is occurring, to make sense of what they are seeing and to communicate effectively with others.

The Four Capabilities Leadership Framework

The *Four Capabilities Leadership Framework,* developed at the Sloan School of Management at MIT, provides a scheme that organizes key leadership concepts as a foundation for engineering leadership education. [21] It begins with four assumptions: that leadership is distributed; that it is personal; that it continues to develop throughout one's career, and thus changes over time; and that each individual invents their own framework for how he/she will lead. The central skills are

1. *Sensemaking* -- making sense of the context of the changing world around us, including the use of small experiments to test and gain information
2. *Relating* -- developing trusted relationships with diverse individuals, using inquiry to know how to communicate effectively. and leadership through advocacy, even if one is not a formal leader
3. *Visioning* -- both to create a vision for oneself and to convey that vision to others
4. *Realizing the Vision* (*Inventing*) -- takes on a more complex meaning for engineers. Engineering leaders, like other leaders, need to invent ways to think through situations, and create ways of organizing their work with others. For engineers, the tasks of organizing work are central to their profession. This organization may involve establishing design teams, designing, setting up production and implementation, establishing who will do testing and by what means, operating, and a host of other activities.

In the Bernard M. Gordon – MIT Engineering Leadership Program, we have been working on adapting this more generic model of leadership to the context of engineering. We have added to the MIT Sloan Four Capabilities Model a leading set and a final set of skills and attributes. The first set includes issues of leadership that have to do with attitudes and character, for example, initiative, the will to deliver, resourcefulness, integrity, and loyalty. The last set concentrates on a firm foundation of engineering knowledge and skills. The customized leadership model has six central skills:

1. The Attitudes of Leadership (Core Personal Values and Character)
2. Relating to Others

3. Making Sense of the Context
4. Creating a Purposeful Vision
5. Realizing the Vision
6. Technical Knowledge and Critical Reasoning

The full description of the *Gordon-MIT Engineering Leadership Program Capabilities of an Engineering Leader* can be found at http://web.mit.edu/gordonelp/Capabilities.html.

When one compares the structure of the *Gordon-MIT Engineering Leadership Program Capabilities of an Engineering Leader* with the existing CDIO Syllabus, including the proposed modifications, we see a great deal of overlap. The newly proposed section 4.7 of the CDIO+LE Syllabus summarizes the overlap and identifies aspects of new content that should be added. In order to better prepare engineering students for leadership, we propose the following modifications to Version 2.0 of the CDIO Syllabus (see Appendix F):

- 2.5 -- Add the reorganized and expanded list of attitudes and personal skills indicated in the new 2.5.6 to 2.5.11
- 3.1.4 -- Re-label *Team Leadership*
- 3.4 -- Add a new section on Informal Communication, including the previously defined 3.4.1 to 3.4.4

In addition, we recommend adding the entire section 4.7 *Leading Engineering Endeavors*, but only to the CDIO+LE Syllabus. This new section defines the remaining topics in *Creating a Purposeful Vision* (4.7.1 to 4.7.3) and *Realizing the Vision* (4.7.4 to 4.7.9) (see Appendix F):

- 4.7.1 -- *Thinking Creatively and Imagining Possibilities* (expands *Creative Thinking* 2.4.3)
- 4.7.2 -- *Defining the Solution* (expands *Understanding Needs and Setting Goals* 4.3.1)
- 4.7.3 -- *Creating New Solution Concepts* (expands 4.3.2 and 4.3.3)
- 4.7.4 -- *Building and Leading an Organization and an Extended Organization* (builds on 4.2.4)
- 4.7.5 -- *Planning and Managing a Project to Completion* (builds on 4.3.4)
- 4.7.6 -- *Exercising Project/Solution Judgment*
- 4.7.7 -- *Innovation* – the conception, design and introduction of new goods and services (builds on 4.4)
- 4.7.8 -- *Invention* – the development of new devices, materials or processes that enable new goods and services
- *4.*7.9 -- *Implementation and Operation* – the creation and operation of the goods and services that will deliver value (the leadership of 4.5 and 4.6)

The Expansion of the CDIO Syllabus to Include Entrepreneurship: CDIO+L+E

Successful engineering entrepreneurship consists of engineering, plus engineering leadership, plus specific domain knowledge associated with business formulation and start-ups. As illustrated in Figure 5, we now define the knowledge and skills necessary for *Entrepreneurship*, over and above those described in the baseline CDIO Syllabus, v. 2.0, with the proposed additions for engineering *Leadership*. Again, we examine appropriate models of entrepreneurship on which to base our discussion.

In the view of classical economics, *entrepreneurship* involves the redirection and mobilization of capital and human resources to form a new economic activity. This

perspective considers any major innovation in an established firm to be entrepreneurship if it involves a novel economic activity that departs from the firm's prior business model, and accepts the risks of placing substantial investments in new products and creating new markets that did not previously exist. Today, the term *entrepreneurship* generally refers exclusively to starting a new company, while launching a radically new line of business is sometimes called *intrapreneurship,* or more simply *innovation* (as was discussed in a previous section). [22]

Engineering education should prepare students for both forms of entrepreneurship, which are more easily accommodated than intrapreneurship. In many instances, science- and technology-based discovery and invention in established companies may not require business innovation because often they do not require changes in markets. When engineering is a major component of a product that is intended to disrupt existing markets, much more care is needed in the design process, and the engineer needs to understand the trade-offs between product novelty and importance of time to market, product margins and hurdle rates needed to justify company investment, and other business considerations that influence design and implementation strategies. These issues are well addressed in the product development literature and can be included without difficulty in any engineer's education. In the context of the CDIO Syllabus, these aspects of learning would be largely addressed by the modifications discussed with respect to innovation.

Preparation for entrepreneurship, that is, the start of a new company, involves unique competencies. There are analogues, such as the similarity between recognizing new opportunities enabled by advancing technology, or writing business plans for either a new product line or a new company. However, there is an array of skills that engineers in an established company might never face, such as finding and hiring an entire company of talented professionals willing to accept risk, using equity to motivate innovation, or creating a new company culture where none existed.

In order to capture these additional skills of entrepreneurship, we propose that Section 4.8 be added to the CDIO+LE Syllabus. This new section would include the following topics (see Appendix F):

- 4.8.1 -- *Company Founding, Formulation, and Organization*
- 4.8.2 – *Business Plan Development*
- 4.8.3 -- *Company Capitalization and Finances*
- 4.8.4 -- *Innovative Product Marketing*
- 4.8.5 -- *Conceiving Products and Services Around New Technologies*
- 4.8.6 – *The Innovation System, Networks, Infrastructure, and Services*
- 4.8.7 -- *Building the Team and Initiating Engineering Processes* (conceiving, designing, implementing and operating)
- 4.8.8 -- *Managing Intellectual Property*

SUMMARY

This paper has presented the following key concepts:

- The CDIO Syllabus is a rational, detailed, and relatively complete taxonomy for the knowledge, skills, and attitudes that graduating engineers should possess; and, it has been stable for almost ten years

- Its high-level structure is consistent with the four pillars of learning outlined by UNESCO
- It can be instrumental in the design of constructively aligned learning outcomes, curricula, teaching approaches, student learning assessment, and program evaluation
- The CDIO Syllabus is well aligned with other outcomes-based taxonomies developed by national accreditation and evaluation bodies, and has been found to be more comprehensive and more detailed
- Based on comparisons with other taxonomies, and the frequent user questions raised over the years, particularly around innovation, invention, and sustainability, modifications in content and in labeling are proposed to the baseline CDIO Syllabus, creating Version 2.0
- In order to better serve programs interested explicitly in engineering leadership and entrepreneurship, an expanded document is proposed, called the *CDIO+LE Syllabus*

In summary, we have found the CDIO Syllabus to be a remarkably robust document, but one that can be improved. We propose two steps: the incorporation of modest changes to the baseline CDIO Syllabus, and the creation of an extended version covering leadership and entrepreneurship.

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APPENDIX A. The CDIO Syllabus (English)

1 TECHNICAL KNOWLEDGE AND REASONING
- 1.1. KNOWLEDGE OF UNDERLYING SCIENCES
- 1.2. CORE ENGINEERING FUNDAMENTAL KNOWLEDGE
- 1.3. ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE

2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES
- 2.1. ENGINEERING REASONING AND PROBLEM SOLVING
  - 2.1.1. Problem Identification and Formulation
  - 2.1.2. Modeling
  - 2.1.3. Estimation and Qualitative Analysis
  - 2.1.4. Analysis With Uncertainty
  - 2.1.5. Solution and Recommendation
- 2.2. EXPERIMENTATION AND KNOWLEDGE DISCOVERY
  - 2.2.1. Hypothesis Formulation
  - 2.2.2. Survey of Print and Electronic Literature
  - 2.2.3. Experimental Inquiry
  - 2.2.4. Hypothesis Test, and Defense
- 2.3. SYSTEM THINKING
  - 2.3.1. Thinking Holistically
  - 2.3.2. Emergence and Interactions in Systems
  - 2.3.3. Prioritization and Focus
  - 2.3.4. Tradeoffs, Judgment and Balance in Resolution
- 2.4. PERSONAL SKILLS AND ATTITUDES
  - 2.4.1. Initiative and Willingness to Take Risks
  - 2.4.2. Perseverance and Flexibility
  - 2.4.3. Creative Thinking
  - 2.4.4. Critical Thinking
  - 2.4.5. Awareness of One's Personal Knowledge, Skills, and Attitudes
  - 2.4.6. Curiosity and Lifelong Learning
  - 2.4.7. Time and Resource Management
- 2.5. PROFESSIONAL SKILLS AND ATTITUDES
  - 2.5.1. Professional Ethics, Integrity, Responsibility and Accountability
  - 2.5.2. Professional Behavior
  - 2.5.3. Proactively Planning for One's Career
  - 2.5.4. Staying Current on World of Engineer

3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION
- 3.1. TEAMWORK
  - 3.1.1. Forming Effective Teams
  - 3.1.2. Team Operation
  - 3.1.3. Team Growth and Evolution
  - 3.1.4. Leadership
  - 3.1.5. Technical Teaming
- 3.2. COMMUNICATION
  - 3.2.1. Communication Strategy
  - 3.2.2. Communication Structure
  - 3.2.3. Written Communication
  - 3.2.4. Electronic/Multimedia Communication
  - 3.2.5. Graphical Communication
  - 3.2.6. Oral Presentation and Interpersonal Communication
- 3.3. COMMUNICATION IN FOREIGN LANGUAGES
  - 3.3.1. English
  - 3.3.2. Languages within the European Union
  - 3.3.3. Languages outside the European Union

4 CONCEIVING, DESIGNING, IMPLEMENTING AND OPERATING SYSTEMS IN THE ENTERPRISE AND SOCIETAL CONTEXT
- 4.1. EXTERNAL AND SOCIETAL CONTEXT
  - 4.1.1. Roles and Responsibility of Engineers
  - 4.1.2. The Impact of Engineering on Society
  - 4.1.3. Society's Regulation of Engineering
  - 4.1.4. The Historical and Cultural Context
  - 4.1.5. Contemporary Issues and Values
  - 4.1.6. Developing a Global Perspective
- 4.2. ENTERPRISE AND BUSINESS CONTEXT
  - 4.2.1. Appreciating Different Enterprise Cultures
  - 4.2.2. Enterprise Strategy, Goals and Planning
  - 4.2.3. Technical Entrepreneurship
  - 4.2.4. Working Successfully in Organizations
- 4.3. CONCEIVING AND ENGINEERING SYSTEMS
  - 4.3.1. Setting System Goals and Requirements
  - 4.3.2. Defining Function, Concept and Architecture
  - 4.3.3. Modeling of System and Ensuring Goals Can Be Met
  - 4.3.4. Development Project Management
- 4.4. DESIGNING
  - 4.4.1. The Design Process
  - 4.4.2. The Design Process Phasing and Approaches
  - 4.4.3. Utilization of Knowledge in Design
  - 4.4.4. Disciplinary Design
  - 4.4.5. Multidisciplinary Design
  - 4.4.6. Multi-objective Design
- 4.5. IMPLEMENTING
  - 4.5.1. Designing the Implementation Process
  - 4.5.2. Hardware Manufacturing Process
  - 4.5.3. Software Implementing Process
  - 4.5.4. Hardware Software Integration
  - 4.5.5. Test, Verification, Validation and Certification
  - 4.5.6. Implementation Management
- 4.6. OPERATING
  - 4.6.1. Designing and Optimizing Operations
  - 4.6.2. Training and Operations
  - 4.6.3. Supporting the System Lifecycle
  - 4.6.4. System Improvement and Evolution
  - 4.6.5. Disposal and Life-End Issues
  - 4.6.6. Operations Management

APPENDIX B. The CDIO Syllabus (Swedish)

CDIO – Måldokument

MATEMATISKA, NATURVETENSKAPLIGA OCH TEKNIKVETENSKAPLIGA KUNSKAPER

- **KUNSKAP I GRUNDLÄGGANDE MATEMATISKA OCH NATURVETENSKAPLIGA ÄMNEN**

- **KUNSKAP I TEKNIKVETENSKAPLIGA ÄMNEN**

- **FÖRDJUPADE KUNSKAPER I NÅGOT/NÅGRA TILLÄMPADE ÄMNEN**

INDIVIDUELLA OCH YRKESMÄSSIGA FÄRDIGHETER OCH FÖRHÅLLNINGSSÄTT

- **INGENJÖRSMÄSSIGT TÄNKANDE OCH PROBLEMLÖSANDE**
  - **Problemidentifiering och formulering**
  - **Modellering**
  - **Kvantitativa och kvalitativa uppskattningar**
  - **Analys med hänsyn till osäkerheter och risker**
  - **Slutsatser och rekommendationer**

- **EXPERIMENTERANDE OCH KUNSKAPSBILDNING**
  - **Hypotesformulering**
  - **Informationskompetens**
  - **Experimentell metodik**
  - **Hypotesprövning**

- **SYSTEMTÄNKANDE**
  - **Helhetstänkande**
  - **Interaktion och framträdande egenskaper hos system**
  - **Prioritering och fokusering**
  - **Kompromisser och avvägningar i val av lösningar**

- **INDIVIDUELLA FÄRDIGHETER OCH FÖRHÅLLNINGSSÄTT**
  - **Initiativförmåga och risktagande**
  - **Uthållighet och anpassningsförmåga**
  - **Kreativt tänkande**
  - **Kritiskt tänkande**
  - **Självkännedom**
  - **Nyfikenhet och livslångt lärande**
  - **Planering av tid och resurser**

- **PROFESSIONELLA FÄRDIGHETER OCH FÖRHÅLLNINGSSÄTT**
  - **Yrkesetik, integritet, ansvar och pålitlighet**
  - **Professionellt uppträdande**
  - **Aktiv karriärplanering**
  - **Att hålla sig à jour med professionens utveckling**

FÖRMÅGA ATT ARBETA I GRUPP OCH ATT KOMMUNICERA

- **ATT ARBETA I GRUPP**
  - **Att skapa effektiva grupper**
  - **Grupparbete**
  - **Grupputveckling**
  - **Ledarskap**
  - **Gruppsammansättning**

- **ATT KOMMUNICERA**
  - **Kommunikationsstrategi**
  - **Budskapets struktur**
  - **Skriftlig framställning**
  - **Multimedia och elektronisk kommunikation**
  - **Grafisk kommunikation**
  - **Muntlig framställning**

- **ATT KOMMUNICERA PÅ FRÄMMANDE SPRÅK**
  - **Engelska**
  - **Språk i länder av regionalt industriellt intresse**
  - **Andra språk**

PLANERING, UTVECKLING, REALISERING OCH DRIFT AV TEKNISKA SYSTEM MED HÄNSYN TILL AFFÄRSMÄSSIGA OCH SAMHÄLLELIGA BEHOV OCH KRAV

- **SAMHÄLLELIGA VILLKOR**
  - **Ingenjörens roll och ansvar**
  - **Teknikens roll i samhället**
  - **Samhällets regelverk**
  - **Historiska perspektiv och kulturella sammanhang**
  - **Aktuella frågor och värderingar**
  - **Utvecklande av ett globalt perspektiv**

- **FÖRETAGS- OCH AFFÄRSMÄSSIGA VILLKOR**
  - **Förståelse för olika affärskulturer**
  - **Planering, strategier och mål för affärsverksamhet**
  - **Teknikbaserat entreprenörskap**
  - **Att arbeta framgångsrikt i en organisation**

- **ATT PLANERA SYSTEM**
  - **Att specificera systemmål och -krav**
  - **Att definiera systemets funktion, koncept och arkitektur**
  - **Att modellera system och att säkerställa måluppfyllelse**
  - **Ledning av utvecklingsprojekt**

- **ATT UTVECKLA SYSTEM**
  - **Konstruktionsprocessen**
  - **Konstruktionsprocessens faser och metodik**
  - **Kunskapsanvändning vid konstruktion**
  - **Disciplinär konstruktion (inom ett teknikområde, t.ex. hydraulikkonstruktion)**
  - **Multidisciplinär konstruktion**
  - **Konstruktion med hänsyn till multipla, motstridiga mål**

- **ATT REALISERA SYSTEM**
  - **Utformning av realiseringsprocessen**
  - **Tillverkning av hårdvara**
  - **Implementering av mjukvara**
  - **Integration av mjuk- och hårdvara**
  - **Test, verifiering, validering och certifiering**
  - **Ledning av realiseringsprocessen**

- **ATT TA I DRIFT OCH ANVÄNDA**
  - **Att utforma och optimera driften**
  - **Utbildning för drift**
  - **Systemunderhåll**
  - **Systemförbättring och -utveckling**
  - **Systemavveckling**
  - **Driftsledning**

APPENDIX C. The CDIO Syllabus (French)

Translated Into French by École Polytechnique de Montréal

1 CONNAISSANCES TECHNIQUES ET RAISONNEMENT
- **1.1 CONNAISSANCE DES SCIENCES DE BASE [a]**
- **1.2 CONNAISSANCE DES PRINCIPES FONDAMENTAUX D'INGÉNIERIE [a]**
- **1.3 CONNAISSANCES AVANCÉES EN INGÉNIERIE [k]**

2 COMPÉTENCES ET HABILETÉS PROFESSIONNELLES ET PERSONNELLES
- **2.1 RAISONNEMENT TECHNIQUE ET RÉSOLUTION DE PROBLÈMES [e]**
  - 2.1.1 Identification de problèmes et formulation
  - 2.1.2 Modélisation
  - 2.1.3 Estimation et analyse qualitative
  - 2.1.4 Analyse d'incertitude
  - 2.1.5 Solutions et recommandations
- **2.2 EXPÉRIMENTATION ET DÉCOUVERTE SCIENTIFIQUE [b]**
  - 2.2.1 Formulation d'hypothèses
  - 2.2.2 Documentation écrite et électronique
  - 2.2.3 Enquête expérimentale
  - 2.2.4 Vérification d'hypothèses et tactique d'étude
- **2.3 PENSÉE SYSTÉMIQUE**
  - 2.3.1 Pensée holistique
  - 2.3.2 Émergence et interaction de systèmes
  - 2.3.3 Établissement des priorités et focalisation
  - 2.3.4 Compromis technique, discernement et vue d'ensemble dans la résolution de problèmes
- **2.4 HABILETÉS ET ATTRIBUTS PERSONNELS**
  - 2.4.1 Avoir de l'initiative et savoir prendre des risques
  - 2.4.2 Persévérence et flexibilité
  - 2.4.3 Pensée créative
  - 2.4.4 Pensée critique
  - 2.4.5 Être sensible aux connaissances, habiletés et attitudes des autres
  - 2.4.6 Curiosité intellectuelle et intérêt pour l'acquisition continue du savoir [i]
  - 2.4.7 Gestion du temps et des ressources
- **2.5 HABILETÉS ET COMPÉTENCES PROFESSIONNELLES**
  - 2.5.1 Éthique professionnelle, intégrité, responsabilité et fiabilité [f]
  - 2.5.2 Conduite empreinte de professionnalisme
  - 2.5.3 Planification de carrière proactive
  - 2.5.4 Mise à jour des connaissances en ingénierie

3 HABILETÉS INTERPERSONNELLES, TRAVAIL D'ÉQUIPE ET COMMUNICATION
- **3.1 TRAVAIL D'ÉQUIPE [d]**
  - 3.1.1 Savoir former des équipes efficaces
  - 3.1.2 Organisation en équipe
  - 3.1.3 Croissance et évolution des groupes
  - 3.1.4 Savoir diriger
  - 3.1.5 Organisation d'équipes techniques
- **3.2 COMMUNICATIONS [g]**
  - 3.2.1 Stratégies de communication
  - 3.2.2 Structure des communications
  - 3.2.3 Communication écrite
  - 3.2.4 Communication électronique et multimédia
  - 3.2.5 Communication de données graphiques
  - 3.2.6 Techniques de présentations orales et communication interpersonnelle
- **3.3 COMMUNICATION EN LANGUE ÉTRANGÈRE**
  - 3.3.1 Anglais
  - 3.3.2 Langues régionales des nations industrialisées
  - 3.3.3 Autres langues

4 IMAGINER, CONCEVOIR, RÉALISER ET EXPLOITER DES SYSTÈMES DANS UN CONTEXTE SOCIÉTAL ET D'ENTREPRISE

4.1 CONTEXTE EXTERNE ET SOCIÉTAL [h]

4.1.1 Les rôles et responsabilités d'un ingénieur
4.1.2 L'impact de l'ingénierie dans la société
4.1.3 Règlementation de l'ingénierie
4.1.4 Le contexte historique et culturel
4.1.5 Les valeurs et les enjeux contemporains [j]
4.1.6 Développement d'une perspective globale

4.2 CONTEXTE COMMERCIAL ET D'ENTREPRISE

4.2.1 Compréhension des différentes cultures corporatives
4.2.2 Stratégie d'entreprise, établissement des objectifs et planification
4.2.3 Entrepreneuriat technique
4.2.4 Savoir travailler efficacement au sein d'une organisation

4.3 IMAGINER ET CONCEPTUALISER DES SYSTÈMES D'INGÉNIERIE [c]

4.3.1 Établir les objectifs et les spécifications d'un système
4.3.2 Définir les fonctions, le concept et l'architecture
4.3.3 Modélisation de systèmes et atteinte des objectifs
4.3.4 Développement et gestion de projets

4.4 CONCEVOIR [c]

4.4.1 Processus de conception
4.4.2 Mise en phase du processus de conception et de l'information afférente
4.4.3 Organisation de l'information dans le cadre de la conception
4.4.4 Conception à l'intérieur d'une discipline
4.4.5 Conception dans un cadre multidisciplinaire
4.4.6 Conception à objectifs multiples(DFX)

4.5 RÉALISER [c]

4.5.1 Conception du processus de mise en œuvre
4.5.2 Processus de fabrication du matériel
4.5.3 Processus de réalisation d'un logiciel
4.5.4 Intégration matériel-logiciel
4.5.5 Test, vérification, validation, et certification
4.5.6 Gestion de la mise en œuvre

4.6 EXPLOITER [c]

4.6.1 Conception et optimisation des opérations
4.6.2 Formation et opérations
4.6.3 Cycle de vie d'un système
4.6.4 Amélioration et évolution des systèmes
4.6.5 Questions relatives à la fin d'un systèmes
4.6.6 Gestion des opérations

APPENDIX D. The CDIO Syllabus (Spanish)
(Traducción FCFM - Universidad de Chile)

1,1 Demostrar capacidad de usar los principios de las ciencias básicas
1,2 Aplicar los principios de las ciencias de la ingeniería
1,3 Demostrar capacidad de aplicar el conocimiento de las áreas profesionales de la ingeniería.

2. Habilidades y atributos personales y profesionales

2,1 Analizar y Resolver problemas de Ingeniería
- Identificar y formular problemas
- Crear y usar modelos
- Estimar y analizar problemas en forma cualitativa
- Analizar problemas bajo condiciones de incertidumbre
- Resolver problemas y hacer recomendaciones

2,2 Conducir investigación y experimentos sobre problemas ingenieriles
- Formular hipotesis
- Realizar búsquedas de la literatura escrita y electrónica
- Conducir investigaciones experimentales
- Probar y defender hipotesis

2,3 Pensamiento sistémico
- Pensar holísticamente
- Reconocer la aparición de nuevas propiedades y la interacción entre elementos de un sistema.
- Identificar factores, sus prioridades y detectar aquellos de mayor relevancia
- Identificar trade offs (tasa de sustitución) y, elección de soluciones que balancean múltiples factores y que incorporan juicio

2,4 Dominar habilidades personales que contribuyan al éxito de la práctica de la ingeniería, entre ellas:
- Iniciativa y voluntad de aceptar riesgos
- Perseverancia y flexibilidad
- Pensamiento creativo
- Pensamiento crítico
- Conciencia de sí mismo
- Curiosidad y aprendizaje continuo
- Gestión del tiempo y recursos

2,5 Dominar habilidades profesionales que contribuyan al éxito de la práctica de la ingeniería, entre ellas:
- Ética profesional, integridad y responsabilidad
- Comportamiento profesional
- Planificación proactiva de su carrera
- Actualidad de conocimiento en el campo de la ingeniería

3. Habilidades interpersonales: trabajo en equipo y comunicación.

3,1 Liderar y trabajar en grupos

- Formación de equipos efectivos
- Capacidad de operación de equipos
- Identificar y desarrollar habilidades para el crecimiento y evolución del equipo
- Ejercer liderazgo de equipo y capacidad de dirección de equipos
- Capacidad de trabajar en distintos tipos de equipos y colaborar técnicamente con los otros miembros del equipo.

3,2 Comunicación efectiva

- Analizar situaciones y elegir estrategias comunicacionales
- Construir estructuras comunicacionales adecuadas
- Comunicación por escrito
- Comunicación por medio electrónico/multi media
- Comunicación por medio gráfico
- Comunicación en presentaciones orales

4. Concebir, diseñar, implementar y operar sistemas en empresas y contextos sociales.

4,1 Reconocer la importancia del contexto social en la práctica de la ingeniería Entender el rol y la responsabilidad de los ingenieros

- Comprender el impacto de la ingeniería en la sociedad
- Describir las regulaciones sociales sobre la ingeniería
- Describir el contexto histórico y cultural preponderantes
- Desarrollar una perspectiva global

4,2 Apreciar diferentes culturas empresariales y trabajar exitosamente en organizaciones

- Apreciar diferentes culturas empresariales
- Reconocer la estrategia empresarial, sus metas y sus sistemas de planificación
- Reconocer el emprendimiento técnico
- Trabajar exitosamente en organizaciones

4,3 Concebir y aplicar ingeniería a los sistemas

- Fijar las metas y requerimientos de un sistema
- Definir función, conceptos y arquitectura de un sistema
- Desarrollar modelos de sistema que permitan evaluarlo
- Gestionar proyectos de desarrollo

4,4 Diseñar sistemas complejos

- El proceso de diseño
- Explicar las fases de un proceso de diseño y los enfoques
- Uso de conocimiento técnico en el diseño
- Diseño de procesos de la Disciplina
- Diseño multidisciplinario
- Diseño de Procesos con múltiples objetivos

4,5 Implementar procesos de hardware y software y gestionar los procedimientos de implementación

- Diseñar el proceso de implementación
- Describir el proceso de fabricación del hardware
- Describir el proceso de implementación del software
- Describir la integración de hardware y software
- Probar, verificar, validar y/o certificar el proceso
- Gestión de la implementación

4,6 Operar sistemas complejos, procesar y gestionar operaciones

- Diseñar y optimizar operaciones
- Describir la capacitación en operaciones
- Funciones de soporte a lo largo del ciclo de vida del sistema (eg: mantención, logística, etc)
- Reconocer la evolución y los mejoramientos del sistema y su eliminación
- Gestión de Operaciones

APPENDIX E. The CDIO Syllabus (Chinese)

1 **技术知识和推理**	1.1 相关科学知识 （由具体专业确定） 1.2 核心工程基础知识 （由具体专业确定） 1.3 高级工程基础知识 （由具体专业确定）	
2个人能力、职业能力和素质	2.1工程推理和解决问题的能力	2.1.1 发现问题和系统的表述问题 2.1.2 建模 2.1.3 估计与定性分析 2.1.4 带有不确定性的分析 2.1.5 解决方法和建议
	2.2实验和发现知识	2.2.1 建立假设 2.2.2 查询印刷资料和电子文献 2.2.3 实验性的探索 2.2.4 假设检验与答辩
	2.3 系统思维	2.3.1 全方位思维 2.3.2 系统的显现和交互作用 2.3.3 确定主次与重点 2.3.4 解决问题时的妥协、判断和平衡
	2.4个人能力和态度	2.4.1 主动性与愿意承担风险 2.4.2 执着与变通 2.4.3 创造性思维 2.4.4 批判性思维 2.4.5 了解个人的知识、能力和态度 2.4.6 求知欲和终身学习 2.4.7 时间和资源的管理
	2.5职业能力和态度	2.5.1 职业道德、正直、责任感和负责任 2.5.2 职业行为 2.5.3 主动规划个人职业 2.5.4 与世界工程发展保持同步

3人际交往能力：团队工作和交流	3.1团队工作	3.1.1 组建有效的团队
		3.1.2 团队工作运行
		3.1.3 团队成长和演变
		3.1.4 领导能力
		3.1.5 形成技术团队
	3.2 交流	3.2.1 交流的策略
		3.2.2 交流的结构
		3.2.3 书面的交流
		3.2.4 电子及多媒体交流
		3.2.5 图表交流
		3.2.6 口头表达和人际交流
	3.3使用外语的交流	3.3.1 英语
		3.3.2 其他区域工业国的语言
		3.3.3 其他语言

4在企业和社会环境下构思、设计、实施、运行系统	4.1外部和社会背景环境	4.1.1 工程师的角色与责任 4.1.2 工程对社会的影响 4.1.3 社会对工程的规范 4.1.4 历史和文化背景环境 4.1.5 当代课题和价值观 4.1.6 发展全球观
	4.2企业与商业环境	4.2.1 重视不同的企业文化 4.2.2 企业战略、目标和规划 4.2.3 技术创业 4.2.4 成功地在一个组织中工作
	4.3系统的构思与工程化	4.3.1 设立系统目标和要求 4.3.2 定义功能、概念和结构 4.3.3 系统建模和确保目标实现 4.3.4 开发项目的管理
	4.4 设计	4.4.1 设计过程 4.4.2 设计过程的分段与方法 4.4.3 知识在设计中的利用 4.4.4 单学科设计 4.4.5 多学科设计 4.4.6 多目标设计（DFX）
	4.5 实施	4.5.1 设计实施过程 4.5.2 硬件制造过程 4.5.3 软件实现过程 4.5.4 硬、软件集成 4.5.5 测试、证实、验证和认证 4.5.6 实施过程的管理
	4.6 运行	4.6.1 运行的设计和优化 4.6.2 培训与操作 4.6.3 支持系统的生命周期 4.6.4 系统改进和演变 4.6.5 弃置与（产品或系统）生命终结问题 4.6.6 运行管理

APPENDIX F. The CDIO Syllabus (v. 2.0) and the CDIO+LE Syllabus

May 2009

With minor clarifications and additions, principally on Sustainability and National Standards,
Additions that make it the CDIO+EL Syllabus (Entrepreneurship, Leadership) in blue
Coordinated with UNESCO four pillars
Entrepreneurship and Leadership are added as part of the CDIO+EL Syllabus

1 DISCIPLINARY (SUBJECT-BASED) KNOWLEDGE AND REASONING (was TECHNICAL KNOWLEDGE AND REASONING) (UNESCO: Learning to know)
- 1.1. KNOWLEDGE OF UNDERLYING MATHEMATICS AND SCIENCES [a]
- 1.2. CORE ENGINEERING FUNDAMENTAL KNOWLEDGE [a]
- 1.3. ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE, METHODS AND TOOLS [k]

2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES (UNESCO: Learning to be)
- 2.1. ANALYTICAL REASONING AND PROBLEM SOLVING (was ENGINEERING REASONING AND PROBLEM SOLVING) [e]
  - 2.1.1. Problem Identification and Formulation
  - 2.1.2. Modeling
  - 2.1.3. Estimation and Qualitative Analysis
  - 2.1.4. Analysis With Uncertainty
  - 2.1.5. Solution and Recommendation
- 2.2. EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY [b]
  - 2.2.1. Hypothesis Formulation
  - 2.2.2. Survey of Print and Electronic Literature
  - 2.2.3. Experimental Inquiry
  - 2.2.4. Hypothesis Test, and Defense

[Revise text one layer down to include the issues of human and social science research]
- 2.3. SYSTEM THINKING
  - 2.3.1. Thinking Holistically
  - 2.3.2. Emergence and Interactions in Systems
  - 2.3.3. Prioritization and Focus
  - 2.3.4. Trade-offs, Judgment and Balance in Resolution
- 2.4. CREATIVE AND CRITICAL THINKING, LEARNING AND PERSONAL RESOURCES (was PERSONAL SKILLS AND ATTITUTES)
  - 2.4.1. (Moved to 2.5.6)
  - 2.4.2. (Moved to 2.5.8 and 2.5.9)
  - 2.4.3. Creative Thinking
  - 2.4.4. Critical Thinking
  - 2.4.5. Self-awareness and Meta-cognition (was Awareness of One's Personal Knowledge, Skills, and Attitudes)
  - 2.4.6. Lifelong Learning and Educating Others [i] (was Curiosity and Lifelong Learning)
  - 2.4.7. Time and Resource Management
  - 2.4.8. Knowledge Integration (Ensembling)
- 2.5. ETHICS, PROFESSIONAL RESPONSIBILITY, EQUITY, AND OTHER CORE PERSONAL VALUES (was PROFESSIONAL SKILLS AND ATTITUDES)
  - 2.5.1. Ethics, Integrity and Social Responsibility [f] (was Ethics, Integrity, Responsibility and Accountability)
  - 2.5.2. Professional Behavior and Responsibility [f]
  - 2.5.3. Proactively Planning for One's Career
  - 2.5.4. Staying Current on the World of Engineering
  - 2.5.5. Equity and Diversity
  - 2.5.6. Initiative and the Willingness to Make Decisions in the Face of Uncertainty(moved from 2.4.1, was Initiative and Willingness to Take Risks)
  - 2.5.7. Responsibility, Urgency and Will to Deliver (moved from 2.4.2 was part of Perseverance and Flexibility, and 2.5.1 Professional Ethics, Integrity, Responsibility and Accountability)
  - 2.5.8. Resourcefulness and Flexibility (moved from 2.4.2 was part of Perseverance and Flexibility)
  - 2.5.9. Trust and Loyalty
  - 2.5.10. Vision and Intention in Life

3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION (UNESCO: Learning to live together)

- 3.1. TEAMWORK [d]
  - 3.1.1. Forming Effective Teams
  - 3.1.2. Team Operation
  - 3.1.3. Team Growth and Evolution
  - 3.1.4. Team Leadership (was leadership)
  - 3.1.5. Technical and Multi-disciplinary Teaming (was Technical Teaming)
- 3.2. STRUCTURED COMMUNICATIONS [g] (was Communications)
  - 3.2.1. Communications Strategy
  - 3.2.2. Communications Structure
  - 3.2.3. Written Communication
  - 3.2.4. Electronic/Multimedia Communication
  - 3.2.5. Graphical Communication
  - 3.2.6. Oral Presentation (was Oral Presentation and Inter-Personal Communications)
- 3.3. COMMUNICATIONS IN A FOREIGN LANGUAGE
  - 3.3.1. Communications in English
  - 3.3.2. Communications in languages of regional industrial nations (was incorrectly "of the EU")
  - 3.3.3. Communications in other languages (was incorrectly "outside the EU")
- 3.4. INFORMAL COMMUNICATIONS: RELATING TO OTHERS
  - 3.4.1. Inquiry, Listening and Dialog
  - 3.4.2. Negotiation, Compromise and Conflict Resolution
  - 3.4.3. Advocacy
  - 3.4.4. Establishing Diverse Connections (Grouping)

4 CONCEIVING, DESIGNING, IMPLEMENTING, AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND ENVIRONMENTAL CONTEXT – INNOVATION (UNESCO: Learning to do)

- 4.1. EXTERNAL, SOCIETAL, ECONOMIC AND ENVIRONMENTAL CONTEXT [h]
  - 4.1.1. Roles and Responsibility of Engineers
  - 4.1.2. The Impact of Engineering on Society and the Environment
  - 4.1.3. Society's Regulation of Engineering
  - 4.1.4. The Historical and Cultural Context
  - 4.1.5. Contemporary Issues and Values [j]
  - 4.1.6. Developing a Global Perspective
  - 4.1.7. Sustainability and the need for sustainable development
- 4.2. ENTERPRISE AND BUSINESS CONTEXT
  - 4.2.1. Appreciating Different Enterprise Cultures
  - 4.2.2. Enterprise Stakeholders, Strategy and Goals (was Enterprise Strategy, Goals, and Planning)
  - 4.2.3. Technical Entrepreneurship (Expanded in 4.8 of the CDIO+LE Syllabus)
  - 4.2.4. Working in Organizations (successfully omitted)
  - 4.2.5. Engineering Project Finance and Economics (added, was in 4.2.2.)
  - 4.2.6. New Technology Development, Assessment and Infusion (added, was in 4.2.2)
- 4.3. CONCEIVING, SYSTEMS ENGINEERING AND MANAGEMENT (WAS CONCEIVING AND ENGINEERING SYSTEMS) [c]
  - 4.3.1. Understanding Needs and Setting Goals (was Setting System Goals and Requirements)
  - 4.3.2. Defining Function, Concept and Architecture
  - 4.3.3. Modeling of System and Insuring Goals Can Be Met
  - 4.3.4. System Engineering and Development Project Management (was Development Project Management)
- 4.4. DESIGNING [c]
  - 4.4.1. The Design Process
  - 4.4.2. The Design Process Phasing and Approaches
  - 4.4.3. Utilization of Knowledge in Design
  - 4.4.4. Disciplinary Design
  - 4.4.5. Multidisciplinary Design
  - 4.4.6. Design for Sustainability, Safety, Operability, Aesthetics and other Objectives (was Multi-Objective Design (DFX))
- 4.5. IMPLEMENTING [c]
  - 4.5.1. Designing a Sustainable Implementation Process (was Designing the Implementation Process)
  - 4.5.2. Hardware Manufacturing Process

4.5.3. Software Implementing Process
4.5.4. Hardware Software Integration
4.5.5. Test, Verification, Validation, and Certification
4.5.6. Implementation Management

4.6. OPERATING [c]

4.6.1. Designing and Optimizing Sustainable and Safe Operations (was Designing and Optimizing Operations)
4.6.2. Training and Operations
4.6.3. Supporting the System Lifecycle
4.6.4. System Improvement and Evolution
4.6.5. Disposal and Life-End Issues
4.6.6. Operations Management

4.7. LEADING ENGINEERING ENDEAVORS [in CDIO+EL Syllabus]

Engineering Leadership builds on factors already included above, including:

- **Core Personal Values and Character of Leadership** including topics in Ethics, Professional Responsibility, Equity, and Other Core Personal Values (2.5), and Self-Awareness and Meta-cognition (2.4.5), and Lifelong Learning and Educating Others (2.4.6)
- **Relating to Others**, including topics in Informal Communications (3.4) Teamwork (3.1) and Structured Communications (3.2), and potentially Communications in a Foreign Language (3.3)
- **Making Sense of Context**, including topics in External, Societal and Natural Context (4.1); Enterprise and Business Context (4.2) and System Thinking (2.3)

In addition there are several topics that constitute creating a **Purposeful Vision (Enterprising)**:

4.7.1. Thinking Creatively and Imagining Possibilities (which builds on and expands Creative Thinking 2.4.3)
4.7.2. Defining the Solution (which builds on and expands Understanding Needs and Setting Goals 4.3.1)
4.7.3. Creating New Solution Concepts (which builds on and expands 4.3.2 and 4.3.3)

And several topics that lead to **Realizing the Vision (Engineering)**

4.7.4. Building and Leading and Organization and Extended Organization (which builds on 4.2.4)
4.7.5. Planning and Managing a Project to Completion (which builds on 4.3.4)
4.7.6. Exercising Project/Solution Judgment
4.7.7. Innovation – the conception, design and introduction of new goods and services (which builds on 4.4)
4.7.8. Invention – the development of new devices, materials or processes that enable new goods and services
4.7.9. Implementation and Operation – the creation and operation of the goods and services that will delver value (which are the leadership of 4.5 and 4.6)

These last three items are in fact the leadership of the core processes of engineering: conceiving, designing, implementing and operating

4.8. ENGINEERING ENTREPRENEURSHIP [in CDIO+EL Syllabus]

Engineering Entrepreneurship includes by reference all of the aspects of Societal and Enterprise Context (4.1 and 4.2), all of the skills of Conceiving, Designing, Implementing and Operating (4.3 – 4.6) and all of the elements of Engineering Leadership (4.7). In addition, there are the Entrepreneurship specific skills:

4.8.1. Company Founding, Formulation and Organization
4.8.2. Business Plan Development
4.8.3. Company Capitalization and Finances
4.8.4. Innovative Product Marketing
4.8.5. Conceiving products and services around new technologies
4.8.6. The Innovation System, Networks, Infrastructure and Services
4.8.7. Building the Team and Initiating Engineering Processes (conceiving, designing, implementing and operating)
4.8.8. Managing Intellectual Property

Biographical Information

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Out-of-Classroom Experiential Learning For Students' Learning in Structural Engineering

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ABSTRACT

Structural engineering modules in Diploma in Civil Engineering and Management (DCEM) course are traditionally perceived by students as "abstract", "dry" and "hard to visualize". Students tend to have difficulties in grasping the basic concepts of structural behaviour. Conventional ways of teaching have shortcomings in terms of motivating students learning structural engineering.

In the context of Conceiving, Designing, Implementing, and Operating (CDIO) framework, this paper discusses the approach conceived and implemented by the module team to make the learning more meaningful and promote student understanding. In particular, "Structural Review" and "Structural Competition" have been used to motivate and enhance students' learning of structural analysis.

Student survey results have demonstrated that the use of fun-based learning activities and competitions increased student's motivation and interest in learning structural engineering as well as developing better problem solving skills.

The paper concludes that the use of these approaches, leveraging on appropriate information technologies, can provide powerful motivational strategies and encourage students to be more participative and creative in their learning.

KEYWORDS

Experiential Learning, Structural Competition, Structural Review, Problem Solving Skills, CDIO Framework, Motivational Strategies.

.

INTRODUCTION

Students learn in many ways – by seeing and hearing; reflecting and acting; reasoning logically and intuitively; memorizing and visualizing; drawing analogies and building mathematical models. Teaching methods also vary. Some lecture, others demonstrate or discuss; some focus on principles and others on applications; some emphasize memory and others understanding. How much a student learns in a class is governed in part by that student's learning ability, prior preparation and also the compatibility of his of her learning style and the lecturer's teaching style.
Mismatches exist between common learning styles of students and traditional teaching styles of lecturers. In consequence, students become bored and inattentive in class, do poorly on tests, and get discouraged about the courses, the curriculum and themselves, and in some cases change to other courses or drop out of the course.
At present, the learning environment for our students is the fairly passive lecture-discussion format where lecturers talk and students listen.
Experiential Learning [1] enables students to experience and learn whereas the lecturer is to explore, provide and facilitates students' learning.

Students from the Diploma in Civil Engineering and Management (DCEM), traditionally have difficulties in grasping the concepts of structural behaviour. They tend to do learning by concentrating on manipulation of equations and memorising particular solutions which obscures the underlying important concepts and principles. These students are usually weak in their foundational knowledge of Mathematics and Physics. They could not appreciate the abstract nature of the underlying basic concepts involved as well as the behaviour of the structures.

On the other hand, the approach at present to teaching these modules by lecturers usually includes a series of lectures on physical laws, mathematical tools and methods for structural analysis and design by using methodology which consecutively subdivides a real world structure into extremely small subcomponents, focusing on a particular element, detaching it from all other connected structural members and then reducing it to a notation system of structural symbols, mathematical equations and annotations. Structural modules delivered in this way will only get students too much involved in calculation tedium and almost never attempts to connect detailed analysis back to broader structure design and construction principles, which results in not seeing the wood from trees.

To address problems existing in the staff teaching and student learning of structural modules, initiatives which are aiming at improving students performance in these structural modules have been proposed by the module team. These initiatives are mainly on four basic areas: increase in active and hands-on learning, emphasis on problem formulation and solution, more focus on concept learning and enhancement of learning feedback mechanisms.

Applying the "CDIO" concept, students experience the 4 stages of C-D-I-O while doing their course work. This is to ensure that students master the fundamental concepts of structural engineering. Module teams believe that abstract structural concepts will become meaningful when students could experience "real-life" phenomena. The goal of experiential teaching and learning is to motivate students to learn curriculum materials and to increase their intrinsic interests in further learning.

OUT- OF - CLASSROOM EXPERIENTIAL LEARNING

Experiential learning uses various tools like games, simulations, role plays and stories in classrooms. The experiential learning mindset changes the way the teachers and students view knowledge. Knowledge is no longer just some letters on a page. It becomes active, something that is transacted with in life or life-like situations. It starts to make teachers experience as the providers, and not just transmitters of the written word. Students become knowledge creators (for themselves) as well as knowledge gatherers.

Besides changing student roles, experiential learning requires a change in the role of teachers. When students are active learners, their endeavours often take them outside the classroom walls. Because action precedes attempts to synthesize knowledge, teachers generally cannot plan a curriculum unit as a neat, predictable package. Teachers become active learners, too, experimenting together with their students, reflecting upon the learning activities they have designed, and responding to their students' reactions to the activities. In this way, teachers themselves become more active; they come to view themselves as more than just recipients of institution's policy and curriculum decisions.

Experiential education [2] empowers students to take responsibility for their own learning; because it requires new roles of students, teachers, and administrators. It can provide a different, more engaging way of treating academic content through the combination of action and reflection.

Staff who is very comfortable with traditional way of delivering lectures remains unconvinced that more interactive teaching will lead to increased student learning and hence improved student performance. Colleagues whom we have talked with are also concerned that the time and effort required for curriculum revision from traditional way of teaching to more interactive teaching would be prohibitive, that their students would learn less content, that outcomes could not be reliably assessed. Such changes would take students and staff alike out of their current comfort zones.

To address the validity of these concerns and to shift our teaching from quantity of learning to quality of learning [3], authors spoke to lecturers who are teaching structural modules and carried out brain-storming sessions. A motivational learning strategy, i.e. interactive and collaborative learning was thus recommended by the authors. The strategy geared towards teaching is the holistic approach which is multifaceted, encompassing a wide variety of creative methods and techniques based on current theories and research of how people learn best. The strategy suggests that teaching focus be put on conceptual understanding of structural behaviour and analytical and design skills of structural systems while allocating more time on interactive learning of students by encouraging collaborative activities. The learning techniques could enhance retention and performance, and hence students become effective learners.

The Background

The module "Structural Analysis & Simulation" is a year-long 2nd year core module from the Diploma in Civil Engineering and Management (DCEM). The perception of this module by many students is "abstract", "dry" and "hard to visualise". Over the past 4 years, the module team had gradually incorporated course-works that require students to explore, participate and apply their knowledge to analyse the various unique structural systems on campus.

The two implemented course-works are designed based on "Out- of Classroom Experiential Learning" concept, i.e. students are involved physically, using their hands to do some works for these two course-works.

These course-works adopted the CDIO framework, i.e. students experience the 4 stages of C-D-I-O while doing their course works. Module teams believe that abstract structural concepts will become meaningful when students could experience “real-life” phenomena.

ARCHIEVING OUT- OF – CLASSROOM EXPERIENTIAL APPROACH BY CONCEIVING, DESIGNING, IMPLEMENTING, OPERATING FUN – FILLED COMPETITIONS AND REAL LIFE ASSIGNMENTS

The interactive and collaborative learning strategy requires students less dependence on rote learning, repetitive tests and a ‘one size fits all’ type of instruction, and more on experiential discovery, engaged learning, the learning of life-long skills, and the building of character through innovative and effective teaching approaches [4].

In order to motivate students to learn structural engineering modules, real time and fun-filled course-works cum competitions on structural analysis and design were conceived in addition to lecture and tutorials sessions. Learning of structural engineering modules now becomes a joyful experience through following the Conceive, Design, Implement and Operate stages of collaborative learning activities.

“Structural Competition”

Students will be assigned to this course work in semester II of each academic year; by then they would have been taught about 75% of the module contents. This assessment requires them to build a bridge truss model made of short timber sticks of about 2 mm diameter.
Students are applying the core knowledge in structural engineering to pitch their skills and knowledge among their peers. They will be able to see, compare and discuss merits and weaknesses of their and peers’ designs.

Models made by students will be tested on the “Structural Simulator” shown in Figure 1 which was developed and fabricated in-house.
The “Structural Simulator” is a mini-instructional bench scale portable laboratory and can be used to do demonstrations and test competitions. It has the ability to display real-time responses of test results. The structural simulation process facilitates real-time comparisons between the analytical predictions and the experimental data.

Preparing the students:

The project brief about the course-work will be prepared and up-loaded into “BlackBoard” (Singapore Polytechnic’s e_Learning platform) together with the supplementary Power Point document of some of the past years tested models. Students will be briefed on the characteristic of axial force members, material properties, joining techniques and load distribution pattern.

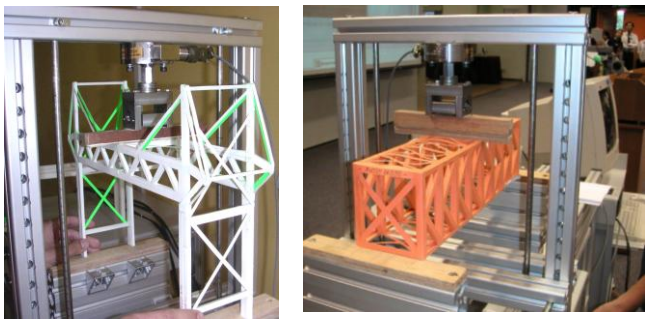

Figure 1. The Structural Simulator

The course-work

The target of the competition is to pursue the highest load-self weight ratio. One point load is applied at the middle of the model via the 100 mm wide loading head.

For the load testing, a vertical load will be gradually applied at the centre point on top of the bridge model. The graph of load versus mid-span deflection will be plotted online. Loading will be increased until the failure of the model. Failure is considered being reached by either of the two conditions: (1) With a monotonic increasing of deformations, the current load level drops below 85% of the previous highest load level; (2) The deflection at the middle of the span exceeds 15 mm.

Relevant CDIO clauses

The following four CDIO clauses are adopted for this course-work:

- Conceive Stage – CDIO Clause 4.3.3:
  Select and Identify suitable truss system for the model
- Design Stage – CDIO Clause 4.4.1:
  Synthesize the chosen truss system by using structural software
- Implementation Stage – CDIO Clause 4.5.3
  Model fabrication process
- Operation Stage - CDIO Clause 4.5.5
  Model testing

"Structural Review"

This course-work is planned for students to explore and to appreciate real structural systems on campus. They learn about structural systems through textbooks, student notes, etc. in which simplifications are already made in many situations. For example, the support conditions, loadings and member profiles. In this assessment, students are to apply knowledge gained from this module as well as from other related modules as well, e.g. the methods learnt in Geomatics to obtain actual dimensions of the structure. After the completion of this experiential learning assessment, students will have better understanding of the performance and behaviour of real structural systems. They will have clearer visualization of how forces and moments are being transferred from the members to supports. Four on campus structural systems are identified and students are required to choose one of these systems as their topic. They need to model the actual structural systems into mathematical models. These proposed structural systems are:

a. SP W515 – Roof Truss
b. SP Phase III Linked Bridge @ T20/21.
c. SP Phase V Linked Bridge @ T12A / T14
d. SP linked walk-way between T12 and T11A.

Students are required to obtain actual measurements on site. They could use their knowledge acquired in Geomatics module to obtain the overall length, width and height of the chosen structures. They have to also assess the dead loads and live loads imposed on the structures by performing appropriate loadings transfer from roof / deck slab to the supporting structural members.

Preparing the students

The project brief about the course-work will be prepared and up-loaded into “BlackBoard” together with the supplementary Power-Point document about the proposed structural systems. Students will be briefed on the proposed structural characteristics, e.g. structural models, support conditions, types of loadings, materials, etc. Lists of live load and dead load for different usage conditions are given and students will be taught how to assign these loadings to the structural system for various usages.

The course-work

This course-work requires students to get-out of their classrooms, into the actual world (i.e. the campus) to do on-site assessment. They will model the actual structures with appropriate loadings on the structure models for analysis using the structural software, SAP2000 [4].
Students are to submit written reports by the due date; and to present their works during tutorial session. Bonus marks will be awarded in two areas: i.e. early submission and adopting “Flash” animation to display structural behaviour.

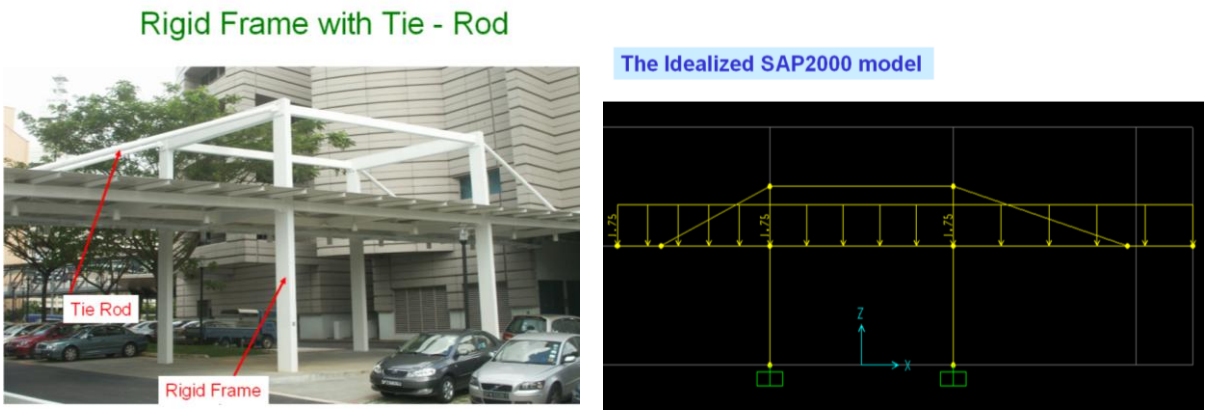

Figure 2. SP new linked walk-way between T12 and T11A

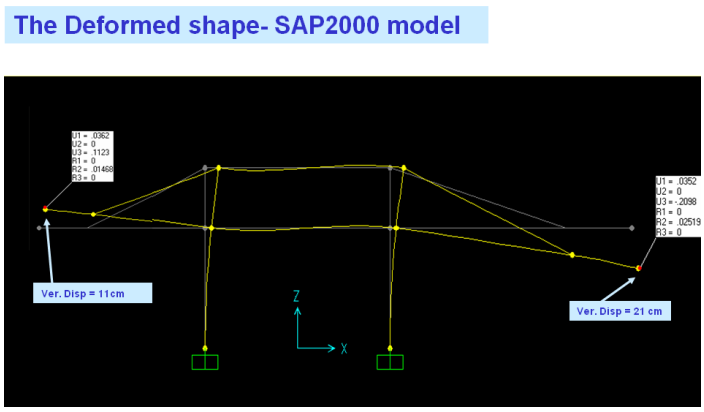

Figure 3. The SAP2000 model

EXPERIEMTIAL LEARNING – MOTIVATING STUDENTS' LEARNING OF STRUCTURAL ENGINEERING WITH REAL – LIFE COURSE WORK AND COMPETITION

"Structural Competition" and *"Structural Review"* have been conducted for a few years. In order to have better understanding and accurate evaluation of the effectiveness of the interactive and collaborative learning strategy, the module team conducted a Black-Board based students' survey. For every question, students need to rate on the scale of "1" to "5" (1- Least, 5- Excellent) in the following areas for both "BEFORE" and "AFTER" these real-life course work and competition:

1) Able to apply knowledge of basic structural fundamental concepts.
2) Able to identify problem, formulate solutions.
3) Able to communicate effectively within the team.
4) Able to function effectively as an individual team member / team leader for the team.

About 100 students participated in the survey; the outcomes of the survey are as shown below. Comments are made *w.r.t*. responses for scale point 4 and 5.

1) Able to apply knowledge of basic structural fundamental concepts:

	Before	After
1	1.45%	1.45%
2	2.90%	0.00%
3	47.83%	17.39%
4	33.33%	50.73%
5	14.49%	30.44%

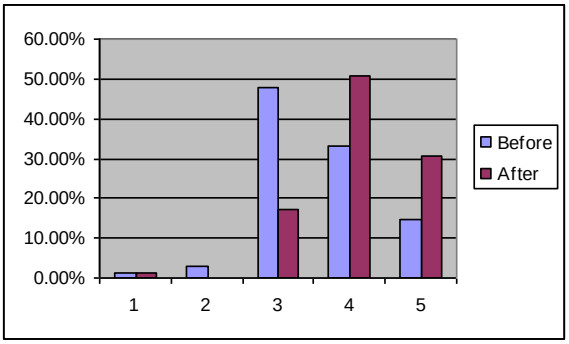

Figure 4 Apply knowledge of basic structural fundamental concepts

Module Team's Comments: Majority (After =81.17% vs. Before = 47.82%) indicated that they were able to apply the knowledge of basic structural fundamental concepts after these course works.

2) Able to identify problem, formulate solutions

	Before	After
1	1.45%	0.00%
2	10.15%	0.00%
3	37.68%	23.19%
4	36.23%	52.17%
5	13.04%	24.64%

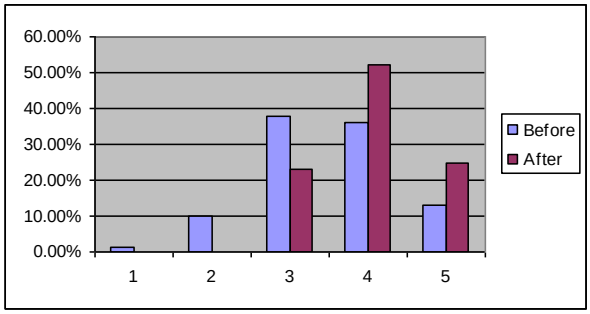

Figure 5 Identify problem, formulate solutions

Module Team's Comments: (After=76.81% vs. Before = 49.27%) of students indicated that they were better in formulating solutions for problem after these course works.

3) Able to communicate effectively within the team.

	Before	After
1	0.00%	0.00%
2	5.80%	4%
3	20.29%	15.94%
4	40.58%	36.23%
5	33.33%	43.48%

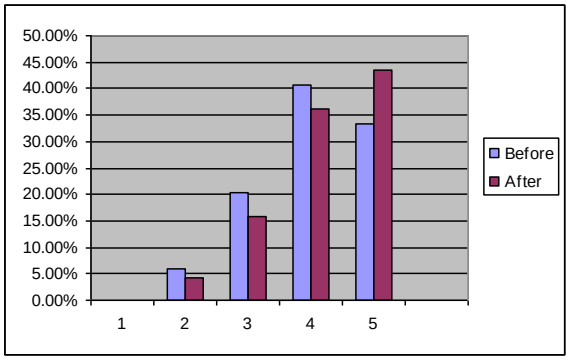

Figure 6 Communicate effectively within the team

Module Team's Comments: Majority (After =79.71% vs. Before = 73.91%) indicated that they are able to communicate more effectively after having gone through these course works.

4) Able to function effectively as an individual team member / team leader for the team.

	Before	After
1	0.00%	0.00%
2	7.25%	0.00%
3	27.54%	24.64%
4	43.48%	39.13%
5	21.74%	36.23%

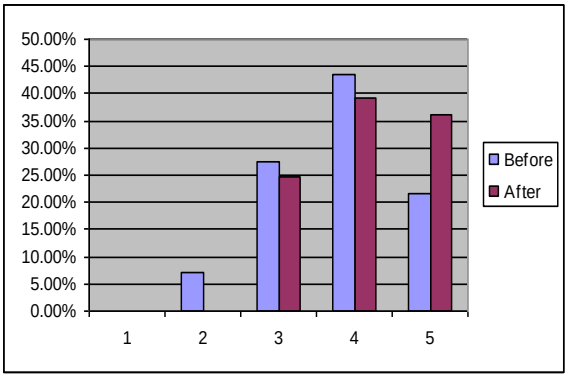

Figure 7 Function effectively as a team

Module Team's' Comments: Majority (After = 75.36% vs. Before = 65.22%) indicated that they had gained much experience in functioning effectively as a team leader / member

The module team is encouraged by the outcomes of the quantitative survey and qualitative responses by the students. Majority of the students (approx 76%) had benefited much from the above two fun-filled experiential learning activities. Students' learning has been greatly motivated and enhanced. Students can now understand better the structural behaviours and the important underlining concepts. They also can now apply textbook structural theories to the real world applications.

The module team also observed in general that students do not view the structural engineering modules as something that are abstract, virtual and difficult to learn.

Some of the students' comments – "Structural Competition"

- Overall, it is a very meaningful experience for both me and my team-mates because we learnt the ups and downs of doing something as a group.
- It was an enjoyable experience to be able to do the bridge competition. This gave us the opportunity to put what we learnt during class lesson into actual use.
- I learnt a lot in this project because it is very interesting and exciting. It also gives me a rough idea on how a real life bridge is constructed.
- Through this project, i understand the important of team effort and also the toughness of build a structure. it require time and human resource to complete the entire project. Hence, I enjoy this project fully.
- Teamwork is essential for the success of our project and no man can work alone.

Some of the students' comments – "Structural Review"

- I hope to have more of such project or assignments be introduced in class to enhance our knowledge of what we learnt in class with relation to everyday structure. This would help us to understand better when we actually see structures outside the classroom.
- This outside classroom work is very useful as it is better then looking at papers. This time doing outside work help to visualise how the structural will be able to bend, deform and how to prevent it from becoming structural unstable.
- I have a better understanding on how to calculate the dead and live loads. In addition, I have became more familiarize with the software. Lastly, I got to apply what I have learnt in class to this project.
- In order to gain my knowledge on trusses, I have searched out information from the internet as well as the school library books to help me have a better understanding about the different types of trusses.
- This course-work gives me a chance to apply the knowledge we learned form the books and enhance the relationship between team-mates.

CONCULSIONS

Out-of-Classroom experiential learning through the activities of "Structural Competition" and "Structural Review" is effective in motivating students to acquire domain knowledge. The initiative by module team supports the skills in problem formulation and modelling in the field of structural engineering. It adopts the CDIO approach and has enhanced students' fundamental concept of structural engineering.

The module teams have achieved the following learning outcomes:

- Engaged learning (less drill and practice)
- Differentiated teaching (less "one-size-fits-all" instruction)
- Guiding, facilitating, modelling (less telling)
- Formative and qualitative assessing (less summative and quantitative testing)
- Spirit of innovation and enterprise (less set formulae, standard answers)

The interactive experiential learning activities have greatly motivated students' learning interests in structural engineering modules, improved their understanding of structural behaviours and developed better problem solving skills which are essential in engineering discipline. Students found that the experience is unique, exciting, and practical. They have enjoyed the learning process and they also have given positive feedback about these experiential learning processes. The experience gained is significant and valuable that many of them have agreed that they would not forget the structural concepts that they have learnt through these experiential learning activities.

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Biographical Information

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PARTICIPATIVE LEARNING WITH G-SCANNER AND iDE'LITE

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ABSTRACT

Participative learning enables students to actively shape and share their learning experience, in achieving the goals of reflection and transformation. The learning process is accelerated through e-learning as students are able to learn better with audio and visual multimedia elements. Some problems do arise with e-learning that was not present in textbook learning though. They are: e-learning navigation are not intuitive; students are lost in the maze of information, students losing attentiveness and concentration after staring at the computer monitor too long, students are unable to link up the information properly with the topics and sub-topics. Most students prefer a handy hardcopy textbook for quick overview and reference. Staffs from the Info-Comm Technology Department of ITE College West have created a technology enabled “Interactive Book” concept to capitalize on the advantages and eliminate the problems. Students are able to draw out internet or movie from the text or picture prints in their textbooks by pointing it with an electronic device called a G-Scanner with software application which the dept has created to provide the interface on the computer. By pointing the G-Scanner on any text or diagram in the booklet and the computer will retrieve and display the multimedia explanation. For practical sessions, students are able to log into a web portal known as iDe’Lite. From there they view videos created for topics that were taught. They can also annotate in the videos and view their teacher’s annotations. From the annotations, the teacher can provide comments or correct their mistakes. Students doing practical can also be video recorded and uploaded to iDe’Lite web portal for future references by students and teachers. With authentic activities, and social interaction and negotiations, comes more effective learning for students. This paper presents the participative learning framework enabled by technologies developed by ITE College West and discusses issues related to its implementation in teaching the core module in IT Essential & PC Support using G Scanner for the delivery of the theory portion and iDe'Lite for lab and demo sessions.

KEYWORDS

PARTICIPATIVE LEARNING , G-SCANNER , iDE'LITE , INTERACTIVE BOOK , EMERGING TECHNOLOGIES

CHAPTER 1 INTRODUCTION

Learning out of the classroom started way back in the 1953 with television learning by the University of Houston. Once the computer age came, learning progressed to the computers.

In 1960, PLATO (Programmed Logic for Automated Teaching Operations) system developed at the University of Illinois at Urbana-Champaign. The PLATO system featured multiple roles, including students who could study assigned lessons and communicate with teachers through on-line notes, instructors, who could examine student progress data, as well as communicate and take lessons themselves, and authors, who could do all of the above, plus create new lessons.

The E-learning revolution has arrived.

E-learning enable students to read the information on a topic, view instructional videos, listen to audio aids, and take quizzes and exercises related to the topic. Students are able to learn better with multimedia.

But E-learning didn't really catch on. There are many reasons some stated by Graham Attwell that many e-learning materials are unattractive and non-compelling and the next reason is the poverty of pedagogies for e-learning.

Other complaints are the E-learning navigation are not intuitive; students are lost in the maize of information, losing attentiveness and concentration after staring at the computer monitor too long, students are unable to link up the information properly with the topics and sub-topics.

CHAPTER 2 EMERGING TECHNOLOGY

People are starting to question although E-learning offers long distance learning and learning at each student's own pace, if it is more effective compared to classroom teaching.

Some people still prefer having textbooks or study materials to refer to and to jot down notes. Their argument is that having a hardcopy, would help them retain information better.

Is it possible to have the best of both worlds?

E-learning is able to captivate the students with multimedia elements and exercises and the students can learn at their own pace. Textbooks and study notes help the students retain information better and easier to browse from chapter to chapter. The potential of paper, such as random-access capability and intuitive search with view format is still an outstanding advantage.

In Info-Communications Technology Department, ITE College West, we have created a new, easy and convenient learning model for students by uniting E-learning with Textbook Learning to capitalize on the advantages and eliminate the problems. This is for the theory. For practical sessions, using the software portal named iDe'Lite, students are able to log in and view videos of their past works and step by step instructional video, along with comments tagging.

With the new learning model, students are able to draw out internet or movie from the text or picture prints in their textbooks by pointing it with an electronic device called a G-Scanner and software application which the dept has created to provide the interface on the computer or mobile handphone.

We have created handy Interactive books for some of our theory lessons which contain the core subject information while the detailed information was digitalized and easy to access through the new system. By pointing the G-Scanner on any text or diagram in the booklet and the computer will retrieve and display the multimedia explanation.

The new learning model with successful unity of E-learning and Textbook Learning has been proven effective and we received excellent feedbacks from students. We are able to have a captivating learning with e-learning elements and students can navigate and retain information better with the textbook provided.

CHAPTER 3 EXAMPLES OF APPLICATIONS

There are many applications that can be developed using the G-Scanner with Interactive Book, together with iDe'Lite. We would just focus on the educational applications as follows:

1) E-Navigation Textbook System

The students use condensed textbooks, G-Scanners and multimedia CDs. The textbook are printed with mind maps for each chapter. A mind map is a diagram used to represent words, ideas, tasks or other items linked to and arranged radically around a central key word or idea. It is used to generate, visualize, structure and classify ideas, and as an aid in study, organization, problem solving, decision making, and writing. (an example shown below in Fig1.1)

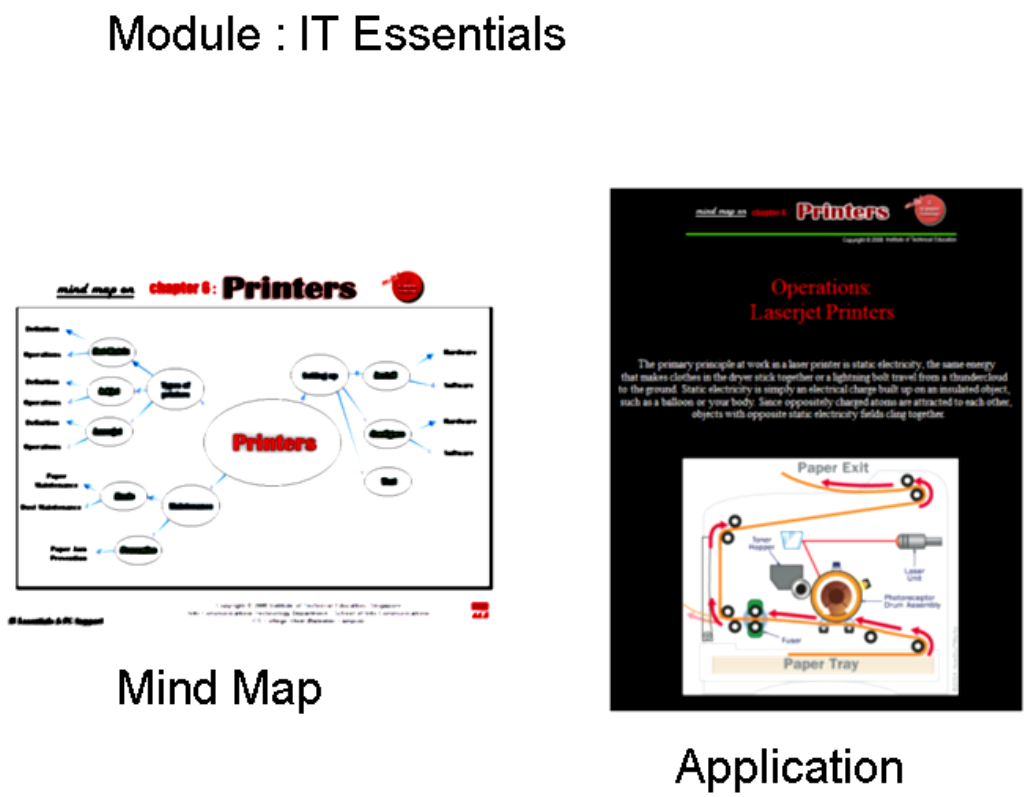

Figure 1-1 : Example of a Mind Map

The mind maps help the students to relate and link the information in the topic for better understanding and recapitulation.

The booklet also contains summaries of the topics taught, condensed information and pointers. This is to keep it handy for quick reference/ overview and not to overload the student with information.

Using the G-Scanner and a computer installed with the user interface application and digital medias, the student can point the G-Scanner on any part of the printed mind maps in the textbook to activate e learning on the PC with interactive video from the iDe'Lite portal, coupled with exercises. They can also view the multimedia presentation of the sub topics. The handy text booklet allows students to see the overview and key concept for the respective topics. Students have feedback that enabling e-navigation on textbook has made learning easier and allow quick reference and retrieval of information.

2) E-Navigation Prospectus

Each new student enrolling into the school is given a prospectus, together with a Cd-rom and a G-Scanner. The student can learn more about the course he or she enrolled for and more about the school. When the picture of particular course, facilities or event is pointed with "G-Scanner", the movies and data of the event are drawn out from attached CD. Student success stories can be incorporated into the CDs for motivation purpose.

This system is a revolution in content organization as it makes an enormous difference to students who would be able to access the data or information they are looking for.

3) E-Navigation Textbook Learning Package to help seniors, physically or mentally disabled students

The keyboard of PCs could be too complicated for seniors, physically or mentally disabled students who have problem keying input text into the computer. With the new learning interface, they can use can achieve what they want by simple and intuitive operation – just touching chosen picture with "G-Scanner". With a booklet on hand, it is easier for mentally disabled students to learn and still be able to navigate around the content of the CD.

4) iDe'Lite portal

ITE College West has created a website portal entitled iDe'Lite which allows students to log in and view past video content related to the modules they took. The videos are recorded and uploaded by lecturers teaching the module.

The iDe'Lite is quite similar to youTube videos, except it has additional features that allow annotations to be typed by lecturers at specific moments of the video to aid the students to understand better the topic the video is showing. iDe'Lite also allows students upload their own video capture of themselves doing work. The teacher would look through their video and comment on their actions and mistakes. Students can then login and view the comments and understand the mistakes pointed out by the teacher.

Interaction through interviews and dialogue is also captured for students' reference. These videos can be shown over and over again to different classes and batches of students. The students can also view the videos at their own learning pace.

CHAPTER 4 THE TRIALS

We tested this project on a class of 26 students with a survey with a survey on why is the subject difficult for them to comprehend. Below are the results of the survey before and after implementation of the project. (Table shown in Fig1-2) The students understand and retain knowledge better after implementing the project.

S/N	Reasons	1st survey responses (Students)	2nd survey responses after implementation of solution (Students)
1	Did not pay attention due to boredom from text based	8	1

	teaching		
2	Notes are difficult to understand and visualize	10	2
3	Do not understand the teacher's description	3	3
4	No problem (NIL)	12	27
5	Duration of lesson too long	3	3

Figure 1-2 : Survey results

We then let the class do assignment 4 after implementing the project. Below is a chart (Figure 1-3) displaying the grades they have achieved. In Assignment 2 and 3, majority scored grades C and D. But after the project is implemented in Assignment 4, the grades for A and B increased. The level of difficulty for assignment 2, 3 and 4 are the same. Assignment 1 is not used in the chart because it is more difficult.

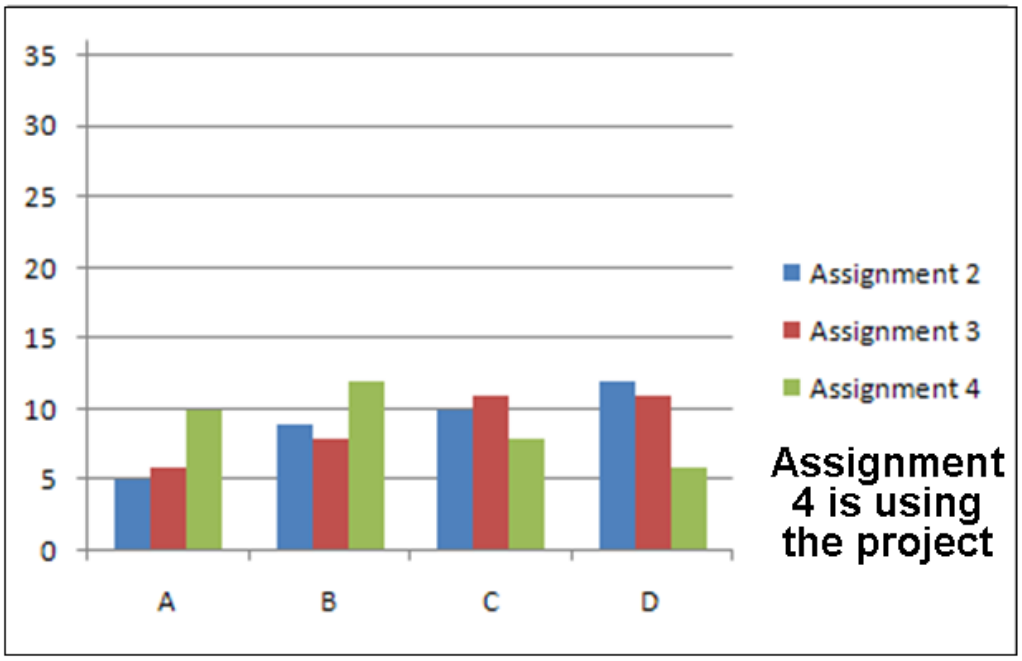

Figure 1-3 : Assignment results

CHAPTER 5 THE BENEFITS

The tangible benefits and intangible benefits are as listed from the implementation of the project.

Tangible Benefits

- Students spend lesser money buying textbooks. Cost savings of up to $170 are saved from buying textbooks from the 2 years course.
- No cost incurred from development
- Better subject grades

Intangible Benefits

- Students are more compelled to learn with the new training materials and methods (Visual aids)
- Students learn faster and better as the new training materials are more visual and audio therefore appeal to their interests.
- Students will contribute to saving the earth by using less paper
- Students has higher retention rate.
- Students will not need to carry around heavy textbooks and lessen their load physically

- Students' morale are boosted

- The students learned better and score better hence strengthening ITE name and image.

- Developing the courseware by ourselves, the team members learnt HTML programming, a new skill for some.

CHAPTER 6 THE TECHNOLOGY

The G-Scanner is basically a small network camera with a dot code transmission device. It is able to read invisible dot codes on printed materials and call out the movies, music or Internet link to be displayed on PCs or handphones. The storages of the information could be CDs installed in the PCs, SD cards or direct downloads through wired/ wireless LAN from Internet servers, of which the codes and the information are tagged (Figure 3.1).

In developing our applications, we have created our teaching materials, printed with invisible dot codes that are tagged to the respective learning contents in digital media, which are stored in CD, SD cards (Figure 2.1) and in our internet server.

Figure 2-1 : User point the G-Scanner on any printed text or picture in the textbook to activate e learning on the Computer.

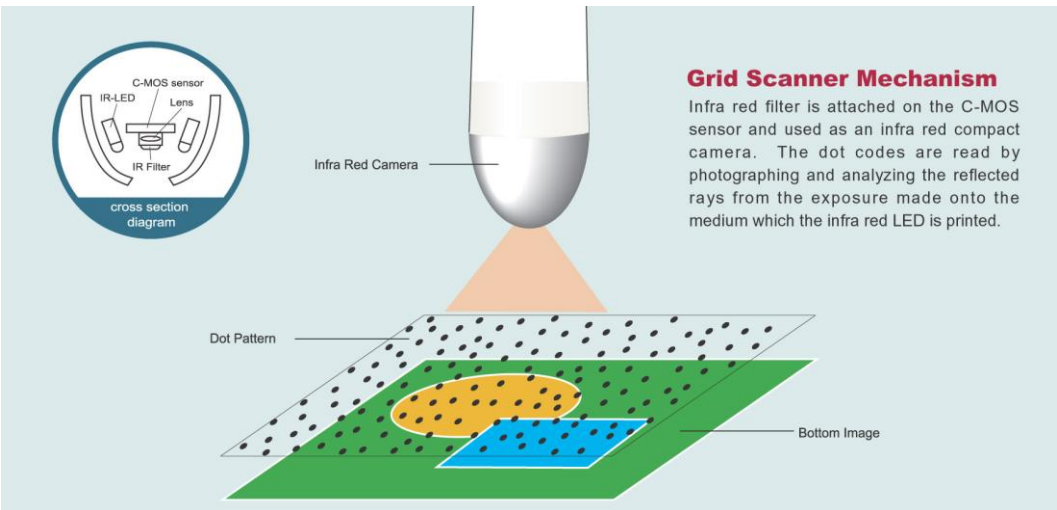

Figure 3-1 : How G-Scanner works

The iDe'Lite portal (Figure 4.1) features streaming videos in flash video (flv) format. They are able to display view cues/ captions along with the video. The cues/ captions can be commentary or instructions to facilitate learning, together with the video, in a practical session. The cues/ captions are inserted in the iDe'Lite software (Figure 4-1) before uploading to iDe'Lite portal.

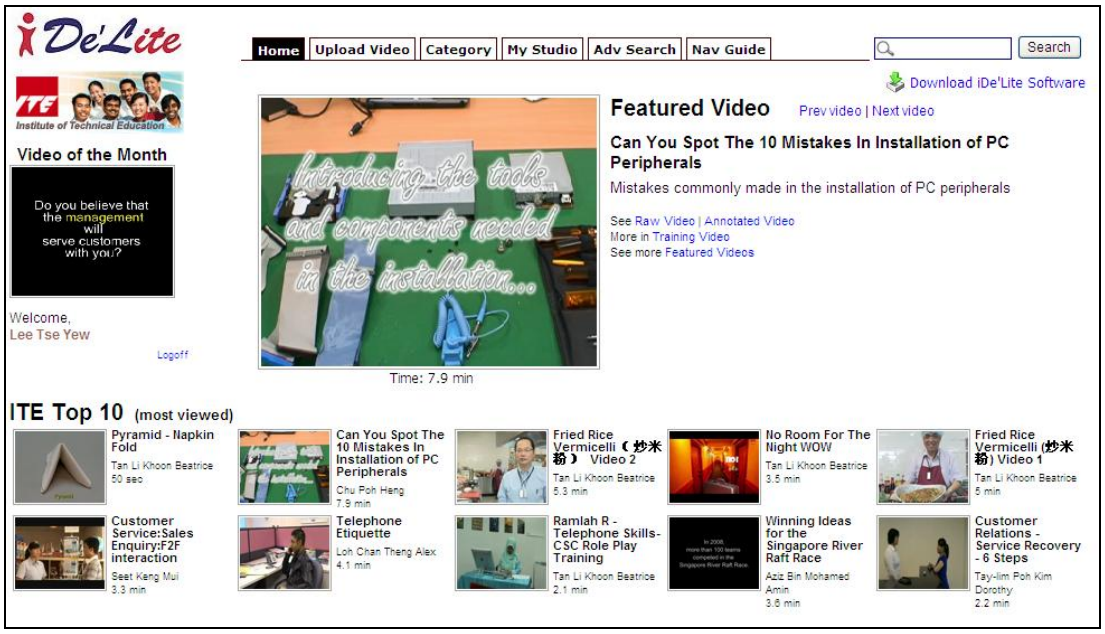

Figure 4-1 : iDe'Lite Homepage

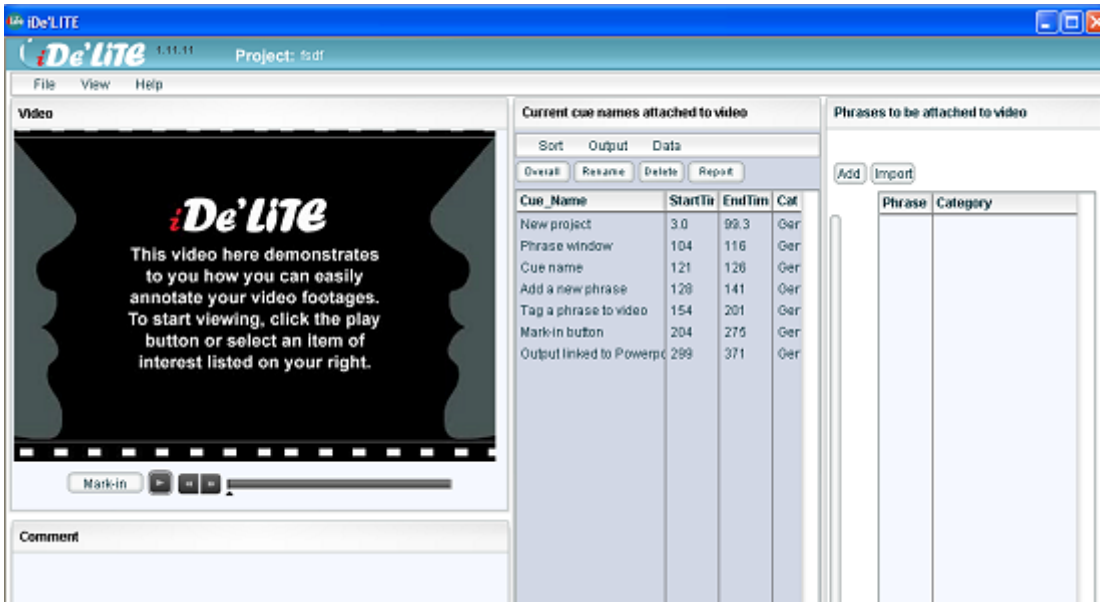

Figure 4-2 : iDe'Lite Software

CHAPTER 7 THE NEXT PHASE

Other ways of pushing the technology further is to put the multimedia content of the subjects on the internet server so that students will not always need to use the cd-rom. The G-Scanner is then able to point to the hyperlink in the web browser and the page containing information will be displayed. The iDe'Lite portal can be refined to include more videos with user feedback and better user management of the videos. The interface will be refined too to make it more intuitive.

There are many more applications that can be developed using this technology that would benefit the educational field.

The applications are only limited by the ideas. And human beings have no lack of ideas. That is what enables us to improve and develop more ground breaking educational technologies for the framework that would make teaching and learning more interesting and effective.

Technology is powered by humans. Humans are the source for technology to happen.

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Biographical Information

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PREPARING FOR SUCCESSFUL CROSS-CULTURAL ENCOUNTERS: A DIFFERENT KIND OF LEARNING

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ABSTRACT

It is crucial for Engineering students to be adequately prepared for successful cross-cultural encounters before they embark on any overseas industrial attachment or community service program. This is because they will be exposed to new kinds of experiences that involve informal, incidental, and experiential learning. In addition, the context in which learning takes place is different. Not only will students encounter different cultural norms and values, they have to cope with these at the national, regional, ethnic and organizational levels. Being able to learn positively from cross-cultural encounters is an essential life skill for all engineering graduates today. Hence, they would need to process their experiences within a cultural framework in order to appreciate and enjoy them more. It would also help deepen their understanding and increase their acceptance of cultural differences. At Temasek Engineering School, Temasek Polytechnic, the overseas internship and community service learning experiences for the Engineering students are varied: students can be posted to educational institutions, companies, or support work of NGOs; they could be in Asian or Western countries, in the city or rural areas of first world or third world countries. A fixed curriculum to prepare students for such varied purposes would be limiting in terms of catering to all learning opportunities. This paper outlines the various ways to prepare Singaporean Engineering students for such encounters. This includes the curriculum for face-to-face and online teaching, and the different forms of delivery. This flexible delivery and training model for such diverse needs has worked as the students have found the training useful. The paper ends with the positive feedback from the students and the potential for further development of this program.

KEYWORDS

Overseas work attachment, overseas community service, preparation for cross-cultural encounters, Engineering students

INTRODUCTION

The Overseas Student Internship Program (OSIP) and Overseas Community Project (OCP) at Temasek Engineering School, Temasek Polytechnic, Singapore, provide students with abundant learning opportunities. While the former provides internships in companies or educational institutions, the latter focuses on community service, often supporting programs run by a non-governmental organisation. Both initiatives increase the Singaporean students' international outlook and global mindset through real world experiences overseas. Knowing how different the West is from the East [1] and being aware of the different dimensions of culture [2 - 4] might help provide Singaporean interns with the right cross-cultural skills to "tune in" to the different cultures overseas.

Adequate preparation is therefore crucial. Sweitzer and King [5] emphasize the need for an intern to understand himself/herself as an individual by being aware of his/her values, reaction patterns, and cultural identity. The individual should also prepare himself/herself by learning more about the placement site and community. Hence, learning about the relevant national, regional, ethnic, organizational and institutional cultures are important to ensure positive experiences for students as well as those in the host country, community, company and/or institution.

"Preparing Engineering OSIP_OCP Students for Successful Cross-cultural Encounters" is an informal program that aims to sensitize students to their host country's culture. It also prepares them for cross-cultural encounters while working with organizations and specific communities. This program has been offered to Engineering students in Temasek Polytechnic, Singapore since 2006. Pioneered by one staff member in Temasek Engineering School, it was intended to support and augment the excellent work that the Liaison officers do to prepare their students for overseas internships and community service.

The need for the cross-cultural training was first realised in the late 1990s with sporadic requests for specific workshops to prepare Engineering students for their overseas attachments. The numbers were small and their training needs were fairly similar as interns were headed for companies and educational institutions in USA, England, Germany and Australia. The aim then was to prepare the would-be interns for the initial culture shock and provide them with survival tips for an extended stay of a few months. Differences in norms were emphasized.

Since then, the OSIP has expanded to include placements in more institutions, companies and countries. As Sweitzer and King [5] recommended that interns be more aware of themselves as well learn about their placement site and community, the less visible parts of culture, namely the norms and values of both the host institution or company, as well as home and host countries were emphasized. Hence, the program was expanded to encourage interns to be more aware of their Singapore culture, and learn about the organizational culture of their internship site, and the national and regional cultures of their host country before leaving for their overseas attachment. This is important as culture exists at different levels [2 – 3].

Subsequently, the overseas placements were expanded to include short-term community projects lasting 10 to 14 days. The first request for cross-cultural training for community service was articulated in 2005. It was for a group working with the Operation Hope Foundation (Singapore) and headed for Kampong Prey Veng, Hope Village, Cambodia. They had planned to bring solar technology to the village. Since the students would have had direct contact with the community at large, they needed to be aware of how they as Singaporeans would react to others and make and impact on their lives. This was in keeping with Sweitzer and King's [5] advice that interns understand themselves as individuals by being aware of their values, reaction patterns, and cultural identity (subgroup membership, including attitude towards other groups). The program was offered to subsequent teams working on similar projects, as well as those involved in other types of community service e.g. teaching English and Information Technology. It was also important to find out how learning took place in the communities that were to serve and the purpose of the training they were to provide.

With the expansion of OSIP and OCP, particularly to several locations in Asia, there was a need to provide a comprehensive program that could be offered on a more regular basis. Finally, the "Preparing Engineering OSIP_OCP Students for Successful Cross-cultural Encounters" program was offered under the school's Learning Development Program in 2006. This paper will provide the background to the conceptualization of the program, the delivery

of the curriculum, the outcomes of the program through the eyes of the students and staff, and recommendations for further development.

UNIQUE CHALLENGES, UNIQUE PROGRAM

Conceptualizing and planning the program were not easy tasks. Each year, the overseas internship and community service destinations increase, together with the types of activities and work involved. Currently, the overseas internship and overseas community service programs span 11 countries. For the year, 2008/2009, 83 students and 111 students went for their OSIP and OCP respectively. See Table 1 for details of countries and programs.

Table 1
Destinations for OSIP and OCP

Country	OSIP	OCP
China/HK	X	
Indonesia	X	
Vietnam	X	x
Cambodia	X	x
Japan	X	
USA	X	
Malaysia	X	
Myanmar	X	
India	X	
Laos		x
Thailand		x

Challenges

The scope of the programs was extremely broad, and there was not one typical overseas experience. The first challenge was to determine the range of learning outcomes. This was because the goals and the settings of the programs varied greatly. The OSIP aimed to provide students with a global mindset; the OSIP involved the bringing of expertise to a developing country to help the less fortunate, at the same time providing participants a chance to experience life and culture in a third world country. Hence, the needs for cross-cultural understanding would be different. For instance, the OSIP students require more understanding of organizational culture than the OCP students.

The second challenge was the variations of placements. The sites were in different regions and countries. The OSIP postings could be in developing and developed countries while the OCP focused on developing countries in Asia. The organizations students were attached to or worked with differ. OSIP attachments were at educational institutions of higher learning like MIT, and companies like TEAC, while the OCP mainly involved assisting non-governmental organizations like Operation Hope (Singapore). In addition, the duration the programs ranged from ten days to several months. The numbers for each trip would vary: students could be alone, in pairs, in small or large groups. They could be unescorted or escorted by staff members.

It was evident that the program had to be broad enough to encompass the range of learning experiences but yet sufficiently customized to the needs of the individuals. The program would include generic topics, as well as cover areas tailored to the type of attachments and the unique communication challenges of each setting. Generally, the program would emphasize the understanding of culture at the national, regional, and organizational level,

and the identification of cultural differences. Students would be more aware of how to impress people overseas and/or avoid offending them. Where the settings differed, the students would have learning experiences tailored to their needs.

Program Aims

It was decided that the aims of the program were to equip students with sufficient generic and specific skills for successful cross-cultural communication overseas. For the generic part of the program, students were expected be able to know about the types of culture they may encounter, categorize the information in terms of norms and values. For the specific part of the program, students were expected be able to perform their tasks with cultural sensitivity.

Resources

The resources were placed online on Blackboard 6 to give students an idea of the range of learning that was available and needed. All Engineering students would have access to the online materials in the semester prior to and during their internship semester, regardless of whether they intended to apply for OSIP or OCP.

Online materials could be used for preparatory work and referred to during their attachment. Online resources included vital information, cross-cultural lessons, tips by students and staff and experiences from returnees. See Figures 1 for online folders available for students on Blackboard 6.

Course Documents

1. <u>What are the various schemes</u>
What is the difference: SIP, OSIP and OCP? These are terms of three related schemes. Read the power point slides to find out.

2. <u>Readiness Rating</u>

These are related to your English Language, Interpersonal and Intercultural Skills, attitude towards work and community service.

3. <u>All about Interviews</u>
Students may have to go through a selection interview to get their dream placement. Preparing for an interview is not easy. This folder provides tips on how to prepare for the interview, from the resume, cover letter, questions asked and answered, dressing, body language and etiquette.

4. <u>Survival Tips Contributed by staff and students</u>

How to be a good ambassador overseas by a Senior Student Ambassador

Survival Tips for your OSIP and OCP by LSL, SH/Eng Com Skills

5. <u>Language Lessons</u>

Here are some language lessons for you ...

Students have been posted to Indonesia, Japan, China, Hong Kong, South Korea, Thailand, Vietnam and Taiwan. So be prepared. If you wish to improve your English, the links to free online Business English lessons may be useful too.

6. Country Profiles

Here are profiles of a few countries: Cambodia, Myanmar, Vietnam

7. First hand experiences
Enjoy these encounters: Teams to Cambodia (Solar 1, 2, 3 teams etc); LL at MIT, Boston

8. All about Intercultural Communication
These resources will help you better adjust to the new culture in the host country.

9. Types of organizations
Organizations can be governmental, non-governmental, profit or non-profit. Some of these are also educational institutions. These web quests will help you discover the differences.

10. Organizational Culture
Organizational Culture.ppt (263.5 Kb)
Organizational_Culture_SIP.doc (36 Kb)

In order to excel in your OSIP, you need to understand the corporate culture in the host country. These resources will help you do just that.

Figure 1: Online resource folders

Authentic materials

To provide authentic learning materials, students were invited to provide online resources. Students who had been overseas shared their experiences:

1. An Engineering student ambassador who spent a year in a high school in Japan shared how to be a good ambassador overseas through a set of slides with voice recording.
2. An intern attached to the GAMBIT Lab, MIT in 2007 shared how to prepare for an internship interview at an American University. She also shared her experience at MIT.
3. An intern attached to a private organisation that offered the Singapore national curriculum shared her experiences in Southern Vietnam, and provided insights to the national and organizational culture.
4. The team that helped out at the Project Khmer Hope in Cambodia in 2007 shared how they prepared for their English teaching stint.

Other students pitched in and provided language lessons:

1. An Indonesian student provided 10 useful Indonesian words and phrases, their meanings, and pointed out sensitivities that had to be observed in intercultural communication. She included this in her script:

> And while you are still learning the words and phrases, you can always smile to the people you meet; it's the best form of communication internationally… Remember that Indonesia is a country that values courtesy, relationship between people as well as

religion more than anything else. So, please be careful of your words and manners. Be respectful especially to the elderly. You must bend your body a bit and say "permisi" which means "Excuse me" when you walking pass by them to show your respect. … All the best to you. Enjoy your time in Indonesia.

2. A Myanmar student taught students how to pronounce ten common words and phrases that were used in Myanmar; she included an interesting commentary that accompanied the lovely pictures of her country.
3. A Singaporean provided a list highlighting differences between the Chinese terms used in Singapore and China.

In the July 2008, when two groups of students explored the use of wikis, blogs and podcasts, live chats, and Illuminate Live! the sharing was even richer. All these were available on the Blackboard Enterprise version that was being trialed at Temasek Polytechnic.

UNIQUE DELIVERY

The delivery of the program had to be flexible as the students received their "postings" at different times throughout the year. Hence preparatory learning opportunities needed to be available "on demand". The program had to be offered in a non-traditional, non-formal learning manner:

1. Face-to-face sessions (seminars and customized workshops)
2. Blended learning (use of online materials during workshops)
3. Online access (for independent work).

It provided students with the opportunity to learn with the tutor, with others and/or on their own:

For the first and second options, group sizes varied from 5 to 24. While seminars and workshops were open to those who were interested, the more common and effective method was for the Liaison Officers and accompanying staff to request for training. Students were encouraged to explore the materials on their own, especially if they did not have a chance to attend any training sessions.

Workshops

Below is an example of a very successful one day program offered on 19 December 2007 for both aspiring OSIP and OCP students. As a follow-up activity, the students were encouraged to explore the online materials for themselves.

PROGRAM

0900 Welcome & bonding activity (getting to know you)
0910 OSIP_OCP – what is the difference?
0920 Introduction to different types of culture (national, regional and organizational)
0945 Planning for projects and break
1000 Bonding activity 2
1010 What's the difference? Different types of organizations
1025 What you need to know about organizational culture
1045 Planning for projects and break
1100 Bonding activity 3
1110 What to look out for national and regional cultural differences
1140 Planning for group projects
1145 Confirm group projects and resource persons
1200 Working lunch – discuss group project
1400 Groups sharing (report on project work)
1500 How to get that dream placement at an institution or company
Prizes; Continuing as a learning community online
1600 END

Linda Fang Dec 2007
Learning Dvpt Prog
2

General workshops were offered to students going to different destinations and programs, with an emphasis on their site and community culture. These proved to be as effective as the specialized or customized workshops, and at times even more interesting given the diverse destinations and placements involved. Conducting such workshops in computer labs provided "on-the-spot blended learning". Each student added to the discussions and shared knowledge online as well as in class. The following sample texts from the Blackboard discussion board helped students to know more about their organizations and their culture, where possible. Sample 1 was submitted by a student headed for TEAC in Australia:

Forum: Something about the organisation I will be attached to Times Read: 8
Date: Mon Mar 03 2008 10:59
Author: E0K, CCS
Subject: TEAC Australia

The parent company of TEAC Australia, Singapore's TT International Limited (TTIL), has announced its intention to enter into a conditional share sale agreement with Austral Waste Group Limited (AEG) to inject into AWG its entire stake in TEAC Australia.

Also with a Master Licence by TEAC Corporation Japan on November 15, 2007, TTIL will be able to distribute TEAC products in Brunei, Cambodia, Indonesia, Laos, Myanmar, Malaysia, Singapore and Vietnam on an exclusive basis, and Thailand on a non-exclusive basis.

This would increase the abilities of a growing of TEAC Australia. Hopefully, with the OSIP, we would be able to contribute in the company's success.

Sample 2 was a group project, submitted by their leader. They were headed for Cambodia:

Forum: Learning about your Com Service Organisation Times Read: 10

Date: Thu Mar 06 2008 11:50
Author: E0K, WJ
Subject: Operation Hope foundation

1.What is this organisation?

Operation Hope is a Singapore based charity dedicated to transforming the lives of orphans and the poor through relief and development projects in third world countries.

2.Are there similar organisations around the world?

yes, singapore international foundation, the rolex awards of enterprise, singapore management university.

3.Why is involved in community service?

To transform the lives of orphaned children and the poor in third world countries by building and operating orphanages and community centres thereby creating a better future both for the children and the surrounding population

Link: http://www.ohf.org.sg/HVPV1.htm

Group project by GH,. HC, LT, ZW

Specialized workshops were offered to groups headed for one specific destination. For students who aspired to apply for an internship at the GAMBIT Lab, MIT, they were exposed to the learning culture at MIT. For the Solar Teams, much time was spent on understanding the mindset of the Cambodians, their needs, their taboos and communicating the transference of technology in a culturally acceptable way.

Customized workshops were available for those involved in teaching programs to Cambodia, Vietnam, Laos and Myanmar, in terms of equipping them with culturally sensitive teaching skills. Cultural differences had to be considered when teaching English. The students learnt how learners in each culture preferred to learn, and the teaching methodology they would be most comfortable with. Students were given the chance to plan lessons for beginners. In one instance, students preparing to teach English at a private educational company in Cambodia had selected the language structure from an English Language text book for a lesson which they titled “What are you doing today?” The lesson focused on using the verb in the continuous tense. They then drew visuals to help elicit answers e.g. I am working today. The purpose was to teach them to contextualize lessons and use visuals that locals could relate to. Another example was the lesson to be used at a language camp in Vietnam. The students decided to use a “game” approach to teach instructions and test their students (see photo 1 below).

Photo 1: Lesson Plan for "Blind Man"

The blindfolded person was asked to do the following: turn right, left, walk two steps forward/backward to reach the "treasure" item. They demonstrated the lesson in class and proved that it worked well.

POSITIVE, UNIQUE & MEANINGFUL LEARNING EXPERIENCES

If the learning was positive, it was also special for each student when it met his or her needs. In that way learning was unique and meaningful.

Positive Feedback

From the students' feedback, it was obvious that they had learnt much, and in varied ways. The following feedback relates to the different delivery systems.

Workshop, 19 Dec 2007

Students who attended this workshop had an interest in OSIP_OCP but did not yet have a confirmed place. They voluntarily attended this six-hour workshop during their term break. The 20 participants enjoyed the workshop and found it beneficial. The following comments from selected students attest to their positive learning experience:

> Everyone who came back from the trips were moved and it made a huge impact in our lives. (Student 1)
>
> We have to take note of a lots of things; notice their culture; be very cautious about how you speak. (Student 3)

> There is a different culture between here and other countries. Must know what they like to do and better avoid to do the things they don't like. Must know the knowledge of their country and try to avoid offending them. (Student 5)

> I learnt the different cultures of people in the different provinces. I also learn some experiences encountered in the working world in different countries. (Student 6)

> I have learnt a lot about different countries have different formality, manners. And we need to know about the type of culture in an organization. (Student 8)

Solar 4 OCP Workshop

MY, the OCP-Cambodia SOL4R Team Leader gave feedback on behalf of his team that went to Kampong Prey Veng in 2008.

> Regarding the pre-trip training, it was quite useful as it helped prepare us mentally for the trip in terms of communication and the different culture to be experience there. During the pre-trip training, there was a session when we were to research about Cambodia. These session was most beneficial to my members and I as it helped us realised the taboos of Cambodia, what to and what not to when we are there, and also what Cambodia has to offer to us. This made us more conscious of Cambodia and prepared of what is to come. … With this training, many of us were there with a clear mind, allowing us not to create any intercultural miscommunications. With this in mind, we were able to recognise the differences there were in Phom Penh, Cambodia and allow us to adapt to these differences and also to appreciate it.

Teaching Workshop

This feedback is from JO, who returned from his English teaching attachment at a private company in Yangon, Myanmar. He attended a workshop on how to teach English in Myanmar. Part of the workshop involved cultural sensitivities.

> From my experience above I found the 1 day course conducted by … [name of trainer] very useful and enriching. On her topic of Intercultural Communication, she taught us on Identifying Causes of Intercultural Miscommunication and preventing or rectifying intercultural experiences. She told me that in other countries you must not expect everyone to be able to conduct themselves fluently with you, due to language and cultural barriers, the people in Myanmar are generally humble and friendly but are also weak in the English Language, and therefore will usually take some time to translate what they meant into English. And if I was able to enjoy this differences and adapt to the culture of that person, I would be able to adapt well. Therefore I applied what I learnt in …[name of trainer] course, of being patient and adopting an open minded mindset during my OSIP programme.

Usefulness of Online Resources

Not only were the training sessions useful, students also found the online resources useful. LJT, who was attached to a private educational centre in Myanmar, comments on the usefulness of the online resources, particularly "Tips on Surviving Your OSIP/OCP" and other teaching tips.

> A workshop was conducted on 4th March 2008, Tuesday for all OSIP/OCP students. The materials provided under the Course Documents were very useful. It prompts us to think about some factors regarding going overseas that we have not thought of. To be specific, this slide on "what about the invisibles", broaden some questions that I

could look into to prepare for my OSIP trip. I went online and read up about the country's values, beliefs and about the people. Understanding the people's values and belief helped me when I first communicate with the people there. I was more careful and patient listening to them instead of the usual way we talk in Singapore. At the same power point slides, we learn how to teach. Some examples are like:

- Use lots of games, songs, basic vocabulary
- Pronunciation exercises
- Simple conversation / role plays
- Bring pictures, magazines, newspapers from Singapore
- Be prepared to draw on the board to explain new words & phrases

If I didn't have read this, I might not have thought of it myself when I was there teaching the Summer English class. I manage to apply games and interactive lessons which made the lessons much more fun.

Summary of Learning

There were unending benefits from this flexible program. Hopefully, these vignettes will prove this claim. The following observations were from the trainer and other staff members.

Opening minds to independent learning

The workshops were designed to open the minds of the students and encourage them to ask questions to extend their learning. One activity which required students to articulate what they did not know generated positive response. A group of students who were headed for a company in Cambodia realized that there were three factories at three different locations. Instead of waiting for their Liaison Officer to provide them with the answers, they decided to learn more about the three factories and find out if their role and functions differed. They had learnt that it was good to ask questions and look for answers for themselves.

Culturally sensitive students

The students were able to understand the theoretical aspects of culture and used the terms like norms and values with ease when categorizing the information they found on the internet. They were happy to view the world through cultural lenses. When they shared their stories to their juniors upon their return, they were then filled with understanding and appreciation, rather than prejudice and disdain. A good example was the sharing from the "English for Friendship Team" that was in Laos in August 2008. They entitled the slide, "Good Tips for aspiring ones" and highlighted six qualities that would lead to successful cross-cultural community service encounters.

> Volunteering is an unforgettable experience. It can be one of the most rewarding and enriching things you'll ever do but at the same time, before you get out there, it can be very daunting.
>
> Patience: The key to successful skills transfer projects. It's easy to get caught up in achieving outcomes and want to steam full speed ahead. Enthusiasm is great but it must be balanced with patience. Different things are important in different cultures. Relationships are a core part of culture so it pays to put time and energy into building rapport and trust. These things do take time to establish "You can't go into a community and expect to be immediately accepted and liked – it takes time and you must earn respect and friendship. The same as it does when someone new comes into your work or home situation". Gaynor Nicols
> So take your time to get settled and shed your expectations. Don't expect to get started on the first day of your project. Ultimately you will achieve a lot more if you put

your early efforts into getting to know the people you will be working with first and foremost.

Listening: It follows that where relationships are important so is communication – in particular listening. Being able to listen, watch and ask questions enables you to gain insight into exactly what skills are necessary and the best ways in which to share them.

Openness**:** It's not just about skills transfer. Indeed it's highly likely one of your motivations is to learn more about culture and you won't be disappointed. Many of the participants come back humbled, often expressing a sense that they have gained more than they could possibly have given. There are so many lessons to learn about ourselves and the way we relate to others and the world around us. Volunteering is a wonderful opportunity for personal growth and development.

Flexibility**:** There will be times when things don't go to plan or you will need to work within very limited resources. This is your chance to get creative. Your ingenuity can be priceless in these situations projects and can bring about surprising results. We learnt that we had to change our teaching style to fit a different learning culture and to relax and go with the flow more, make learning more like a social activity.
Skills transfer is about hands on learning. Encouraging people to apply what you are sharing reinforces their understanding and builds confidence. Always look for opportunities to make skills sharing as practical as possible.

Perspective: Your contribution will and does make a difference. That said, things take time – don't expect to change things overnight or seek dramatic results. Often it's the less tangible things, like increasing someone's self esteem or broadening their horizons, that make the most priceless and powerful difference. Just your presence, the fact that you have gone out of your way to be there, is actively contributing to the reconciliation process.

Sharing: You're there to share skills, aren't you? But be open to sharing your world too. When on a project you will share yourself as well as your skills. You'll find this happens fairly naturally, but one great way to engage is to take a small photo album with pictures of where you live, your family etc - to help people get a sense of who you are. Last, but by no means least, you may find you end up sharing long term friendships well after your project is completed. So be yourself, relax, enjoy, have fun and share!

Considering others

The program prepared students to be aware of norms and values of the country they were heading to. The face-to-face sessions were ideal times to address behavior that could be unacceptable, disrespectful or shocking. They went on to look up on the accepted codes of behavior. The students, who went to a private teaching centre in Myanmar wrote this:

> In the programme, we were asked to find cultural information for Myanmar. Through browsing the internet, I found out that they do have wearing restriction in the country. For example, females shouldn't be wearing revealing clothes that will expose their legs or shoulders. Therefore I prepared all the clothing without that isn't revealing like bring only t-shirts and jeans for casual wear. When I arrived in the country, I quite relieve that I have made a right choice of bring t-shirts and jeans. Most of the females were wearing their traditional skirts with normal tops. But there were also working females wearing skirts that were covering their knees, which I think that is accepted in Yangon

The program also helped change habits of students. One group, who found it extremely difficult to come in time for their 9.30 am session, found out that in Cambodia, anyone who did not wake up at dawn was considered lazy. They immediately resolved to bring alarm clocks with them on their trip. Their Liaison Officer who accompanied them on the trip vouched that no one ever late when they were in Cambodia.

Bringing technology with humility

Students hoping to bring new technology over for a community project to a third world country were challenged to do so humbly. They had to consider whom they could persuade as early adopters of the new technology. MF had a chance to demonstrate an English language online program to the principal and teaching staff at the Project Khmer Hope. He did it with such clarity and humility that he won the hearts of his audience.

Dedicated Teachers

If a syllabus was in place and curriculum materials prepared, training was based on the lessons students were to teach. The students who went the Training Centre run by Project Hope Khmer in Cambodia in April 2008 taught from the "English in Action" book which was based on the Total Physical Response method. They discussed the language features, practiced teaching, and evaluated the strengths and limitations of the method. Being mindful of the errors they could make, they brought along their dictionary and grammar book and were careful to use Standard English in class.

For students hoping to teach English in companies, and no existing syllabus or materials some training was provided. They reflected on what learners of English as a Foreign Language would need, particularly if they were beginners, and reviewed lessons in several language books for their cultural suitability. They looked for objects or concepts that might not exist in the culture of the country they would be teaching English in. For instance, words like "snow" and "sheep" could be replaced by "rain" and "cows" respectively for lessons taught in Cambodia. The students then used an existing lesson and drew visuals that locals might relate to. They produced very focused, interesting and workable lessons.

Preparing for MIT GAMBIT Lab experience

The students who were vying for an internship at the GAMBIT Lab, MIT had to prepare for their selection interviews. Besides preparing their cover letter, resume and interview questions, they were given a chance to find out more about the GAMBIT Lab, education at an American Ivy League university and culture in the United States, particularly life in Massachusetts. For them, dialoguing with the trainer over several sessions helped them prepare for the different academic and social culture they would encounter. Their "opening up" to other educational cultures was noticeable.

CONCLUSION

The cross-cultural OSIP_OCP program is useful for engineering students. It provides boundless learning experiences that are determined by the students themselves. Being able to process overseas internship encounters through a cultural framework helped students understand, accept and enjoy the differences, ensuring a successful and enjoyable learning experience overseas. They too were able to make a more positive impact overseas. This program can be easily modified to use the more pervasive interactive media technologies available today.

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Biographical Information

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PROVIDE HOLISTIC DEVELOPMENT THROUGH PROJECT-BASED LEARNING IN ENGINEERING MODULES

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ABSTRACT

In traditional engineering education, it is common to find lessons being dominated by hour-long lectures during which most, if not all of the materials prepared for the module are being dispensed in a transmittal mode with little active participation from students. It is also typical to find these lessons designed primarily for the development of technical knowledge and skills with little focus on the personal and interpersonal skills development of the student. Much education research has shown that this approach is inadequate to prepare our graduates with expertise in their field of qualification as well as with highly developed interpersonal, personal and transferable professional skills attributes. A change is required. This paper presents how a change in lesson design adopted by "IC Layout", a module offered under the Electronics and Computer Engineering Diploma of Ngee Ann Polytechnic, addresses some of the concerns mentioned above. The key change involved the incorporation of project-based learning where students assume the role of IC layout engineers working in a team to build a layout of a Linear Feedback Shift Register. In this project-based learning experience, students identify their knowledge gaps in cell layout methodologies and perform background research to fill those gaps, they apply knowledge gained to build and verify their layouts according to design rules. As a final deliverable, students will have to communicate their best layout by presenting justifications on why their layout is the best. This lesson design also aims to simulate a real working environment by exposing students to technologies and experiences of a real work place with the use of platforms such as wiki where students share and review information posted by other team members, co-author documents that explains the concepts of cell layout methodologies, evaluate and critique the product of other members, and collaboratively builds on each others work to present the final product. These experiences have increased the level of students' engagement in learning. They tend to show greater interest in the topics and demonstrated a deeper understanding in the concepts and theories related to this module.

KEYWORDS

Project-based learning, experiential learning, learning design

INTRODUCTION

Project-based learning is not something new. William H Kilpatrick published paper "The Project Method" in 1918 systematically explained and rationalized project-based learning [1].

The project approach is enticing because it offers the student more control of the learning process resulting in higher student involvement and motivation. The degree of freedom granted to the student in the learning process depends on the type of project based approach used. In

open ended or unstructured projects, students are given guidelines and little structure to encourage risk taking and innovative thinking. On the other end, structured projects are characterized by the many constraints or limitations placed by the instructor. These constraints may include product specifications and functions, methodologies used or specific sources of information. Somewhere in-between these extremes are the semi-structured and real-life projects [2]. The project can be topic-related or genre-related.

The process used in project-based learning typically consists of the following activities: (a) project definition (b) investigation (c) processing of data (d) realization and (e) evaluation. The degree of freedom given to students in each of these activities will depend on the type of project-based learning approach used by the instructor. The requirements of the project is first clarified and understood. During the investigation phase, activities will include finding resources, collecting data, interviewing, observations and selecting the appropriate data. In the processing activities phase, the student tries to make sense of the data collected through analysis, classifying and synthesis. In the realization phase, students will conceptualize possible solutions, learn how to prioritize and manage their time and produce a prototype or model. Evaluation of the project could be done individually or in groups through presentations, reports, self-reflection, peer and self-assessment [1][3].

Assessment of the project could be either summative or formative or both. The summative assessment would be used to evaluate the final outcome of the project. It could be based on reports, presentation or viva. The formative assessment could be use to evaluate the students work as they progress through the project. By pacing the deadlines of the formative assessments, the progress of the students can be monitored and timely feedback can be given to the students. This forces them to start work early and prevents them from producing a rush job near the project deadline [2].

The project based learning approach demands a lot of time and effort from both student and teacher. Another concern is the degree of subjectivity in the assessment in project-based learning. However with properly designed assessment rubrics and team assessment, the degree of subjectivity can be reduced.

USE OF TECHNOLOGY IN PROJECT-BASED LEARNING

Project-based learning can leverage on Web 2.0 applications to make the process more efficient, visible and collaborative. The Web 2.0 applications can support the following areas in project-based learning: student collaboration, collection of data and information, organizing data, contacting experts, producing artifacts, constructing content, self-reflection, peer-review of learning content, ongoing feedback [4].

Table 1 shows some of the Web 2.0 learning activities that can be used to support project-based learning.

Table 1
Sample of Web 2.0 Tools for Use With Project-Based Learning

Learning Activity	Web 2.0 Technology	Examples of Web 2.0 tools
Online Resources	Search engines Web feeds	http://www.google.com.sg http://news.bbc.co.uk

Constructing Content	Wikis Vidcast Podcasts Photographs Mindmapping Maps	http://www.wikispaces.com http://www.teachertube.com/ http://www.podomatic.com/ http://www.flickr.com http://bubbl.us/edit.php http://maps.google.com
Reflection	Blogging	http://www.blogger.com/

The internet has made searches for information more effective and efficient. Many search engines are available out on the web. Also information can be pushed to the student's desktop using RSS feeds. However, the student must learn to be critical of the data presented on the internet and verify the authenticity of the information.

Students could collaboratively construct the content using either text using wikis or document sharing web sites; or diagrams using mind maps and concept maps; or using photographs or videos.

The students' progress in the project can be monitored by asking the students to reflect on their learning journey in their blogs.

APPLICATION OF PROJECT-BASED LEARNING TO INTEGRATED CIRCUIT LAYOUT

Context

The students taking the Integrated Circuit Layout (ICL) module are final-year students doing a 3-year Electronic and Computer Engineering Diploma course offered by Ngee Ann Polytechnic, Singapore.

The students would have done some digital integrated circuit layout (or IC Layout) in their second year module, Microchip Technology (MCTE). They would have learnt how to layout primitive digital cells like the inverter logic gate (Figure 1).

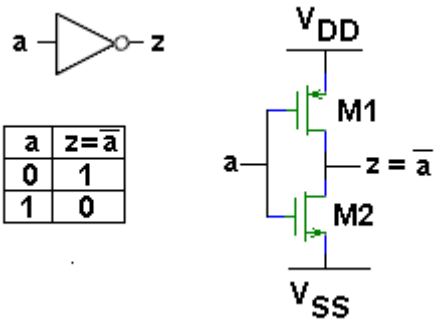

Figure 1: CMOS inverter logic gate.

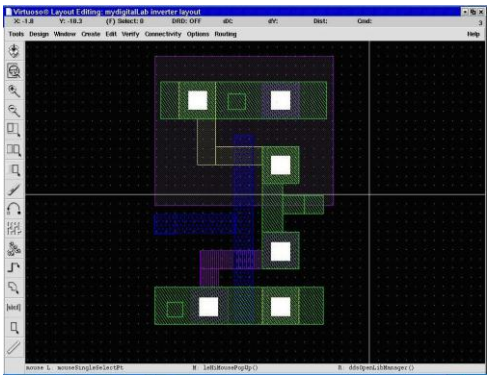

Figure 2: Layout of a CMOS inverter gate.

In a very brief summary, computer functions are carried out by logic gates like the one in Figure 1. Some logic gates are more complex than others. However, all logic gates would be made up of two or more transistors connected together to form the logic function. The transistor is formed by patterning different process layers on a semiconductor wafer using photolithography. The patterns are drawn manually on a PC using some IC Layout editing software. Figure 2 shows the layout of a CMOS inverter gate.

Students taking the ICL module would scaffold on their MCTE IC layout knowledge to learn about IC layout methodologies to layout more complex circuits and subsystems. They are also introduced to industry based IC layout design rules which are meant to ensure that the structures patterned are reproducible consistently on the microchip. These topics form about 30% of the module. Previously, these topics could be covered in 10 hours using the traditional lecture/ tutorial/ lab approach. However, because a major portion of these topics involves rules and methodologies, the students find the lectures too abstract and uninteresting.

Hence the project-based approach was tried.

Requirements

The structured project approach was adopted due to the limited time allocated for these topics. The students were grouped into teams of 3-5 students. The groups were required to layout a linear feedback shift register circuit (LFSR) designed in another module which the students were taking in the same semester. The LFSR circuit (Figure 3) designed by the students differed slightly due to different pseudo-random numbers to be generated.

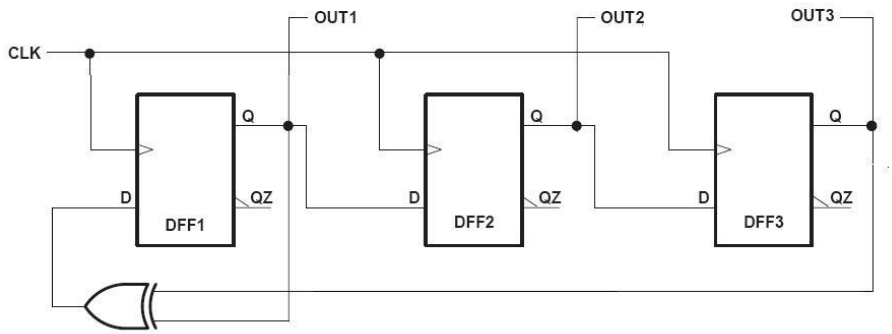

Figure 3. Linear Feedback Shift Register.

Each group is to complete the layout of the LFSR using the ECAD software which can be access on campus. The layout must have no design rule errors and is to be correctly connected. The layout should occupy minimum area and conform to the standard cell layout methodology.

The students have to collect, collaborate, construct and record their understanding of Digital IC layout methodologies in their wiki. They are to layout primitive logic cells and create a library of IC layout cells called a Standard Cell Library. They will then use the cell library created to the layout of the LFSR. Upon completion they will reflect on their work. The e-portfolio tool in the Blackboard suite is used by students to deposit their completed work and to record their reflections.

Implementation

Students in groups of 4-5 students work on the project over 6 weeks. There are deliverables at every stage of the project to monitor the students' progress and provide timely feedback.

The schedule is given to the students at the beginning of the term so that the students are aware of the deadlines. The schedule follows the sequence: (a) project clarification (b) investigation (c) processing of data (d) realization and (e) evaluation.

Table 2
Work Schedule

Week no.	Objectives	Resources/ Tools
1	To form groups. Ice-breaking.(#) Clarification of project specifications. (#) Learn how to use the e-learning platform.	Blackboard™
2	Find information regarding a list of topics which will be useful for their projects. Identify knowledge gaps.	Library Web Search Engines
3	Understand, organize and summarise the information collected. Share and review content information. (#)	Wiki

4	Plan and design standard cell library.(#) Apply the information to layout the primitive logic cells. Create the standard cell library.(#)	ECAD software
5	To layout the LFSR using the cell library created by the group. To verify that the LFSR layout follows the design rules and is connected correctly.	ECAD software
6	Upload completed layout of logic cells and LFSR to their e-portfolio. Compares and contrasts the layout of the LFSR done by each member of the team. Decide on which LFSR layout is the best. (#) Reflect on their LFSR layout and how it conforms to the standard cell layout methodology. They are also to reflect on how they could improve their layout and the way they have carried out their work so as to improve their productivity	e-portfolio

(#) – group work

The ice-breaking activity in the first week help the students form small learning communities and iron-out any technical problems due to unfamiliarity with the platform used or the on-line tools to be used in the e-activities that follows.

Students are guided in their collecting of information by a list of questions from the instructor. These open-ended questions ensure that the students do not stray too far from the topic, given the tight project schedule. They may inquire further into the questions arising from their answers.

The students construct their content knowledge in a wiki. Their group mates review and modify the content. The instructor is able to view the history of the amendments and note the contributions of the team members.

In week 4, the students apply their new knowledge of the Standard Cell Layout Methodology to the construction of a set of rules for their Standard Cell Library. Each student will create a layout a primitive logic gate based on the design rules and the rules they had created for their Standard Cell Library. The layout process will require students to plan, design and verify that the layout done is correct. The student must analyze the error reports and correct the layout. Only when their layout is error free can they proceed to layout the LFSR in week 5.

On completion, the student will upload their work to their e-portfolio. They reflect on their work vis-à-vis the Standard Cell Layout Methodology and their peers work.

Assessment

The structured project is given 20% weight in the module assessment. 65% of which is individual assessment and 35% of the marks for this activity is given for group work. 60% of the

mark is allocated for formative assessment and the remaining 40% for summative assessment. Table 3 shows a detailed breakdown of the marks allocated for each activity.

Table 3
Allocation of marks

	Individual	Group	Total
Ice Breaker	5		5
Content Creation	20	5	25
Planning		10	10
Layout of Primitive Cell (*)	20		20
Creation of Standard Cell library (*)		10	10
Layout of LFSR (*)	10		10
Evaluation		10	10
Reflection	10		10
TOTAL	65	35	100

(*) Summative Assessment

The rubrics used for the formative assessment is shown in Append A. The summative assessment is mainly obtained from the design rule check report and other reports generated by the ECAD tool.

Evaluation

An indication of the effectiveness of the project-based method used can be extracted from the reflections of the students. Out of the class of 42 students, over 90% of the students indicated that they have learnt how to layout using the Standard Cell Methodology from the project. Besides the content knowledge, 33% appreciated the teamwork; 21% learnt the value of planning and 21% felt a sense of achievement and satisfaction upon completion of the project. The details of their feedback are shown in Table 4.

Table 4
Data from Students' Reflection

Learning Areas	% of class agreeing that they have benefited from the project
Technical Knowledge (Example: Learnt how to use Standard Cell Methodology from the project)	90%
Personal and Professional Skills and Attributes	
Teamwork	33%
Sense of Achievement	21%
See Value in Planning	21%
Learnt/ Applied Problem Solving Skills	14%
Time-Management	10%

Sample size: 42 students

Here is a sample of some of the students' reflections:

> "I felt that this layout was one of the best I have done, because the amount of time and effort that I have put in were much more compared to the other assignments. I followed the design rules and guidelines while accomplishing this task. For example, not using long poly silicon lines to connect from one gate to another as it will result in signal skews."
>
> "During this project, we discussed the problems together, helped each other and stayed back at school until it finished. This was very inspiration among us and I learnt how to communicate with each other."
>
> "I was still thrilled with the first hands-on experience in my life in doing an IC layout. Most importantly in this mini-project, I learnt to appreciate the value of team-working in IC layouts as each person's job is equally important; regardless of how much weight his/her work carry."
> "This DFF lab took about 2 weeks time for us to finish, I have to stay back every evening to catch up with my progress. It was really an exhausting period. On the day of submission, when I look at my work, I was full of satisfaction. From a person that do not know layout design to a person that can produce out the complicated DFF layout. It was a journey of growth,"

The results of summative assessment showed 100% of the students completed the layout of the primitive logic cells and the LFSR in the given time. Their layout conformed to the Standard Cell Methodology and met the design rules requirements. Their layouts passed the DRC and LVS verification checks performed by the ECAD tools.

It was observed that the students' successful experience in the structured project produced a more positive climate in the classroom thereafter. This may be because they were then able to relate the downstream lessons with their project experience.

SUMMARY

By leveraging on the Web 2.0 tools, project-based learning is made more collaborative and allows the students to reach out to more resources than the campus can ever hold. It allows students to collaboratively construct online content and reflect on their learning.

The structured project was a suitable alternative method of delivering the topics in the Integrated Circuit Layout module that were "dry", rule-based rich content and too abstract for the students. The students are more motivated and willing to put in extra effort because of the engaging nature of project-based learning. The visible outcomes of their efforts give these students a sense of satisfaction and achievement. They achieve a better understanding by constructing the content themselves, monitor their progress and work together to achieve the desired outcome. While the content knowledge may become obsolete in future, the soft-skills that they learnt and experience in this project will help them in their lifelong learning journey.

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APPEND A

Rubric used for Formative Assessment

Tasks completion	**Level 1 (0-30%)**	**Level 2 (30 to 60%)**	**Level 2 (60 to 80%)**	**Level 3 (80 to 100%)**
Ice Breaker	No participation	NA	Participated	participated well
Content Creation: research	Information that lacked relevance, quality, depth and balance.	information from a limited range of sources and displayed minimal effort in selecting quality resources	information from a variety of relevant sources--print and electronic	1. Information from a variety of quality electronic and print sources. 2. Sources are relevant and balanced.
Content Creation: synthesis	Not logically or effectively structured.	could have put greater effort into organizing the content	logically organized the product and made good connections among ideas	1. Developed appropriate structure for communicating content 2. Information is logically and creatively organized with smooth transitions.
Content Creation : citation	Clearly plagiarized materials.	Need to use greater care in documenting sources.	1. Documented sources with some care 2. Sources are cited. 3. Few errors noted.	1. Documented all sources. 2. Sources are properly cited. 3. No errors noted.
Content Creation (G)	1. Developed a question requiring little creative thought.	1. constructed a question that lends itself to readily available answers	1. focused and challenging question	1. Thoughtful, creative question 2. breaks new ground or contributes to knowledge in a focused, specific area
Planning (G)	1. task divided amongst members	1. Task divided amongst members 2. non-well defined specifications for standard cell library	1. Task divided amongst members 2. fairly-well defined but incorrect specifications for standard cell library	1. task divided amongst members 2.well defined and correct specifications rules for standard cell library

Layout of primitive cell (I)	1. layout was incomplete	1. Layout was completed 2. Layout cleared Design Rule Check	1. Layout was completed 2. Layout cleared Design Rule Check 3. Layout corresponds with schematic (LVS)	1. Layout was completed 2. Layout cleared Design Rule Check 3. Layout corresponds with schematic (LVS) 4. Layout is optimised for area and can be used in the cell library 5. Layout was completed on time.
Creation of Standard Cell Library (G)	1. No missing layout cells in the cell library	1. No missing layout cells in the cell library 2. Cell library corresponds does not meet the specs in part(4)	1. No missing layout cells in the cell library 2. Cell library corresponds meets the specs in part(4)	1. No missing layout cells in the cell library 2. Cell library corresponds meets the specs in part(4) 3. Cell library delivered on time.
Layout of LFSR (I)	1. layout was incomplete	1. Layout was completed 2. Layout cleared Design Rule Check	1. Layout was completed 2. Layout cleared Design Rule Check 3. Layout corresponds with schematic (LVS)	1. Layout was completed 2. Layout cleared Design Rule Check 3. Layout corresponds with schematic (LVS) 4. Layout is optimized for area and can be used in the cell library 5. Layout was completed on time.
Evaluation (G)	1. Restating information. 2. Conclusions were not supported by evidence.	1. Conclusions could be supported by stronger evidence. Level of analysis could have been deeper.	1. good effort was made in analyzing the evidence collected	1. Analyzed the information collected and drew appropriate and inventive conclusions supported by evidence.
Reflection (I)	1. Lackluster	1. Somewhat superficial consideration of issues	1. Accurate consideration of issues	1. Excellent evaluation of the issues

(I) - individual
(G) – group work

SOFTWARE DEVELOPMENT PROCESS AT LEI-ISEP

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ABSTRACT

The software development process is the backbone of any Informatics Engineering program. This paper presents the LEI-ISEP (Informatics Engineering program at Instituto Superior de Engenharia do Porto) software development process, based on the well known Unified Process, and the way it is iteratively and incrementally introduced to the students over 5 semesters.

KEYWORDS

Unified Process, CDIO, RUP, Software Process

INTRODUCTION

A key requirement of CDIO is the students' ability to autonomously conceive and implement systems, using industry best practices. To this effect, several engineering Programs have defined process models to be used in project courses (e.g. Linkönping Project Management Model – LIPS [1]).

A small market (employer) inquest proved that the lack software development process knowledge and practice was the most common weak spot of LEI-ISEP's graduates, as well as the graduates from every other major university in the North of Portugal (the inquest was restricted to the North of Portugal). Thus, the Informatics Engineering Department decided to define as a priority the teaching of an iterative software/system development process in LEI-ISEP, which should be used by all courses.

LEI-ISEP PROGRAM AND THE CDIO APPROACH

LEI-ISEP is a 6 semester bachelor program in Informatics Engineering, a common type of program in Southern Europe that combines computer science and computer engineering. LEI-ISEP adopted the CDIO principles [2] as the reference for the learning process, notably the introduction of a laboratory-project course in each semester and a capstone project in the last semester. About 85% of the students opt to implement the capstone project in an outside organization/enterprise.

Capitalizing on the experience of DTU (Technical University of Denmark), the semester at LEI-ISEP is divided in two time slots:

- Week 1 to 12, the students have classes of 4 or 5 “common/classical” courses. Most courses include have a final exam (ranging from 40 to 60% of the final grade) and assessment by tests, small projects, etc.

- Week 13 to 16, the students have only a laboratory-project course in which they have to implement a “large” project from a given set of requirements (the project complexity increases from semester to semester). The project to implement is related to the subjects learned on the first 12 weeks, thus allowing the students to reflectively improve their knowledge on the subjects.

The rationale behind this spiral approach is to present the student increasingly difficult challenges that he has to solve as a member of a team, using the competences acquired in ordinary courses and in the previous projects. One can define three levels:

- Application development, encompassing the 1st and 2nd semester, where general introductory subjects are introduced: Math and Programming. In the 2nd semester, a specialized course in Software Engineering provides the students with the competences in the software development process needed to step to the next level.

- System development, encompassing the 3rd and 4th semesters. In this intermediate level, core informatics engineering subjects are introduced. These subjects, which any professional in this field must master, include operation systems and networks, advanced OO modeling and algorithms, data base programming and software development. The students are also introduced to the system concept, which is composed of several components, and introduces new concepts such as component integration, component redesign/replacement, system reliability and individual component failure, etc.

- Project management, encompassing the 5th and 6th semesters. In this advanced level, specialized informatics engineering and management (e.g. enterprise management, project management, etc.) subjects are introduced. The software and computing worlds change at a fast pace and some courses have to be updated almost yearly, in order for the students to be able to have successful capstone project/internship.

The learning process of LEI-ISEP’s first 5 semesters is summarized in Figure 1. It’s worth mentioning that each LAPR (Laboratory-Project) course has a soft skills module (16 hours/semester) focusing on complementary subjects such as writing skills, teamwork, etc. The students are allocated a lab and there is always a teacher present to monitor the work and provide help. Thus more hours allocated to the initial LAPR, while in the last ones the students are expected to develop their project almost autonomously. Actually, in LAPR5 the teacher’s role is mostly to act as the client. The “official” classroom hours of the actual project development component of each LAPR ranges between 24 hours/week (LAPR1 and LAPR2) and 16 hours/week (LAPR4 and LAPR5) over 4 weeks. This is enough for the students to implement the first year’s projects, but the actual workload in the other LAPR courses is much higher.

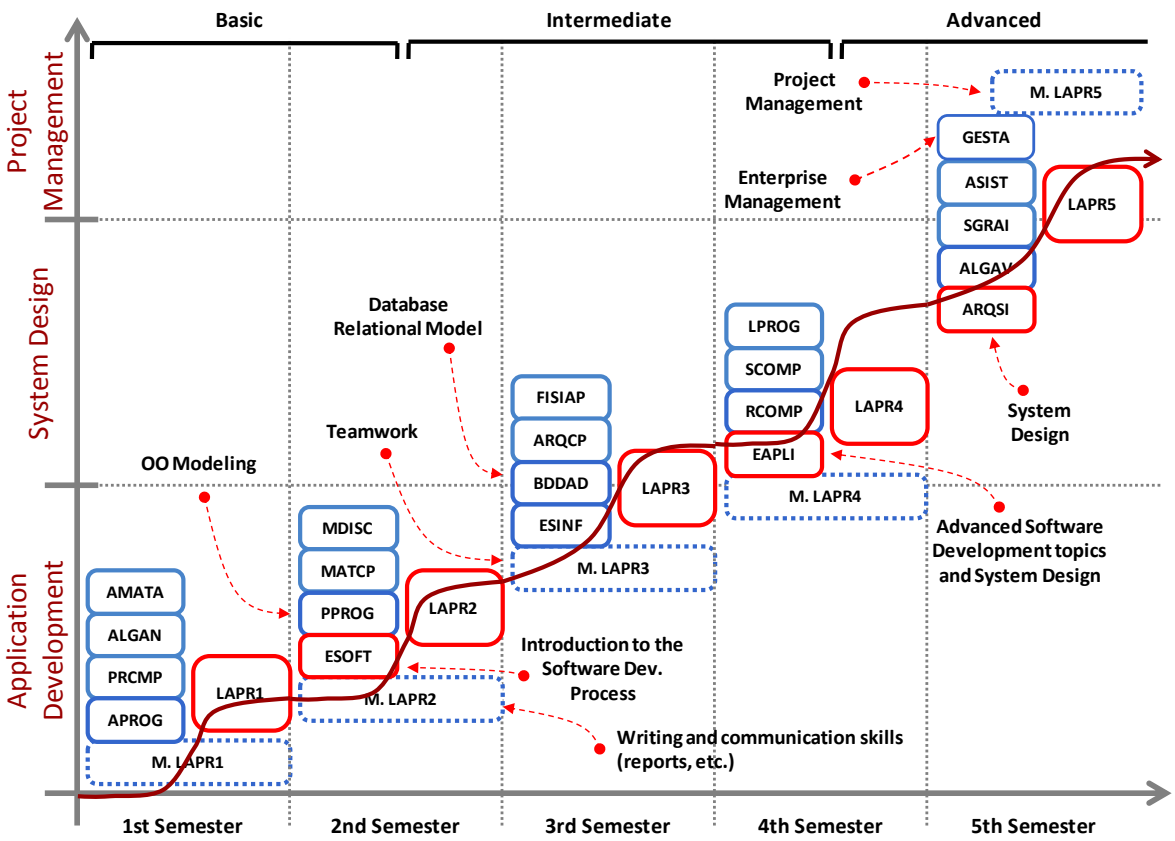

Figure 1 - LEI-ISEP learning process

SOFTWARE DEVELOPMENT PROCESS

The IEEE Computer Society defines software engineering as “the application of a systematic, disciplined, quantifiable approach to the development, operation, and maintenance of software; that is, the application of engineering to software.” [3]

While many advances have been made in the computer science and software engineering fields, general software practice still produces insecure, unsafe, or unusable programs that are delivered late and over budget. Today, in spite of the best efforts of the computer science and software engineering communities, software developers do not regularly use the best available known methods. Many follow a largely intuitive craft-like practice by picking up new methods from their peers and by using techniques that have long been discredited.

A software development process is a structure imposed on the development of a software product/system. There are several process models, each describing approaches to a variety of tasks or activities that take place during the process [4]. There are many processes and one cannot definitely choose one as the best, as the choice of the process to use is very much dependent on the type of system to be developed, the tools used in its development and the size and internal organization of the development team.

One widely used development process is the Unified Process (UP) [5], an extensible framework for the iterative and incremental development of systems that can be customized for specific organizations or projects. With iterative development, the project is divided into small parts. This allows the development team to demonstrate results earlier on in the process and obtain valuable feedback from system users. Often, each iteration is actually a mini sequential process with the feedback from one phase providing vital information for the

design of the next phase. There are many commercial development processes based and/or inspired on the UP, being the Rational Unified Process (RUP) [6] one of the most widely used. OpenUP [7], from the Eclipse Foundation is a lightweight/agile version of the UP that can be used by small teams and in small projects.

There was an internal argument on the choosing of software development process to use at LEI-ISEP, being the faculty divided between an iterative model (UP based) or an agile one (Scrum, XP, etc.). In the end, a UP based process was chosen, because it provides a structured approach to software development, which may be easier for the beginner (student) to follow. RUP was the processes of choice, as it is a refinement of the UP and the Informatics Engineering Department (DEI) has a close relation with IBM (RUP is a product of Rational, a division of IBM), having access to IBM's catalogue of teaching and e-learning materials. This is paramount in order to train the faculty and thus speed the adoption of the development process.

RUP is based on a set of building blocks, describing what is to be produced, the skills required and the step-by-step explanation describing how specific development goals are achieved. The main building blocks are:

- Roles (who) – A Role defines a set of related skills, competences, and responsibilities.

- Work Products (what) – A Work Product represents something resulting from a task, including all the documents and models produced while working through the process.

- Tasks (how) – A Task describes a unit of work assigned to a Role that provides a meaningful result.

A project is implemented in several iterations and, within each iteration, the tasks are categorized into nine disciplines, six engineering disciplines (Business Modeling, Requirements, Analysis and Design, Implementation, Test, Deployment) and three supporting disciplines (Configuration and Change Management, Project Management, Environment). The relative importance of each discipline changes from iteration to iteration, as the project moves from design to deployment. RUP has determined a project lifecycle consisting of four phases, as depicted in Figure 2:

- Inception - The primary objective is to scope the system adequately as a basis for validating initial costing and budgets.

- Elaboration - In this phase the problem domain analysis is made and the architecture of the project gets its basic form. The key domain analysis for the elaboration is system architecture.

- Construction - In this phase, the main focus goes to the development of components and other features of the system being designed.

- Transition - The primary objective is to 'transition' the system from the development into production, making it available to and understood by the end user. The activities of this phase include training of the end users and maintainers and beta testing of the system to validate it against the end users' expectations.

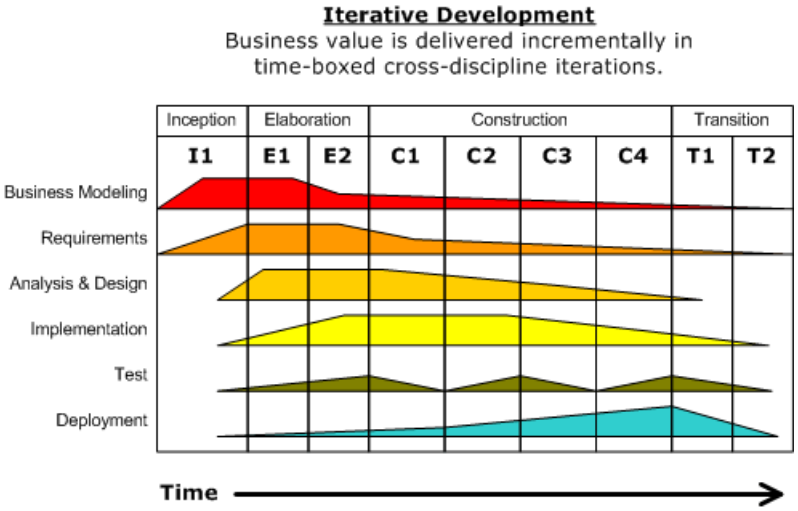

Figure 2 – UP Iterative development and the 6 main disciplines

LEARNING THE SOFTWARE DEVELOPMENT PROCESSES IN LEI-ISEP

RUP is a very large framework and many disciplines are too complex to be included in a bachelor degree, thus it was decided that some disciplines should only be studied in depth on a master degree. Furthermore, it was decided that the proficiency level the students should attain on the core disciplines of the process should be somewhere between Analysis and Synthesis (Bloom's scale) and that they should use the process on their capstone project. This level of proficiency requires a prolonged and repetitive use of the process in several courses, especially each semester's LAPR course. The solution was the development of an iterative approach for the teaching of the software development process, encompassing five semesters and three proficiency levels, compatible with LEI-ISEP's learning process depicted in Figure 1.

Basic Process

The Basic Process is to be used only in the 1st semester's project course, LAPR1, which is designed to meet CDIO standard 4 - Introduction to Engineering, and in the first 12 weeks of the 2nd semester. This process provides an overview of the iterative software development process at a level that can be understood by 1st year students with little knowledge about software development. There is no explicit reference to RUP's disciplines, as it is depicted in Figure 3.

Intermediate Process

The Intermediate Process is to be used in the 2nd (after week 12) and 3rd semesters. The students are introduced to the RUP in the 2nd semester, in a course named "Software Engineering" (ESOFT), thus this process includes four RUP disciplines. Of the two left out, Business Modeling is somewhat included in the Advanced Process, while Deployment is not covered at all in LEI-ISEP.

While the Basic Process is supposed to be used only with the very simple of the problems, where requirements are clearly identified in the problems wording, the Intermediate Process is to be used in more demanding projects, thus the inclusion of the Requirements and Analysis and Design disciplines. Though the process is the same for two semesters, 3rd semester's projects (LAPR3) are naturally more demanding and complex.

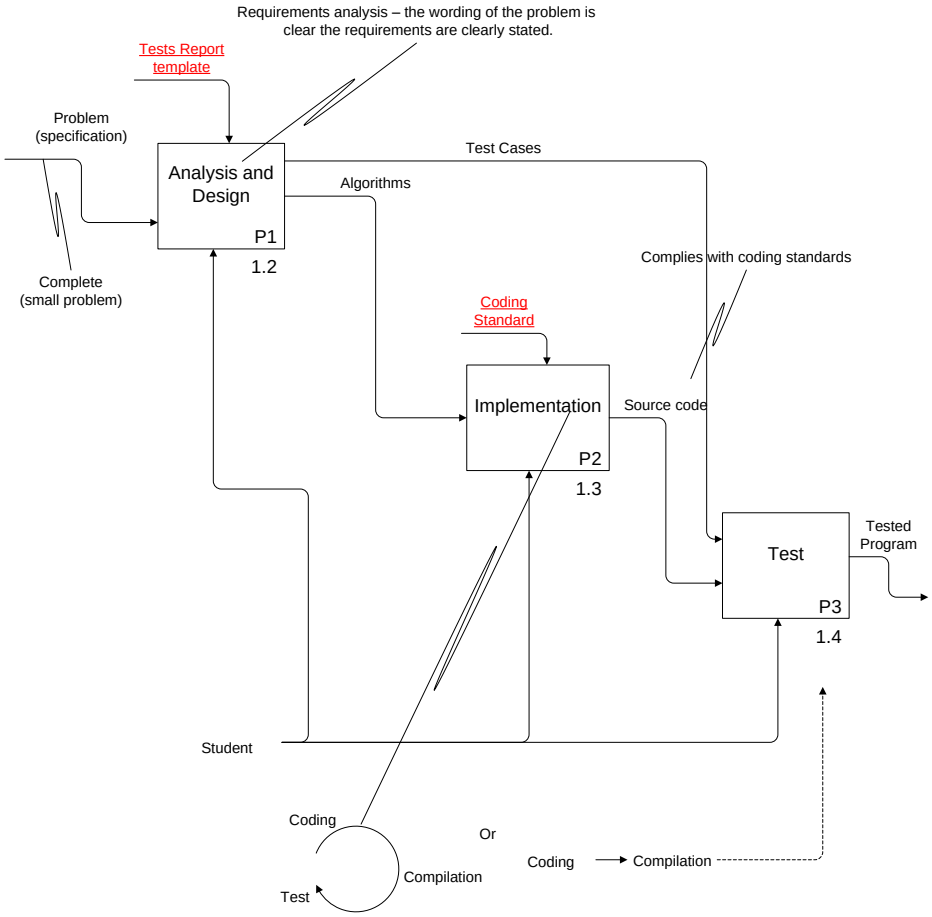

Figure 3 – LEI-ISEP's Basic Process

Advanced Process

The Advanced Process is to be used from the 4th semester (after week 12) onwards, including in the capstone project (6th semester). At the moment there are actually two versions of this process, as Project Management is only introduced in the 5th semester, in LAPR5. This is going to change in the near future, as project Management will be moved to LAPR4 (4th semester).

The advanced development process topics are introduced in two courses, EAPLI (Advanced Software Engineering) in the 4th semester and ARQSI (System Engineering) in the 5th. This iterative and incremental topic introduction, combined with a project course each semester, allows the student to fully understand (reflective observation [8]) the importance of the software development process in his professional life. We believe ISEP's graduates are starting to be agents of change in the Portuguese software industry and the industry seems to recognize that: this school year there were 230 internship offers by the industry while there were only 140 eligible students.

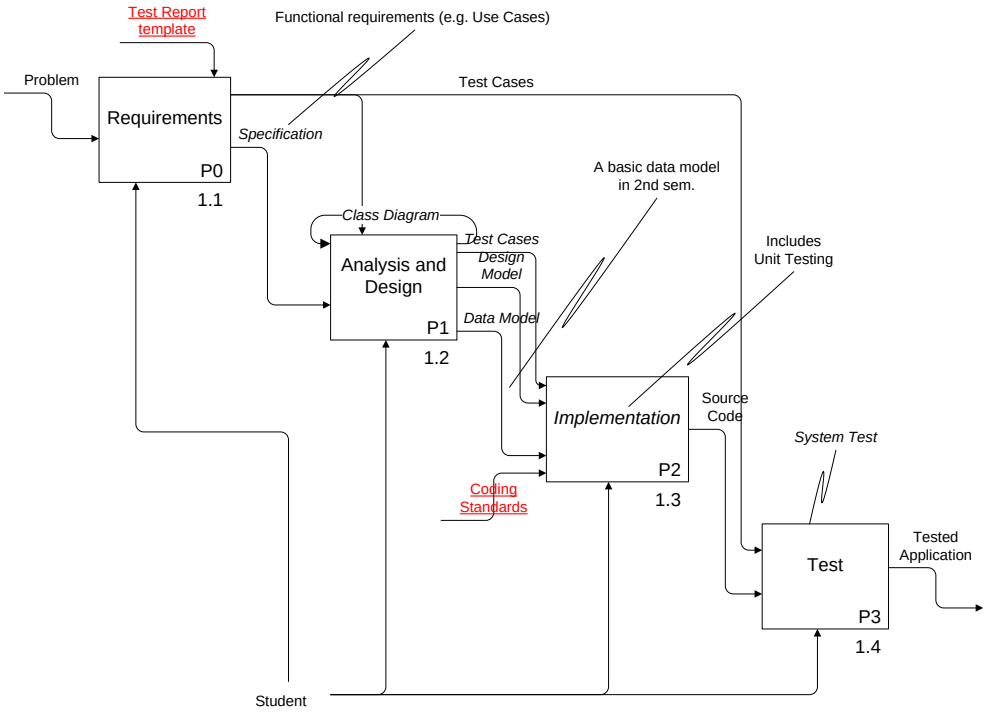

Figure 4 – LEI-ISEP's Intermediate Process

Faculty training

Faculty training is a key success factor for this endeavor. Unfortunately, the software development process hasn't been a popular research topic among the faculty. ISEP has to renowned research centers in the computing area, one on Artificial Intelligence (agents, decision support systems, etc.) and another one on Real-time Systems and Networks. Hence, most masters and PhDs have focused on these topics.

The lack of alignment between faculty interests and the LEI-ISEP Program's it's not exclusive to ISEP. The broader the theme the worse it is, as research nowadays is much focused and results oriented. The software development process is a broad subject and it requires a lot of practice in real projects. The inspiration for a fast solution for this problem come from the six-sigma business management strategy, especially the martial arts inspired implementation roles [9]. Under the direction of the LEI-ISEP's Program director, a *Champion* was chosen to lead the process of defining a software process and a task force was assembled (black belts in six-sigma terminology), composed of specialists in the field, most of them responsible for the courses most related to the subject.

The task force developed a development process proposal and some of the related support documentation (document templates, usage guides, etc.). The process was then introduced in the core courses: the three software engineering related courses and the five project courses. These last courses present an interesting challenge, as they include teaching staff from all other courses of the same semester. In some courses there are over 30 teachers involved. The only solution to disseminate the process practices in an efficient manner was the creation of an intermediate level of responsibility, the "green belts" that were trained and act as disseminators and "experts" for the remaining staff. At the time of the writing of this paper it is too soon to present a reliable assessment of the enforcement of this strategy. Nevertheless, the first results are encouraging.

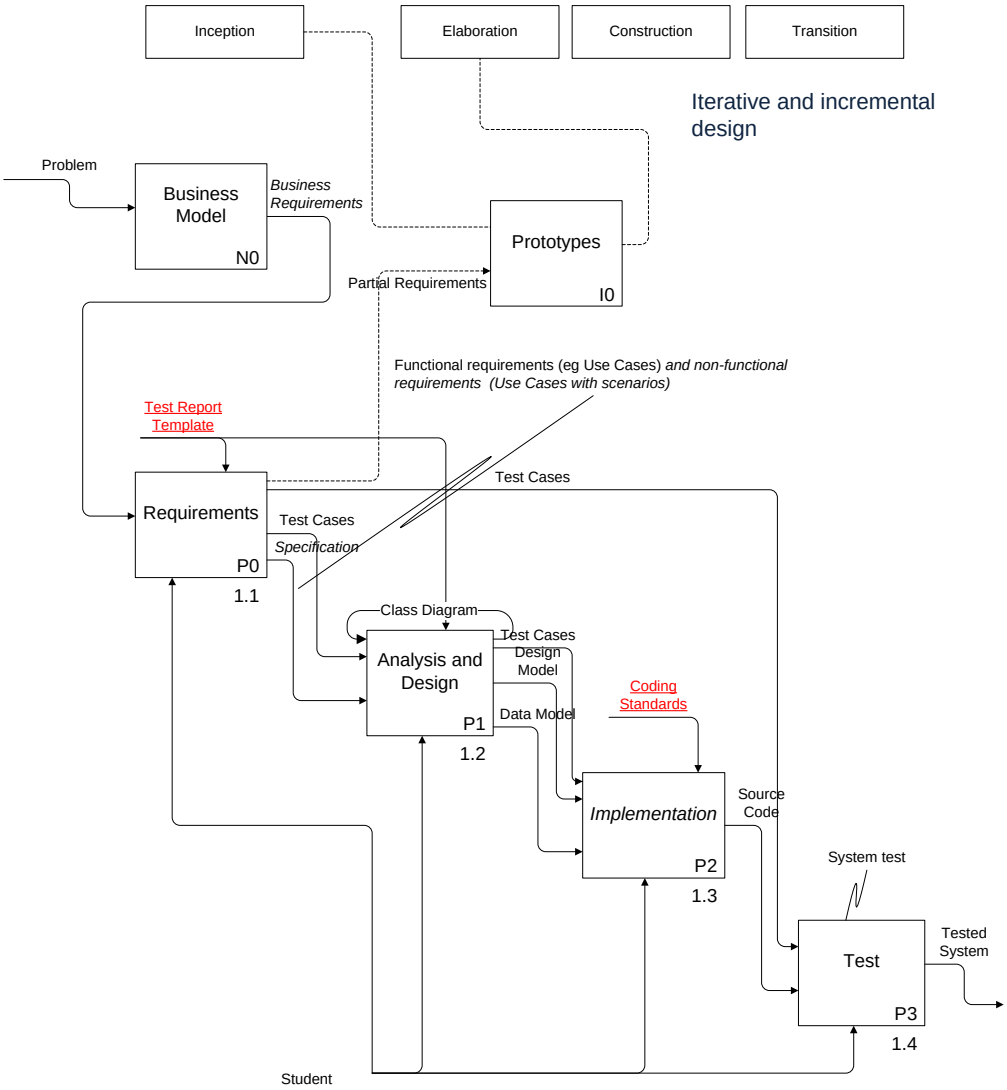

Figure 5 – LEI-ISEP's Advanced Process

CONCLUSION

ISEP identified that the practice of a Software Development Process would be a key differentiator for its graduates in Informatics Engineering, a program already recognized to be in the top 5 in Portugal. Nevertheless, learning a Software Development Process is a prolonged process by itself. This lead to the development of an iterative and incremental approach for introducing the process to LEI-ISEP's students.

The results of this process will only be fully measurable in a couple of years, when current students finish their bachelor degrees and we start having feedback from the industry, but the process has already provided very interesting results, especially in faculty involvement and training.

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Student Engagement in a One Day One Problem PBL Class

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ABSTRACT

Problem-based learning (PBL) is adopted in a unique One-Day One-Problem approach at Republic Polytechnic (RP), Singapore. The basis is that students learn best through engagement. This engagement at RP starts in response to a question or a problem, and continues with reasoning and understanding by students throughout the day. This paper presents the RP's PBL practises in the School of Engineering in student engagement and daily reflection by citing one of the daily problem "Heart Rate Filters" in the module "Linear Circuits and Control" to show how students are engaged through problem trigger, simulation and class discussion throughout the learning process. This new form of engagement broadens the educational experience of engineering students and increases students' interest in engineering education.

KEYWORDS

Problem Based Learning, Student Engagement, Reflective Learning, Holistic Assessment.

1. INTRODUCTION

Student engagement plays an important role in students' learning process in any form of education. Students learn best through engagement and active learning, and by using self-monitoring and reflection to guide their learning (Blank 1997; Dev 1997; Kushman 2000; McCormick 2003; Woods 1995). Research has shown that educators who are most successful in engaging students is to develop activities that best suit students' basic psychological and intellectual needs in mind (Ames 1992; Anderman & Midgley 1998; Strong et al. 1995). Thus, the challenge for every institute is to constantly review their course content to improve on student engagement.

The One-Day-One-Problem PBL in Republic Polytechnic (RP) emphasizes on students' engagement during their learning journey. Students are assigned into small teams and worked together to solve a problem daily. All learning engagements of regular modules at RP are initiated by a statement demanding a response from the students. Collaborative self-directed learning during each engagement culminating with a presentation, defence and reflection is expected of students. This is RP's strategy to apply PBL to meet its specific mission of training professionals out of secondary school graduate and to prepare them for real world challenges (Glen & Alwis 2002).

In the School of Engineering, Republic Polytechnic, the design of the daily learning activities for students is based on the Kolb's descriptive model of learning process. Kolb's learning cycle consists of four stages: Concrete Experience is followed by Reflective Observation that generates the Abstract Conceptualisation. This leads to Active Experimentation that will generate a new Concrete Experience, as shown in Fig.1.

Many use Kolb's descriptive model of learning process as a model of experiential learning. However, problem based learning is different from experiential learning. In our PBL context, concrete experience in the model includes the past experience of students in their daily life, their experience gained through simulation in classroom (Wang, Fong 2006), and their hands-on experience gathered in laboratories and during field trips. With a properly designed problem statement, these experiences will trigger students' curiosity to explore further. In the second stage, students try to figure out the reasons why a topic is important and what they need to learn in order to understand the topic. In the third stage, information about the topic is collected through online resources, textbooks, and discussions. Abstract conceptualization happens at this stage to bring students to a higher level of understanding to the topic, with the support of scaffoldings and helps from facilitator. Finally, in the fourth stage, students apply the topic in problem solving and experiment actively based on their understanding to the topic. In this way, students are engaged throughout the day.

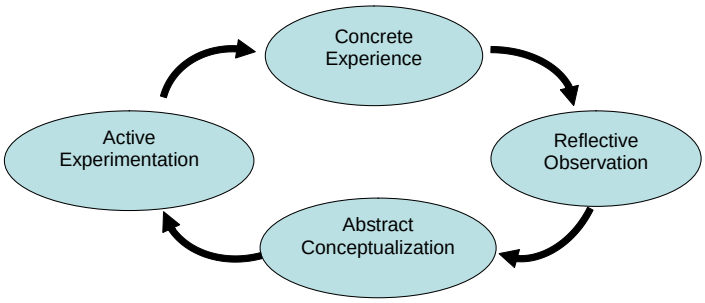

Fig. 1. Kolb's descriptive model of learning process

In the section 2, the student engagement and reflective learning will be discussed further, followed by a case study based on a problem designed for a module called "Linear Circuits and Control", then student learning will be reviewed briefly through their reflection journal. Final will be a brief discussion on incorporating CDIO into our curriculum and the conclusion.

2. STUDENT ENGAGEMENT AND REFLECTIVE LEARNING

Student engagement refers to "student's willingness, need, desire and compulsion to participate in, and be successful in, the learning process promoting higher level thinking for enduring understanding" (Bomia, et al. 1997). In the Republic Polytechnic, we have identified three key elements in our One-Day-One-Problem problem solving process for student engagement that are learning environment, problem statement and daily activities, and reflection, as shown in the Fig. 2.

Learning environment:

To engage students effectively, learning environment is crucial. In RP, the typical number of students in each class is 25. Students are randomly grouped in teams of 5 with the help of a facilitator and they will need to work within their team for the day itself. The classroom layout is designed in such a way that 5 students are sit face to face around a table. There are 5 tables in total in one classroom. Students are expected to share their own ideas, do research and develop possible solutions together with their team mates. Social bonding among students is developed due to a collaborative classroom environment.

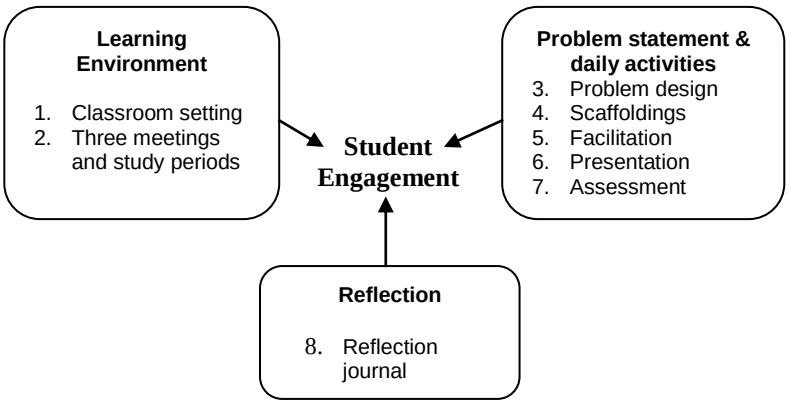

Fig. 2. Three key elements for student engagement in RP

There are three meetings every day for students to interact with the facilitator of the class. While the first meeting is for students to understand the problem and figure out the knowledge they need to learn in order to attack the problem, the second meeting is giving a chance for students to move in the right direction. Normally this is done through the inquiries and questions from facilitator. There are two study periods between three meetings which are for students to do self-directed learning. Students continue to learn through presentations during the third meeting. Challenging questions from facilitator and classmates force presenter and listener think more critically.

Problem statements and daily activities

Problem statement is the key to trigger students to start to learn, and problem must be suitable for students to complete it within a day. The problem design and problem statement crafting become the most critical component for one day one problem approach, especially in engineering.

Recently there are plenty of discussions on engineering education reform. Many reports indicated that traditional engineering education focuses on and encourages largely the study of engineering science. Students in engineering schools get boxed into one-dimensional careers consisting mainly of technical work, eventually get bored and then stagnate in their career (Prados 2004, Duderstadt 2008).

For engineering education in the Republic Polytechnic, holism is a necessity. We believe in an education strategy that will make students regularly evaluate a given scenario, identify, search and gather relevant information, work in teams, reason and justify to form opinions, apply various known tools, convince others and reflect regularly on whatever they do (Wang, Fong and Alwis,2005). To achieve these, the engineering fundamentals covered in traditional curriculum are re-engineered to form a selection of key ideas that define the subject. For each key idea, a context is crafted that motivates a response dealing with the idea strongly. The subject content is secondary and shall get expressed along with the response. Each problem sets an achievable, meaningful & relevant target for the day to the students, thus engage them to complete the daily learning activities.

The students in RP are mainly secondary school graduates who have been so used to traditional lecture system invariably find themselves unfamiliar with the PBL environment. To help the students, well designed scaffolding is provided to nudge them towards developing a comprehensive response. Scaffolding is in the form of worksheet accompanying the problem statement.

In the third meeting, students are required to present and defend their solution in front of their classmates and facilitator, to enhance their communication and critical thinking skills.

We understand that assessment tends to drive students' learning. To engage students beyond contents and knowledge, the assessment in RP includes two main components, daily grade and understanding test grade. Daily grades capture the different facets of the broad perspective of problem solving in a team. Understanding tests are conducted three times per semester for each module to assess the level of understanding of students to the problems they solved.

Reflection:

Problem based learning (PBL) is learning by reflective thinking. As a teaching and learning methodology the problem from a real world context becomes the catalyst for students to

achieve both knowledge and process outcomes but only in as much as students engage with the processes of reflective thinking. Reflective learning is an essential attribute for lifelong learners. This learning process allows an Individual to make sense of their experience and provides them with an opportunity to challenge thoughts and feelings about events and change future behaviour. To further enhance reflective learning, the facilitator of a class posts a reflection journal (RJ) question after the third meeting so that student can reflect on their learning of the day. It helps the students to reflect on their learning process as well as engagement for the day.

In the next two sections, a real problem package in the module “Linear Circuits and Control” will be used to illustrate the student engagement ad reflective learning in RP.

3. PROBLEM DESIGN: HEART RATE FILTER

The heart rate filter was one of the sixteen problem presented to students in the module “Linear Circuits and Control”. The learning objectives for this problem were filter designs and filter application. It should be noted that students had acquired knowledge of basic filters and common types of filters such as low and high pass filters, higher order filters in previous weeks.

The problem designed begins with the forming of a problem trigger. Considerations for good problem trigger include motivational issues and authenticity. Whenever possible, it must also be kept relevant to the industry to better prepare students for future challenges. These characteristics of problem crafting increase the student's willingness and desire to participate in the learning process. In this case, the problem described the need for filters for the biomedical industry where heart rate signals obtained from electrodes are noisy in nature. Fig. 3 shows the basic formulation and layout of the problem statement. (see Appendix A)

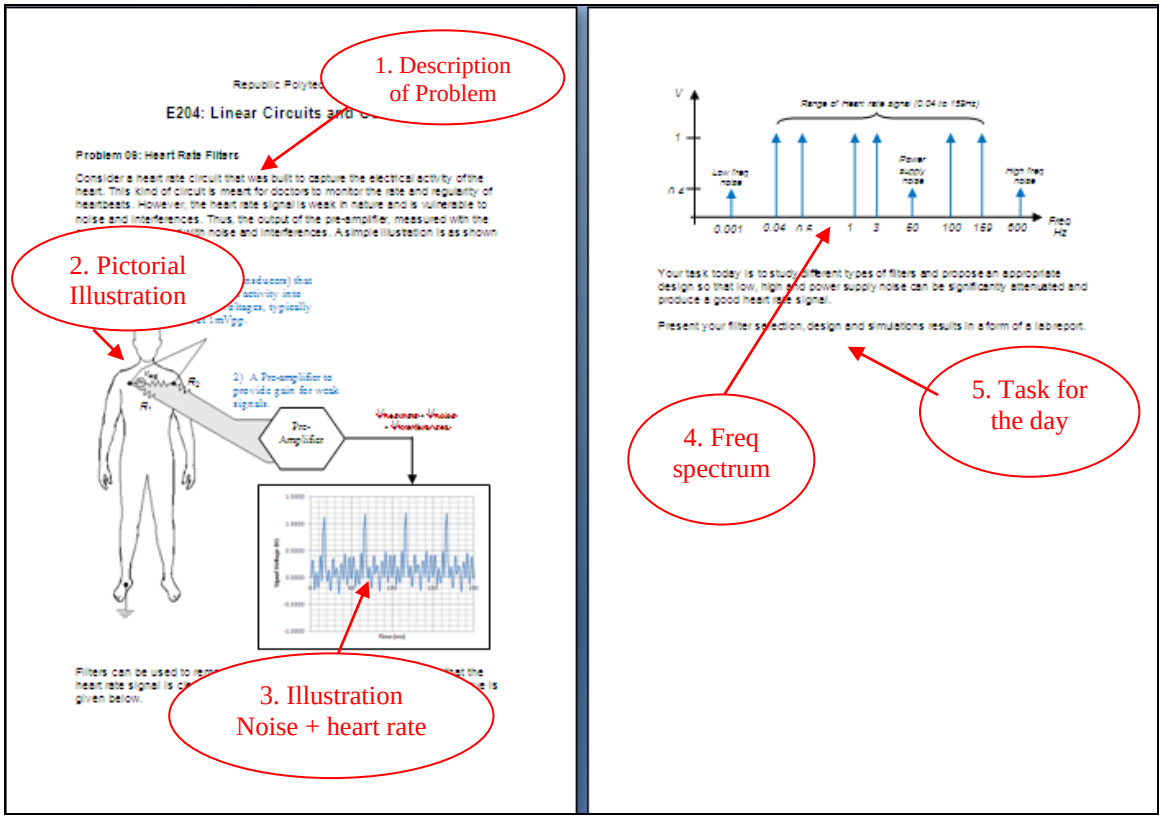

Fig. 3. The Problem Statement of Heart Rate Filter

As discussed earlier, scaffoldings are distributed to students together with the problem statement to assist student in their learning. There is no restriction to the form of scaffold other than its relevance. The following describe some of key scaffolds provide for students in the heart rate filter problem.

Software or hardware scaffoldings are often created to aid student where certain areas of understanding are beyond the learning proximity for the class. Most of students may have rough ideas how heart rate signal is captured and displayed in medical devices in hospitals, but lack of experience of capturing, processing and displaying the signal. Thus in the case of the heart rate filter problem, a scaffold was created in Excel to better illustrate the effect of unwanted signals (noise) which distort a desirable heart signal (Fig.4). The scaffold brought in experience in a simulated environment to facilitate students' reflective observation.

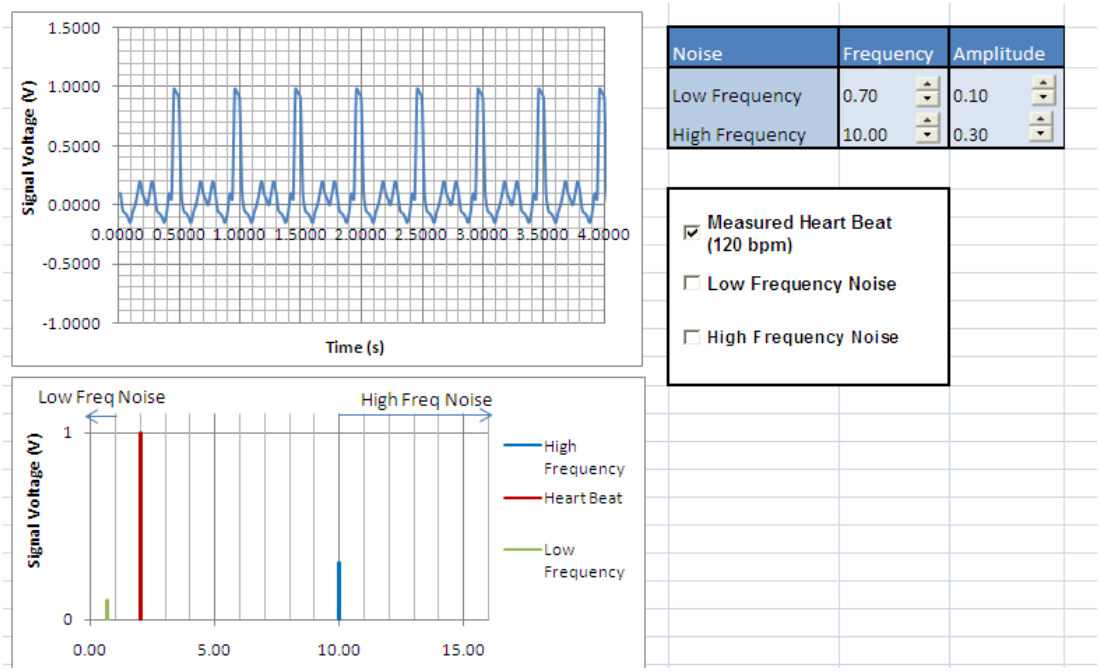

Fig.4. Scaffold created using Excel

The worksheet is another key scaffold provided to students. The questions raised in the worksheet are carefully designed to help student to build understanding of concepts requiring a high level of abstraction. For this problem, students normally are able to figure out the formation of a band pass filter or a band stop filter by a high-pass filter, a low-pass filter and a summing filter, but have difficulties dealing with notch filter. Questions in the worksheet help students to jump from what they can comprehend to more abstract concepts such as central frequency, quality factor and the design of a notch filter. These questions are normally reviewed by a team of facilitators to adjust the level of guidance so as to complement the level of difficulties faced by the students.

Finally, facilitator is also an important scaffold in class. In this problem, facilitators help students learn to use PSpice software to simulate their filter designs whenever necessary. Facilitator monitors the team dynamics in each group, facilitate self-directed learning of each individual student and make sure students are engaged throughout the three meetings.

With the context of filtering noises from heart rate signal, students are more motivated to explore the new concepts brought up by the problem. This can be seen from their reflection journals after the class.

Table below shows some of responses from students who have gone through the “Heart Rate Filter” problem.

Table 1. Reflection Journal response quoted from students

Reflection Journal questions posted by facilitators:	**Student’s response**
Class A: How do you find today’s problem on the application of filters? Do you think it will be beneficial to you?	Today I have tried my best to understand well and perform for this problem. I found that today's problem is not very tough and class discussion enhanced my understanding.
	I find that, by learning the day's problem about filters, give a better view and a larger scope on what are we trying to focus on about handling medical equipments.
	To me it is very beneficial and important as it is regarding and how to handle the equipments stuffs. Not only that, it is also link to what we will do after we graduate. Therefore, having to learn and understanding the scope of how the filtering works, it benefits me for now and also during the working industry.
	As usual, the basic knowledge is very important. Actually we have learnt about filters in the Problem 7. From then on, each day’s problem is going to feed the knowledge of filter step by step to us. So I link today’s problem to the previous two problems. I think they are very helpful for me to understand the new knowledge.

The RJ question probed into student motivation for the day. Most students were able to relate the heart rate filter circuit design to the medical equipment used in industry. The problem scenario helps to trigger students’ interest in their learning, even for those students who may find it tough.

4. RP’s PBL and CDIO

With the main aim of educating students who are able to “*Conceive-Design-Implement-Operate engineering products, processes, and systems in a team-based environment*”, the CDIO Initiative has codified the expected learning outcomes of an engineering education into the CDIO syllabus. This syllabus is organized into four main sections:

1) Technical knowledge and reasoning
2) Personal and professional skills and attributes
3) Interpersonal skills: Teamwork and Communication
4) Conceiving, designing, implementing and operating systems in enterprise and societal context.

As described above, RP’s adaptation of PBL emphasizes learning engineering fundamentals through a well designed context and a series of engaging activities which center on students working in small teams to deal with issues brought up through the daily problems. As the students work through the problems, students identify the learning issues, gather the relevant information, communicate their ideas and develop a possible solution to the problem. They would then need to present and justify their solution to the class. Through this approach, students are able to improve their capability to understand by learning how to learn.

RP’s School of Engineering has been exploring how elements of the CDIO syllabus, especially section 4, can be incorporated to enhance RP’s existing curriculum structure. One recent change that has been implemented is the introduction of a core module, Engineering Design, in the first year curriculum for all engineering students. In addition, the school is

considering getting second year students to be engaged in a design challenge so that they can integrate their learning during their first two years. For third year students, engineering curriculum requires students to complete two project modules, that each is a semester long, to engage students to conceive, design and implement a workable prototype or a system in different areas. Many of the projects are industry initiated.

5. CONCLUSION

With contextualization of abstract engineering concepts, engineering students can be more effectively engaged in their learning process. Properly designed problem trigger, scaffolding like simulation and worksheet, class discussion and self-directed learning make sure students in the Republic Polytechnic to solve a problem a day. The experience prepares student for real world challenges when student graduate from their studies.

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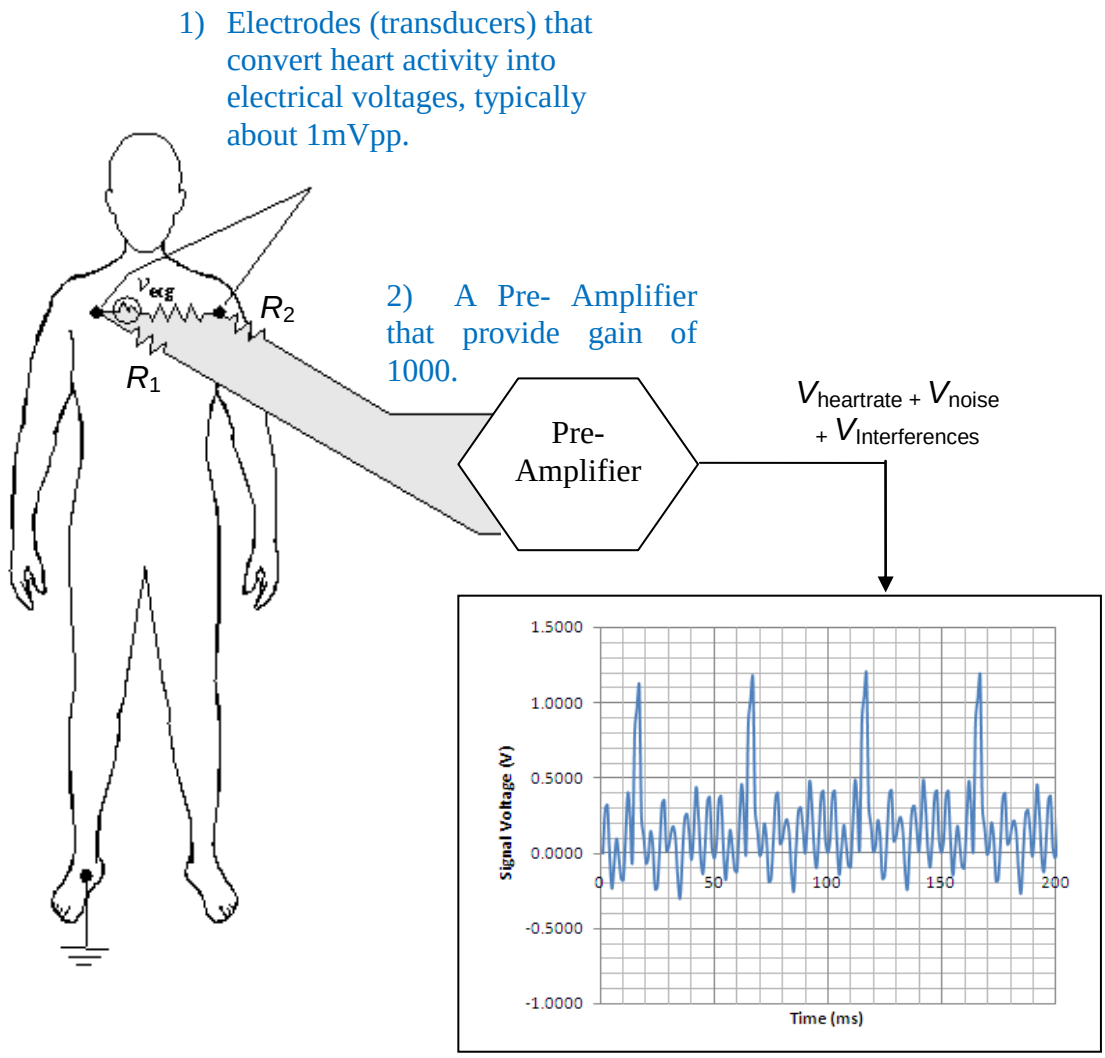
Appendix A

Republic Polytechnic

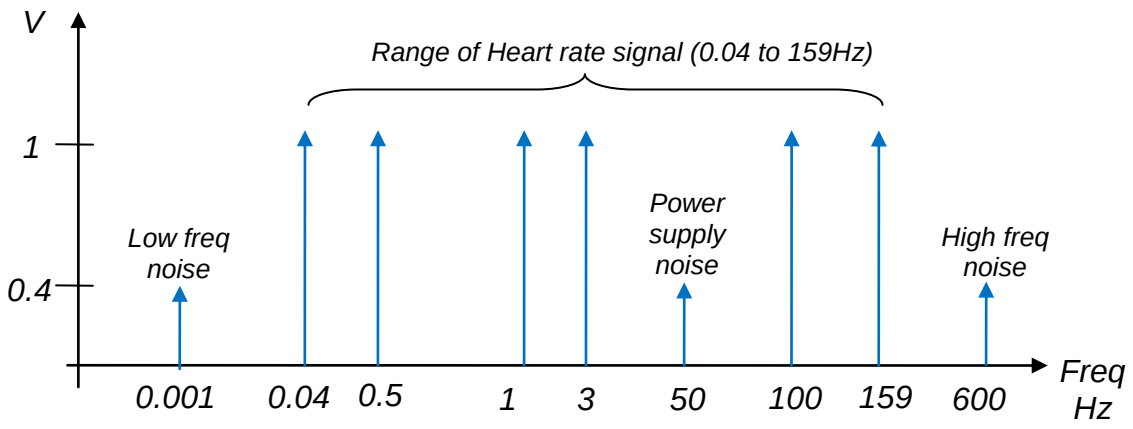
E204: Linear Circuits and Control

Problem XX:Heart Rate Filters

Consider a heart rate circuit that was built to capture the electrical activity of the heart. This kind of circuit is meant for doctors to monitor the rate and regularity of heartbeats. However, the heart rate signal is weak in nature and is vulnerable to noise and interferences. Thus, the output of the pre-amplifier, measured with the oscilloscope is filled with noise and interferences. A simple illustration is as shown below.



Filters can be used to remove the unwanted noise and interferences so that the heart rate signal is clear. Supposing the frequency spectrum of the signal above is given below.



Your task today is to study different types of filters and propose an appropriate design so that low, high and power supply noise can be significantly attenuated and produce a good heart rate signal.

Present your filter selection, design and simulations results in the third meeting.

STUDENT PROFICIENCY EXPECTATIONS AND SELF EVALUATION ON THE CDIO SYLLABUS TOPICS

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ABSTRACT

Students in Mechanical and Materials Engineering at Queen's University were surveyed on the CDIO Syllabus at the end of the Fall Term, half way through their final year in the program. They were asked to provide a 1 to 5 proficiency ranking on all of the 2.X through 4.X elements in the syllabus for both their own current ability and their perception of an appropriate expected proficiency level for a new graduate from an engineering program.

This data set is valuable as a snapshot of student perceptions and for comparison when the same cohort is surveyed subsequent to graduation and entry into the work force. It is particularly valuable as it covers 111 of 116 students enrolled in MECH 460, the fourth year Conceive and Design course that is a core requirement in the MME program.

The results indicate that the students are largely in accord with previously measured expectations of other students and professionals and points out the potential for including greater societal and business context as a program enhancement. The discrepancy between expectations and self assessment requires further examination.

KEYWORDS

CDIO Syllabus, Proficiencies, Self-Evaluation

INTRODUCTION

The CDIO Syllabus provides a list of knowledge, skills and attitudes that are of key importance in the practice of engineering. Combining this list with expectations for proficiency in each of the elements yields objectives for broad learning outcomes that can be applied in designing curricula for engineering programs. CDIO Standard 2 requires that stakeholders, typically through surveys of those stakeholders, validate these outcomes. In an educational setting the obvious direct stakeholders are the students (past and present), the teachers, and the future employers of the students. Although previous surveys [1] have included all three groups, there has been more focus on alumni, faculty, and industry leaders [2,3] than on current students. Student input is important first to be sure there is no disconnect between their objectives and those of the other stakeholders and second to recognize opportunities to differentiate programs and better engage students by including more emphasis on areas they find particularly important. This paper provides data on one group of current students and compares it to previous results.

METHODOLOGY

A survey based on the CDIO Syllabus was administered to a group of fourth year students nearing completion of the seventh semester in the eight semester program in Mechanical and Materials Engineering at Queen's University. All were enrolled in the capstone Conceive and Design course, and the survey was administered in class in November 2008 as part of an anonymous course evaluation. Although this required a paper survey form, it enabled a very high response rate (111 / 116).

Following Bankel et al. [1], this study used a questionnaire asking students to rank each of the second level items 2.X through 4.X from the CDIO Syllabus on the basis of a five point proficiency scale:

1. To have experienced or been exposed to
2. To be able to participate in and contribute to
3. To be able to understand and explain
4. To be skilled in the practice and implementation of
5. To be able to lead or innovate in

To provide context for each of the second level items, a list of all of the subordinate third level items (e.g. 2.1.X) was provided with each item. Item 3.3 Foreign Languages was clarified as "Using a language other than the primary language of instruction at your institution for technical communication" to allow for countries like Canada with more than one official language. Students were required to select a whole number as a response to each item by circling that number. A copy of the form is available electronically.

Students were asked first to complete a ranking for all items based on their own current level of proficiency, and then to complete an identical form for the level of proficiency that should be expected from a new engineering graduate. The forms were collected and the data tabulated in a spreadsheet for analysis and presentation.

Table 1
Student Survey Results: mean and standard deviations for student assessment of their own proficiency level and what proficiency level should be expected in a new graduate.

CDIO Syllabus Learning Objectives		Individual Assessment		Graduate Target	
		Mean	SD	Mean	SD
Personal & Professional Skills & Attributes	2.1 Engineering Reasoning	3.23	0.82	3.58	0.77
	2.2 Experimentation	2.89	0.90	3.30	0.83
	2.3 Systems Thinking	3.00	0.86	3.36	0.84
	2.4 Personal Attributes	3.65	0.80	3.65	0.77
	2.5 Professional Attributes	3.23	0.96	3.53	0.90
Communication	3.1 Teamwork	3.62	0.81	3.73	0.85
	3.2 Communication	3.40	0.77	3.72	0.79
	3.3 Foreign Languages	1.98	1.36	2.10	1.13
Operating Systems in the Enterprise and Social Context	4.1 Societal Context	2.56	0.89	3.06	0.99
	4.2 Business Context	2.60	0.88	2.99	0.93
	4.3 Conceiving	2.94	0.94	3.30	0.93
	4.4 Design Process	3.16	0.88	3.59	0.88
	4.5 Implementing	2.66	0.96	3.31	0.98

	4.6 Operating	2.63	1.03	3.10	0.97

RESULTS

The mean and standard deviation for each item on the survey was calculated from the tabulated data and is presented in Table 1. A copy of the spreadsheet of individual responses is available electronically.

Previous data was available for students and working professionals from three Swedish universities (Chalmers University of Technolgy, the Royal Institute of Technology (KTH), and Linköping University (LiU)) and from the Massachusetts Institute of Technology (MIT) in the USA [1]. This data was for the same proficiency scale on each of the items and is thus directly comparable to the current data.

Data sets are also available for alumni from Queen's University, Belfast [3] and from Queen's University at Kingston [2] (no affiliation), however these data sets result from a ranking of the relative importance of different items in the syllabus, rather than proficiency levels. Although these data have previously been found consistent with the data of Bankel et al. they are not directly comparable to the current data and have been omitted.

Figure 1 compares the expectations collected from Queen's students with the data previously collected for fourth year students at the other universities. Data was also collected for first year students in the previous study, however it was deemed unreliable due to the student's uncertainty on the meaning of some of the items in the syllabus. There is no data for MIT on item 3.3 Foreign Languages as it was not collected in a US environment. There is no data on item 4.3 Conceiving for the Swedish universities as the data were lost due to a software fault. The same data items are missing from the other figures.

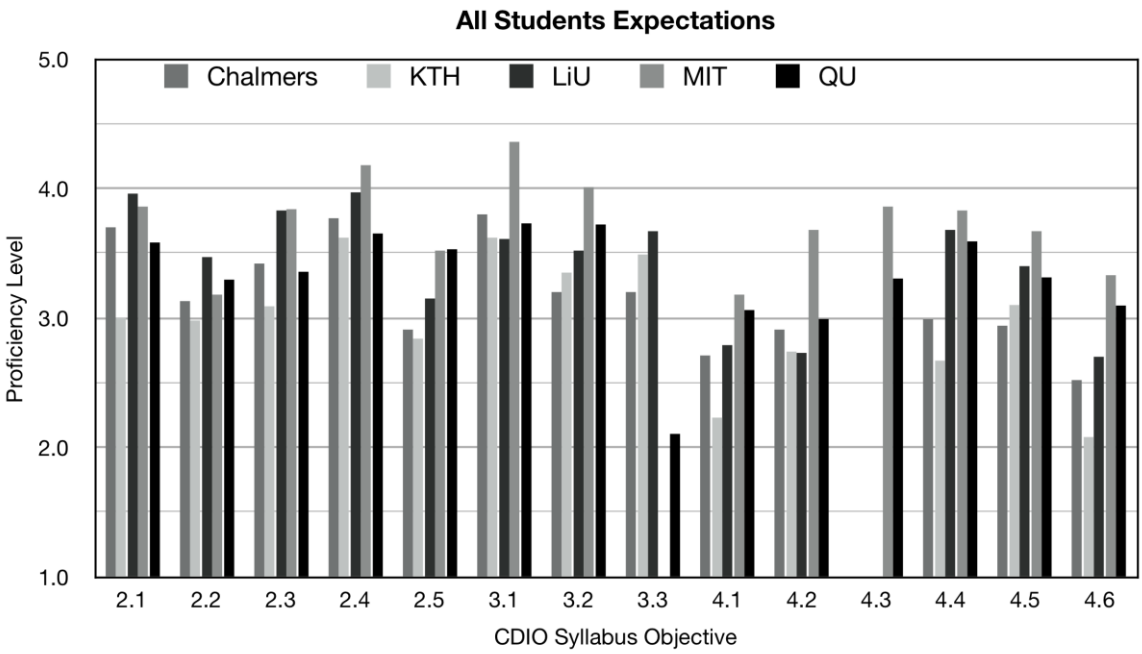

Figure 1. Comparison of fourth year student responses for expectations of proficiency for new graduates of an engineering program.

Figure 2 compares the expectations of Queen's students with the data previously collected for working professionals by the other universities, typically alumni, faculty and industrial contacts. Only aggregate data is presented here, however the previous study separated the

responses into faculty, industry, and alumni at 5 and 15 years post graduation, noting general consensus across groups.

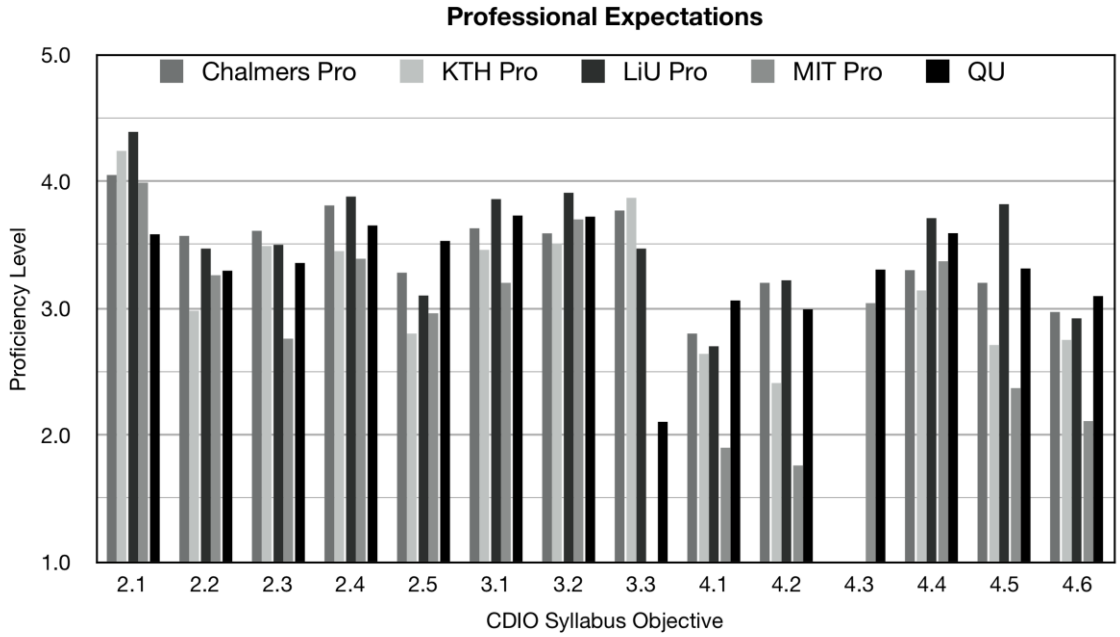

Figure 2. Comparison of working professional and Queen's fourth year student responses for expectations of proficiency for new graduates of an engineering program.

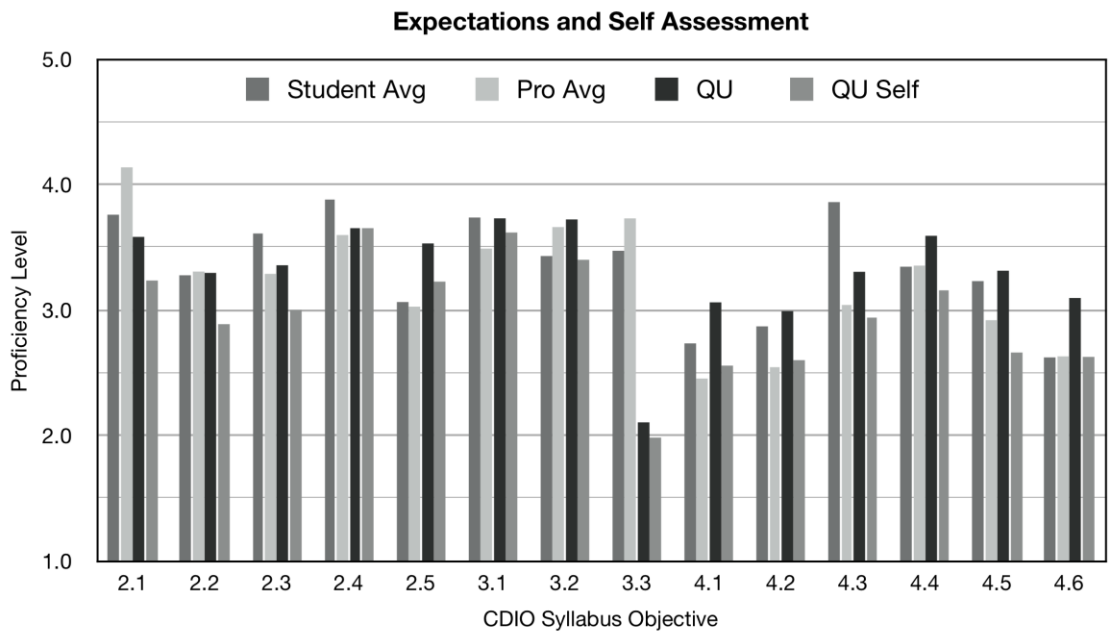

Figure 3. Comparison of expectations of students and professionals with expectations of Queen's students and Self Assessments of Queen's students.

Figure 3 Compares the averages of the expectations of students and working professionals with the current data for the expectations of Queen's students and for the students' self assessment of their own individual levels of proficiency on the various syllabus items.

Bankel et al. [1] did not provide standard deviations for their data set, so a direct comparison of significance cannot be made. It is however, possible to use the confidence in the means of the current data set as an indicator. With 111 samples, a typical mean of 2.97, and standard deviation of 0.92; a T test requires a difference of 0.25 between means for significance at 95% confidence. Thus differences of less than a quarter of a point should probably be ignored. In addition, the small sample sizes for fourth year students from KTH (8) and MIT (6) make comparisons problematic.

DISCUSSION

The first clear feature of all of this data is the degree to which all stake holders share similar opinions on the levels of proficiency expected in the various areas. This has been noted before [1,2,3] and validates the general direction of the CDIO initiative and syllabus. There are, however, some noteworthy differences on some items.

On item 2.1, Engineering Reasoning, the Queen's students are in close agreement with the other students and both are more than half a point below the professionals. This is especially troubling as it indicates many students accept level 3 (understand and explain) rather than expecting level 4 (skilled practice) in this fundamental skill.

On item 2.5, Professional Attributes, and 4.3 through 4.6 (C, D, I, and O) the Queen's students show generally higher expectations. That may be due to their experience of our program post CDIO adoption, which have added emphasis on professional practice issues within design project courses and feature the words Conceive, Design, Implement, and Operate throughout the program.

On item 3.3, there should be no surprise that in Canada, an officially bilingual country, there is some importance placed on communication in another language. Queen's is an English speaking university, so even unilingual students can expect a reasonable degree of success in an international environment where English is the common language. Thus, it is not unexpected that they place less emphasis on this item than both the students and professionals in a Swedish context. That the MIT survey did not include item 3.3 suggests the limited importance placed on other languages within the US curricula and professional environment.

On item 4.1, Societal Context, there was a notably higher ranking in the Queen's data, probably indicative of the general societal trend to more emphasis on social and environmental issues. It is also noteworthy that students in the previous survey ranked this item more than half a point above the professionals.

There is significant variation on item 4.2, Business Context, especially among the different groups of professionals, as note by Bankel et al. [1]. There is a clear indication that students expect to develop proficiency at working within a business context while some industrial respondents might prefer they get that context within their own corporate structure, particularly in the US aerospace industry from which most of the MIT responses were drawn.

In both 4.1 and 4.2 the student data from this survey and the previous one indicates a desire on the part of students to see their studies in a larger context, even though professionals see less of a requirement for developing that context while students are still in university. This represents an opportunity for programs to attract more students, particularly female students,

by further emphasizing the context of an engineering education as improving the state of the world, both economically and socially.

One troubling result of the survey is that students assessment of their own level of proficiency falls consistently below their expectations for a graduating student. The only exceptions are items 2.4, Personal Attributes, and 3.3, Foreign Languages. There are several possible explanations. It may be a matter of modesty, although the result on 2.4 suggests otherwise. It may be that these students were surveyed less than 7/8 of the way through their program and expect to develop further proficiencies before graduation. It may be that students are not reaching their full expectations within our program, or some combination of all three. This issue requires further examination, especially in light of the continuing financial pressure on engineering programs within Ontario, and globally.

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Biographical Information

Rick Sellens is an Associate Professor in the Department of Mechanical and Materials Engineering at Queen's University. His research background is in Fluid Mechanics and more recently in Biomechanics and he has been actively involved in facilities development to support active learning, including the recently completed Integrated Learning Centre at Queen's

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On this page please **circle one whole number** beside each of the topics representing what you think is:

Your own current level of proficiency

Keep in mind that the levels 1 to 5 represent the range of proficiency levels one would expect to find in working professionals. Thus, it would be unusual for even highly skilled practitioners with long experience to have more than a few fives.

		Circle one level of proficiency for each topic				
		1. To have experienced or been exposed to	**2. To be able to participate in and contribute to**	**3. To be able to understand and explain**	**4. To be skilled in the practice or implementation of**	**5. To be able to lead or innovate in**
Personal and Professional Skills and Attributes	**2.1 ENGINEERING REASONING AND PROBLEM SOLVING** *Problem Identification and Formulation* *Modeling* *Estimation and Qualitative Analysis* *Analysis With Uncertainty* *Solution and Recommendation*	**1**	**2**	**3**	**4**	**5**
	2.2 EXPERIMENTATION AND KNOWLEDGE DISCOVERY *Hypothesis Formulation* *Survey of Print and Electronic Literature* *Experimental Inquiry* *Hypothesis Test, and Defense*	**1**	**2**	**3**	**4**	**5**
	2.3 SYSTEM THINKING *Thinking Holistically* *Emergence and Interactions in Systems* *Prioritization and Focus* *Trade-offs and Balance in Resolution*	**1**	**2**	**3**	**4**	**5**
	2.4 PERSONAL SKILLS AND ATTRIBUTES *Initiative and Willingness to Take Risks* *Perseverance and Flexibility* *Creative Thinking* *Critical Thinking* *Awareness of One's Personal Knowledge, Skills and Attitudes* *Curiosity and Lifelong Learning* *Time and Resource Management*	**1**	**2**	**3**	**4**	**5**
	2.5 PROFESSIONAL SKILLS AND ATTITUDES *Professional Ethics, Integrity, Responsibility and Accountability* *Professional Behavior* *Proactively Planning for One's Career* *Staying Current on World of Engineer*	**1**	**2**	**3**	**4**	**5**
Communication	**3.1 TEAMWORK** *Forming Effective Teams* *Team Operation* *Team Growth and Evolution* *Leadership* *Technical Teaming*	**1**	**2**	**3**	**4**	**5**
	3.2 COMMUNICATIONS *Communications Strategy* *Communications Structure* *Written Communication* *Electronic/Multimedia Communication* *Graphical Communication* *Oral Presentation and Inter-Personal Communications*	**1**	**2**	**3**	**4**	**5**
	3.2 COMMUNICATION IN A FOREIGN LANGUAGE *Using a language other than the primary language of instruction at your institution for technical communication*	**1**	**2**	**3**	**4**	**5**

On this page please **circle one whole number** beside each of the topics representing what you think is:

Your own current level of proficiency

Keep in mind that the levels 1 to 5 represent the range of proficiency levels one would expect to find in working professionals. Thus, it would be unusual for even highly skilled practitioners with long experience to have more than a few fives.

		Circle one level of proficiency for each topic				
		1. To have experienced or been exposed to	**2. To be able to participate in and contribute to**	**3. To be able to understand and explain**	**4. To be skilled in the practice or implementation of**	**5. To be able to lead or innovate in**
Operating Systems in the Enterprise and Social Context	**4.1 EXTERNAL AND SOCIETAL CONTEXT** *Roles and Responsibility of Engineers* *The Impact of Engineering on Society* *Society's Regulation of Engineering* *The Historical and Cultural Context* *Contemporary Issues and Values* *Developing a Global Perspective*	**1**	**2**	**3**	**4**	**5**
	4.2 ENTERPRISE AND BUSINESS CONTEXT *Appreciating Different Enterprise Cultures* *Enterprise Strategy, Goals, and Planning* *Technical Entrepreneurship* *Working Successfully in Organizations*	**1**	**2**	**3**	**4**	**5**
	4.3 CONCEIVING AND ENGINEERING SYSTEMS *Setting System Goals and Requirements* *Defining Function, Concept and Architecture* *Modeling of System and Insuring Goals Can Be Met* *Development Project Management*	**1**	**2**	**3**	**4**	**5**
	4.4 DESIGNING *The Design Process* *The Design Process Phasing and Approaches* *Utilization of Knowledge in Design* *Disciplinary Design* *Multidisciplinary Design* *Multi-Objective Design (DFX)*	**1**	**2**	**3**	**4**	**5**
	4.5 IMPLEMENTING *Designing the Implementation Process* *Hardware Manufacturing Process* *Software Implementing Process* *Hardware Software Integration* *Test, Verification, Validation, and Certification* *Implementation Management*	**1**	**2**	**3**	**4**	**5**
	4.6 OPERATING *Designing and Optimizing Operations* *Training and Operations* *Supporting the System Lifecycle* *System Improvement and Evolution* *Disposal and Life-End Issues* *Operations Management*	**1**	**2**	**3**	**4**	**5**

On this page please **circle one whole number** beside each of the topics representing what you think is:

The level of proficiency a new engineering graduate should have

Keep in mind that the levels 1 to 5 represent the range of proficiency levels one would expect to find in working professionals. Thus, it would be unusual for even highly skilled practitioners with long experience to have more than a few fives.

		Circle one level of proficiency for each topic				
		1. To have experienced or been exposed to	**2. To be able to participate in and contribute to**	**3. To be able to understand and explain**	**4. To be skilled in the practice or implementation of**	**5. To be able to lead or innovate in**
Personal and Professional Skills and Attributes	**2.1 ENGINEERING REASONING AND PROBLEM SOLVING** *Problem Identification and Formulation* *Modeling* *Estimation and Qualitative Analysis* *Analysis With Uncertainty* *Solution and Recommendation*	**1**	**2**	**3**	**4**	**5**
	2.6 EXPERIMENTATION AND KNOWLEDGE DISCOVERY *Hypothesis Formulation* *Survey of Print and Electronic Literature* *Experimental Inquiry* *Hypothesis Test, and Defense*	**1**	**2**	**3**	**4**	**5**
	2.7 SYSTEM THINKING *Thinking Holistically* *Emergence and Interactions in Systems* *Prioritization and Focus* *Trade-offs and Balance in Resolution*	**1**	**2**	**3**	**4**	**5**
	2.8 PERSONAL SKILLS AND ATTRIBUTES *Initiative and Willingness to Take Risks* *Perseverance and Flexibility* *Creative Thinking* *Critical Thinking* *Awareness of One's Personal Knowledge, Skills and Attitudes* *Curiosity and Lifelong Learning* *Time and Resource Management*	**1**	**2**	**3**	**4**	**5**
	2.9 PROFESSIONAL SKILLS AND ATTITUDES *Professional Ethics, Integrity, Responsibility and Accountability* *Professional Behavior* *Proactively Planning for One's Career* *Staying Current on World of Engineer*	**1**	**2**	**3**	**4**	**5**
Communication	**3.1 TEAMWORK** *Forming Effective Teams* *Team Operation* *Team Growth and Evolution* *Leadership* *Technical Teaming*	**1**	**2**	**3**	**4**	**5**
	3.2 COMMUNICATIONS *Communications Strategy* *Communications Structure* *Written Communication* *Electronic/Multimedia Communication* *Graphical Communication* *Oral Presentation and Inter-Personal Communications*	**1**	**2**	**3**	**4**	**5**
	3.2 COMMUNICATION IN A FOREIGN LANGUAGE *Using a language other than the primary language of instruction at your institution for technical communication*	**1**	**2**	**3**	**4**	**5**

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		Circle one level of proficiency for each topic				
		1. To have experienced or been exposed to	**2. To be able to participate in and contribute to**	**3. To be able to understand and explain**	**4. To be skilled in the practice or implementation of**	**5. To be able to lead or innovate in**
Operating Systems in the Enterprise and Social Context	**4.1 EXTERNAL AND SOCIETAL CONTEXT** *Roles and Responsibility of Engineers* *The Impact of Engineering on Society* *Society's Regulation of Engineering* *The Historical and Cultural Context* *Contemporary Issues and Values* *Developing a Global Perspective*	**1**	**2**	**3**	**4**	**5**
	4.2 ENTERPRISE AND BUSINESS CONTEXT *Appreciating Different Enterprise Cultures* *Enterprise Strategy, Goals, and Planning* *Technical Entrepreneurship* *Working Successfully in Organizations*	**1**	**2**	**3**	**4**	**5**
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	4.4 DESIGNING *The Design Process* *The Design Process Phasing and Approaches* *Utilization of Knowledge in Design* *Disciplinary Design* *Multidisciplinary Design* *Multi-Objective Design (DFX)*	**1**	**2**	**3**	**4**	**5**
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	4.6 OPERATING *Designing and Optimizing Operations* *Training and Operations* *Supporting the System Lifecycle* *System Improvement and Evolution* *Disposal and Life-End Issues* *Operations Management*	**1**	**2**	**3**	**4**	**5**

	SD	Average	m No.	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu
INDIVIDUAL ASSESMENT																																		
Personal & Professional Skills & Attributes	**0.82**	**3.23**	**2.1**	3	3	4	3	3	4	3	4	3	4	4	2	3	4	3	3	3	4	4	3	3	4	4	2	4	2	3	4	2	4
	0.90	**2.89**	**2.2**	4	2	1	4	3	3	3	2	3	3	5	2	3	3	1	3	3	3	3	4	3	4	4	1	4	3	2	4	3	3
	0.86	**3.00**	**2.3**	3	4	3	3	2	4	3	4	3	4	3	3	2	3	4	4	3	3	3	3	3	4	2	2	3	2	4	4	3	3
	0.80	**3.65**	**2.4**	4	3	5	4	3	4	4	3	4	5	4	3	4	4	5	3	3	4	4	3	4	5	3	3	5	2	3	5	3	4
	0.96	**3.23**	**2.5**	3	3	3	4	1	4	4	4	2	4	4	3	3	3	3	4	4	3	2	4	4	4	3	3	5	3	3	3	4	3
Communcation	**0.81**	**3.62**	**3.1**	4	3	4	5	4	4	4	3	3	3	4	2	3	3	4	4	3	4	2	4	4	5	4	2	4	3	2	4	4	5
	0.77	**3.40**	**3.2**	4	3	4	4	2	4	4	4	3	4	3	2	2	2	4	3	2	3	4	4	4	4	3	2	5	3	2	3	4	4
	1.36	**1.98**	**3.3**	1	4	5	1	1	4	1	1	1	1	3	1	1	1	1	1	1	5	1	5	4	1	1	1	1	1	1	2	1	1
Operating Systems in the Enterprise and Social Context	**0.89**	**2.56**	**4.1**	4	3	4	3	1	1	2	3	2	2	3	2	2	1	3	2	2	2	4	3	4	4	5	3	3	3	2	2	2	3
	0.88	**2.60**	**4.2**	3	1	3	3	1	1	2	2	3	2	4	2	4	1	4	3	1	3	4	3	3	4	3	3	3	1	3	2	2	2
	0.94	**2.94**	**4.3**	3	3	3	4	0	3	3	3	3	4	4	3	3	2	3	3	2	3	4	3	3	3	5	2	4	2	3	3	2	4
	0.88	**3.16**	**4.4**	3	3	3	4	2	4	3	4	4	5	5	3	3	2	5	3	1	3	3	4	3	4	3	2	3	4	2	4	3	3
	0.96	**2.66**	**4.5**	3	2	4	3	2	3	3	2	3	3	4	3	3	2	3	2	1	3	2	4	3	3	4	1	3	3	2	4	1	3
	1.03	**2.63**	**4.6**	4	2	4	3	4	3	2	2	3	4	4	3	3	1	4	3	1	4	4	3	3	4	3	1	4	1	2	3	1	4
EW GRADUATE EXPECTATIO																																		
Personal & Professional Skills & Attributes	**0.77**	**3.58**	**2.1**	3	4	3	3	2	4	5	3	4	4	5	4	3	3	4	4	4	4	4	3	5	3	4	3	4	3	3	4	3	4
	0.83	**3.30**	**2.6**	3	4	3	3	2	2	5	2	3	4	4	4	3	3	5	4	3	4	5	3	5	4	4	3	4	3	2	3	3	3
	0.84	**3.36**	**2.7**	3	3	2	3	2	3	5	3	3	4	4	4	2	2	4	4	3	4	4	4	5	3	3	3	4	3	3	3	2	3
	0.77	**3.65**	**2.8**	3	4	3	3	4	4	4	4	4	4	5	4	4	3	4	3	4	3	4	3	5	4	2	3	4	4	4	4	3	3
	0.90	**3.53**	**2.9**	3	4	3	3	4	4	4	4	3	4	5	3	2	3	5	4	4	3	3	4	5	4	3	3	4	4	3	3	2	3
Communcation	**0.85**	**3.73**	**3.1**	3	4	3	3	4	4	4	3	3	4	4	3	3	3	5	4	4	4	5	4	5	4	4	3	4	4	3	4	2	4
	0.79	**3.72**	**3.2**	3	4	3	3	4	4	4	4	3	4	5	4	2	2	4	4	4	3	4	4	5	4	3	3	4	3	4	4	3	4
	1.13	**2.10**	**3.3**	3	4	2	3	3	1	2	1	2	2	4	2	1	1	1	3	3	4	1	4	3	2	3	3	1	1	1	3	3	1
Operating Systems in the Enterprise and Social Context	**0.99**	**3.06**	**4.1**	3	3	3	3	3	1	4	3	4	3	4	3	4	1	4	2	3	4	4	3	4	4	2	3	4	3	3	4	2	3
	0.93	**2.99**	**4.2**	3	3	4	3	3	1	4	2	3	4	5	5	2	3	4	3	4	3	4	4	5	3	3	3	4	3	3	4	3	3
	0.93	**3.30**	**4.3**	3	3	4	3	3	2	5	3	3	4	5	5	3	3	5	3	3	3	3	3	5	3	4	3	4	3	3	4	3	4
	0.88	**3.59**	**4.4**	3	4	3	3	3	4	5	4	4	3	5	4	3	3	5	4	3	3	4	4	5	3	4	3	4	4	3	4	2	4
	0.98	**3.31**	**4.5**	3	3	4	3	3	2	5	3	3	3	4	4	2	3	5	4	3	3	3	4	5	3	3	3	4	3	2	4	2	3
	0.97	**3.10**	**4.6**	3	3	4	3	3	2	4	2	3	3	4	4	3	3	4	4	3	4	2	4	5	3	3	3	4	3	2	4	1	4

Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu	Stu
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Stu	Stu	Stu	Stu	Stu	Stu	Student #111	
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3	4	3	2	3	0	2	
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4	4	3	3	5	0	3	
4	4	4	3	4	0	3	
4	4	4	3	4	0	3	

DIO Syllabus Learning Objective		ndividual Assessmen		Graduate Target	
		Mean	SD	Mean	SD
Personal & Professional Skills & Attributes	2.1 Engineering Reasoning	3.23	0.82	3.58	0.77
	2.2 Experimentation	2.89	0.90	3.30	0.83
	2.3 Systems Thinking	3.00	0.86	3.36	0.84
	2.4 Personal Attributes	3.65	0.80	3.65	0.77
	2.5 Professional Attributes	3.23	0.96	3.53	0.90
Communicati on	3.1 Teamwork	3.62	0.81	3.73	0.85
	3.2 Communication	3.40	0.77	3.72	0.79
	3.3 Foreign Languages	1.98	1.36	2.10	1.13
Operating Systems in the Enterprise and Social Context	4.1 Societal Context	2.56	0.89	3.06	0.99
	4.2 Business Context	2.60	0.88	2.99	0.93
	4.3 Conceiving	2.94	0.94	3.30	0.93
	4.4 Design Process	3.16	0.88	3.59	0.88
	4.5 Implementing	2.66	0.96	3.31	0.98
	4.6 Operating	2.63	1.03	3.10	0.97

STUDENTS' PERCEPTIONS OF WAYS TO LEARN ENGINEERING MATHEMATICS: ARE THESE WAYS CDIO-RELATED?

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ABSTRACT

To promote active learning, lecturers should know how their students learn. With this knowledge, the lecturers can plan lessons that take advantage of the students' learning preferences or challenge learning approaches that are not particularly beneficial. This study examined what students from Singapore Polytechnic reported about how they learned engineering mathematics. A questionnaire consisting of 57 items was designed to cover activities classified under Conscientious Efforts, Metacognition, Involving Others, and Resources. A group of 235 Year 2 Engineering Mathematics (Maths 2) students rated these activities in terms of frequency of use and helpfulness before and after the Maths 2 module. The findings are interpreted in relation to active learning mentioned in Standard 8 of the 12 CDIO Standards. Lecturers may use similar techniques to better understand how their students learn in order to design lessons that take into consideration these ways of learning.

KEYWORDS

Student perceptions, traditional study behaviour, active learning, social dimension of learning, learning resources, engineering mathematics

INTRODUCTION

Research studies, using both qualitative and quantitative methodologies, have built a body of knowledge and theories about learning experiences of students in higher education [1–4]. Lecturers in higher education can improve their teaching through improving students' learning experiences [5]. They can also conduct studies on student learning in order to gain a deeper understanding of the learning experiences of their students, and accordingly to plan pedagogical strategies that will enhance student learning. Hopefully within engineering education, these learning experiences are consistent with Standard 8 (Active Learning) of the *CDIO* (Conceive, Design, Implement, Operate) *Initiative* [6]. This initiative, which has been officially adopted by Singapore Polytechnic since the academic year 2007/08, is a collaborative effort by leading engineering schools in many countries worldwide, to conceive and develop a new vision of engineering education.

The findings to be reported below come from a study that examined the learning experiences of students enrolled in an engineering mathematics module at Singapore Polytechnic (SP). The study was *not* designed to assess CDIO-related learning experiences because it was planned before SP adopted the CDIO Initiative. Nevertheless, the findings suggest several areas that can be further investigated in future implementation of Standard 8

from the perspective of the students rather than faculty members or standards-setters, in particular with respect to active learning of engineering mathematics.

Lecturing is a standard teaching method used very frequently in tertiary institutions, and it has its proponents and opponents among faculty and students [e.g., 7–9]. In a quasi-experimental study involving 578 first year undergraduates, Struyven, Dochy and Janssens [10] randomly assigned these students to five conditions: one lecture-based setting, and four student-activating learning environments based on different assessment modes, namely peer assessment, portfolio assessment, multiple choice examination, and case-based assessment. Students in the lecture condition were quite positive about their learning and out-performed the other student-activating groups. The peer assessment and portfolio assessment groups were more positive than the multiple choice examination and case-based assessment groups, and one reason was that the first two groups tended to receive more prompt feedback. Indeed, the education literature has consistently found that immediate and focussed feedback given by the teachers to the students as well as using feedback from the students has strong effects on learning [11]. Standard 8 has included getting feedback from students about what they are learning as one way to promote active learning.

Research about teaching of tertiary mathematics has offered new possibilities to promote active learning [12]. For example, Ball, Stephenson, Smith, Wood and Coupland [13] created the *MATH* taxonomy and used it to systematically design mathematics tasks for second year undergraduate students. This taxonomy classified tasks into three groups: Group A (factual knowledge, comprehension, and routine use of procedures), Group B (information transfer and applications in new situations) and Group C (justifying and interpreting; implications, conjectures and comparisons; and evaluation). Under this classification, the students were exposed to a variety of mathematical experiences that focussed their attention on different thinking processes. Engaging in tasks that require different levels of complexity is an important form of active learning. Using the *MATH* taxanomy procedure of tasks assignment ensured active engagement by students and gave lecturers the assurance that the skills finally demonstrated by students were learned with good grasp of conceptual understanding by having adopted a deep approach to learning.

Even though the lecturer or teacher may have planned different types of tasks and assessment modes, several researchers [14, 15] have found that school students may not understand the purposes of the learning activities as planned by their teachers. In an investigation conducted by Bell, Crust, Shannon and Swan [14], only two of the 104 British Year 8 pupils recognised the major intended purpose of the calculator activity. A study of Japanese mathematics lessons by Shimizu [15] found that many eighth-grade students did not recognise the climax of the lesson (called “yamaba”) planned by their teachers. We have also found that SP students reported different perceptions about the lectures and tutorials they had attended [16]. These studies highlight the need to learn more about the learning experiences of the students.

Student learning experiences extend beyond what they are engaged in during the formal lessons planned by the teachers. Outside formal hours, students are expected to complete assignments, to revise for upcoming tests, to work with others on projects, to use resources for their learning, and so on. These study behaviours have not been studied with respect to polytechnic students in Singapore. They can contribute to active learning from the students’ perspective. The rest of this paper describes students’ perceptions of how frequently they had used different study behaviours and how helpful they perceived these behaviours to be in learning an engineering mathematics module.

THE STUDY

Participants

The participants were 235 Year 2 Engineering Mathematics students. In May 2007, they answered a questionnaire (called Student Study Questionnaire, SSQ) about their learning experiences of Engineering Mathematics 1 (Maths 1) in the previous academic year. During the months from May to September 2007, they studied Engineering Mathematics 2 (Maths 2) under a combination of lectures, tutorials, problem-based learning, self-study and a week of e-learning. At the end of October, after the examination of Maths 2, the students took SSQ again in relation to their learning experiences of Maths 2. Their two responses to SSQ can be compared to determine any changes to their perceptions of learning mathematics prior to and after working through Maths 2.

Instrument

The Student Study Questionnaire (SSQ) consists of 57 Likert-type items. The items were developed conceptually with references to the literature [e.g., 17 – 21]. These items cover the following four learning dimensions:

1) Conscientious Efforts (CE); these 13 items encompass efforts that are commonly engaged in by conscientious students as well as the motivation for academic achievement, for example, paid attention to lecturer's explanations, completed tutorial exercises assigned by the lecturer, and was punctual for Maths lessons;
2) Metacognition (MC) in terms of taking control over one's thinking and learning; there are 15 items, for example, recognized when to use the appropriate mathematical formula, and planned my schedule for Maths revision;
3) Involving Others (IO); these 15 items describe learning activities that involve direct as well as implied contact with other people, for example, copied my friends' Maths tutorials, approached Maths lecturers even after class, and presented solutions of tutorials to the class;
4) Resources for learning (RE), covering 10 types, such as worked through past year tests and examination papers in Maths, searched for mathematics resources on the internet, and referred to mathematics books from the library.

There were 4 miscellaneous (MS) items, for example, relaxed after completing each tutorial.

Students were asked to respond to each item in terms of

1) frequency of use, i.e., "How often did you learn in this way?" (1 = Not at all; 2 = Occasionally; 3 = Sometimes; 4 = Quite often; 5 = Often; 6 = Always);
2) helpfulness, i.e., "How helpful it was towards learning Maths 1/2?" (1= Waste of time; 2 = Of little help; 3 = Some help; 4 = Quite helpful; 5 = Helpful; 6 = Very helpful).

The even 6-point Likert-type scales were used to avoid neutral responses [22].

FINDINGS AND DISCUSSION

Frequency of use and helpfulness of Maths 2 study behaviours

This section reports on students' responses to Maths 2 only, and these responses will shed some light about how active they were in their study of this module.

In terms of frequency of use, the means of the 57 items ranged from 1.64 to 4.24. On a 6-point scale, these means indicate frequencies of use from occasionally to quite often. Thus,

none of the study behaviours was reported to be used very often or always. The standard deviations of these items ranged from 1.11 to 1.67, and these suggest that the students reported varying frequencies of using these study behaviours.

In terms of helpfulness, the means ranged from 2.01 to 4.27, and this gives the impression that some study behaviours were perceived to be of little help while others were quite helpful. However, none of the study behaviours was reported to be helpful or very helpful. The standard deviations ranged from 1.28 to 1.66, suggesting that these study behaviours may be more helpful to some students and less so for others.

The top five items in terms of frequency of use are shown in Table 1, together with their mean scores on helpfulness. They were used quite often and were perceived to be quite helpful. None of them were study behaviours involving others, one on conscientious effort (paid attention to lecturer's explanations), one on metacognition (recognised when to use the appropriate formula), two on resources (took note of lecturer's hints for tests and examination; and worked through past year tests and examination papers in Maths) and the remaining one a miscellaneous item (relaxed after completing each tutorial). This finding is not surprising as these are traditional study behaviours typical of students who focus on getting good grades. What is disconcerting is that the more active study behaviours did not have high enough means to be included.

Table 1
Top five items in terms of frequency of use

Cat	Q	Ways of learning Maths 2	Frequency of use		Helpfulness	
			Mean	SD	Mean	SD
CE	2	Paid attention to lecturer's explanations.	4.14	1.47	4.27	1.44
MC	26	Recognised when to use the appropriate mathematical formula.	3.90	1.40	4.07	1.44
RE	44	Took note of lecturer's hints for tests and examination.	3.91	1.54	3.80	1.55
RE	46	Worked through past year tests and examination papers in Maths.	4.24	1.67	4.27	1.65
MS	41	Relaxed after completing each tutorial.	3.99	1.57	3.92	1.63

The 15 items in the metacognitive dimension are active learning study behaviours but are only used from occasionally to quite often, as illustrated in Table 2. Thus, ways must be found to inculcate study behaviours that are more closely aligned with active learning under Standard 8.

Table 2
The 15 metacognitive items

Cat	Q	Ways of learning Maths 2	Frequency of use		Helpfulness	
			Mean	SD	Mean	SD
MC	26	Recognised when to use the appropriate mathematical formula.	3.90	1.40	4.07	1.44
MC	19	Checked my work while doing it.	3.76	1.44	3.70	1.44
MC	23	Analysed mistakes made in solving tutorial problems.	3.71	1.44	3.89	1.43
MC	47	Identified important concepts learnt in Maths.	3.62	1.43	3.80	1.53
MC	33	Was aware of my own thinking during mathematical tasks.	3.57	1.37	3.57	1.45
MC	54	Set personal goals to achieve in Maths.	3.48	1.61	3.52	1.65
MC	5	Was also thinking even though I did not call out the answers to questions asked during lecture.	3.45	1.38	3.52	1.36
MC	9	Made a conscious effort to present mathematical solutions logically.	3.41	1.43	3.50	1.44

MC	57	Planned my own schedule for Maths revision.	3.35	1.64	3.50	1.64
MC	32	Made my own notes in Maths.	3.16	1.53	3.44	1.60
MC	15	Related new concepts taught in Maths to known concepts.	3.06	1.35	3.26	1.42
MC	40	Reviewed my learning after completing each tutorial.	3.06	1.33	3.30	1.41
MC	50	Asked myself a question about the Maths problem/ topic.	3.00	1.39	3.11	1.44
MC	53	Planned the strategies before beginning to solve a problem.	2.98	1.39	3.17	1.46
MC	37	Tried out other possible solutions to a same problem.	2.85	1.30	3.10	1.41
Overall			3.36	1.43	3.50	1.48

The bottom five items in terms of frequency of use are shown in Table 3. The means indicate that they were used only occasionally and even not at all for some students. They were also perceived to be of little help. Lack of use may have led to the low perceived level of helpfulness.

Surprisingly, three of these items were about using technological resources (external links, internet resources, and maths-related software), even though all the students had to own a laptop. From institutional perspective, technological and library resources require substantial funding, and it would be a waste if the students do not use them to enhance their learning of mathematics and other modules. The habit of using relevant resources in learning is essential for lifelong learning as advocated by Standard 8. One suggestion is for the lecturers to require students to use these resources more intensively to complete their assignments.

The remaining item in Table 3 refers to the behaviour of copying their friends' tutorials. Even though this was done occasionally, it was perceived to be of some help (mean close to 3). This behaviour is obviously not aligned with active learning.

Table 3
Bottom five items in terms of frequency of use

Cat	Q	Ways of learning Maths 2	Frequency of use		Helpfulness	
			Mean	SD	Mean	SD
RE	8	Referred to mathematics books from the library.	1.64	1.11	2.01	1.40
RE	11	Used computer-based programs e.g., Graphmatica and online applets.	1.93	1.26	2.07	1.28
IO	1	Copied my friends' Maths tutorials.	2.04	1.18	2.88	1.61
RE	22	Searched for mathematics resources on the internet.	2.15	1.39	2.31	1.40
RE	18	Visited external links provided by Maths website in Blackboard.	2.18	1.32	2.27	1.31

Changes in study behaviours from Maths 1 to Maths 2

The frequency means of study behaviours for Maths 1 ranged from 1.32 to 4.42, and this range was wider than that for Maths 2 (1.64 to 4.24). The means for Maths 1 were higher than for Maths 2 for 41 of the 57 items. Thus, the students were less frequently engaged in most of these study behaviours when they studied Maths 2 compared to Maths 1.

The (Maths 2 – Maths 1) mean differences were computed, and the top nine items with large differences are reported in Table 4. Five items were about making conscientious efforts, one about metacognition, two about traditional resources, and one miscellaneous. Five of them are traditional behaviours commonly associated with following instructions (pay attention to explanation and hints, complete assigned work, copy solutions, and be punctual). The single metacognitive item (recognise which formula to use) and the item on trying the best to solve a difficult problem were aligned with Standard 8. The students also expressed less frequently looking forward to come to Maths 2 classes compared to previous Maths 1

classes (Q55). The challenge is to devise more diverse active learning activities to entice students to want to come for classes [23].

Table 4
Nine study behaviours with frequency means for Maths 1 higher than for Maths 2

Cat	Q	Ways of learning Maths 1 or Maths 2	Maths 1		Maths 2	
			Mean	SD	Mean	SD
CE	2	Paid attention to lecturer's explanations.	4.67	1.15	4.14	1.47
CE	36	Completed tutorial exercises assigned by the lecturer.	4.39	1.37	3.86	1.51
CE	52	Was punctual for Maths lessons.	4.32	1.36	3.74	1.50
CE	55	Looked forward to coming to class.	3.55	1.49	3.13	1.50
CE	13	Tried my best to solve a difficult problem.	4.33	1.32	3.87	1.50
MC	26	Recognised when to use the appropriate mathematical formula.	4.35	1.22	3.90	1.40
RE	4	Copied solutions from the whiteboard/projection on the screen.	4.07	1.47	3.59	1.53
RE	44	Took note of lecturer's hints for tests and examination.	4.58	1.44	3.91	1.54
MS	41	Relaxed after completing each tutorial.	4.53	1.42	3.99	1.57

Table 5 shows the reverse trend. The frequency means for Maths 1 were lower than those in Maths 2. Most of these items were also of low means, suggesting that the students reported only occasional use. Nevertheless, most of these study behaviours are about active learning consistent with Standard 8, such as using technology resources, being proactive in seeking help, and planning for revision.

Table 5
Eight study behaviours with frequency means for Maths 1 lower than for Maths 2

Cat	Q	Ways of learning Maths 1 or Maths 2	Maths 1		Maths 2	
			Mean	SD	Mean	SD
CE	29	Read through Maths lecture notes before the next lecture.	2.29	1.25	2.59	1.34
MC	57	Planned my own schedule for Maths revision.	3.18	1.58	3.35	1.64
IO	7	Approached Maths lecturers even after class.	1.96	1.10	2.19	1.24
IO	28	Presented solutions of tutorials to the class.	2.38	1.31	2.55	1.28
RE	8	Referred to mathematics books from the library.	1.32	0.87	1.64	1.11
RE	15	Accessed Maths website in Blackboard.	3.33	1.53	3.53	1.48
RE	18	Visited external links provided by Maths website in Blackboard.	2.00	1.24	2.18	1.32
RE	22	Searched for mathematics resources on the internet.	1.88	1.23	2.15	1.39

The lowering of frequency of use of traditional study behaviours reported in Table 4 coupled with the increasing use of more active study behaviours reported in Table 5 suggests a slight but discernable trend toward more active learning as the students progressed from Maths 1 to Maths 2. This is promising but the reported frequencies of use of active learning were still quite low. Other CDIO standards such as curriculum development and the enhancement of faculty teaching skills should be considered in tandem with Standard 8 to promote the acquisition and application of more active study behaviours by the students.

In addition to the above analysis by individual items, it is worthwhile to compare the differences between Maths 1 and Maths 2 by the four dimensions used to create the items. Students' responses under these dimensions show high internal consistency measured by Cronbach's alphas of greater than 0.7, as shown in Table 6. Hence, the mean scores of items for each dimension are computed and these are plotted in Figure 1. It is very striking that in terms of both frequency of use and helpfulness for Maths 1 and Maths 2, the trends were consistent in the order: Conscientious effort > Metacognition > Involving Others > Resources. The social dimension of learning as measured by the items under Involving

Others was not reported in the earlier tables because these items had intermediate means between the higher and lowers values.

Table 6
Cronbach's alphas of dimensions of study behaviours

	Maths 1		Maths 2	
	Frequency of use	Helpfulness	Frequency of use	Helpfulness
Conscientious effort (CE)	0.87	0.88	0.92	0.93
Metacognition (MC)	0.87	0.88	0.92	0.93
Involving Others (IO)	0.82	0.84	0.88	0.90
Resources (RE)	0.74	0.79	0.77	0.79

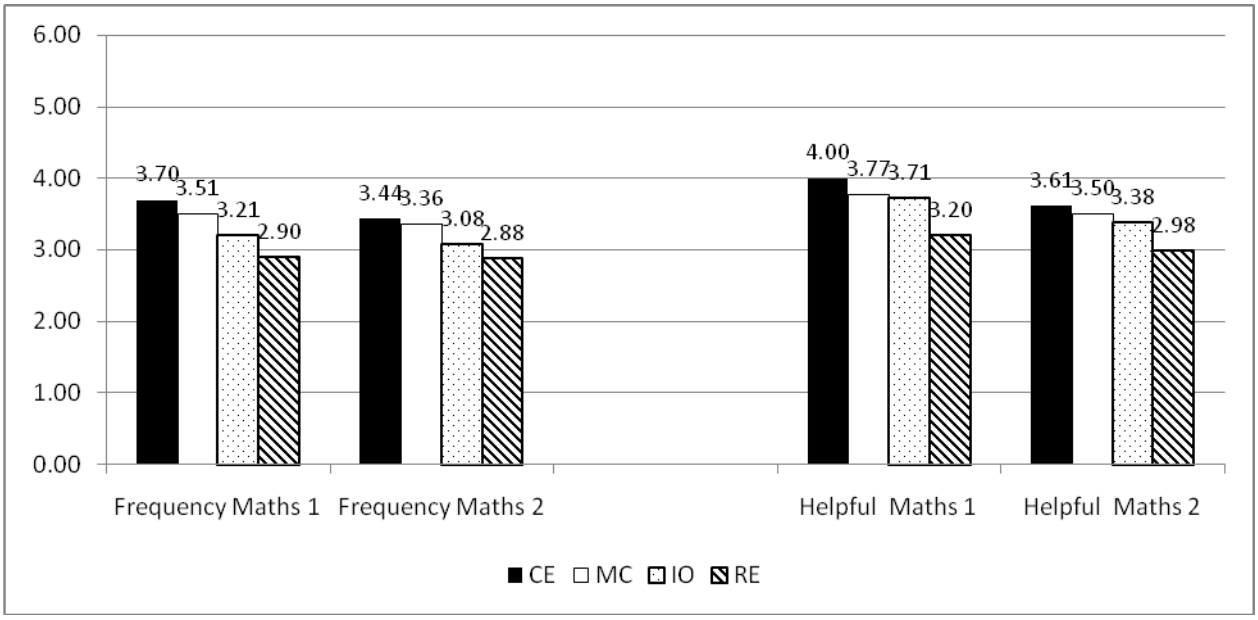

Figure 1. Frequency and helpfulness of Maths 1 and Maths 2 study behaviours

CONCLUDING REMARKS

This study provided empirical data about the learning experiences reported by local polytechnic students on Engineering Mathematics. These students generally made use of traditional study behaviours often related to the transmission mode of learning, believing that these behaviours will help them to learn the module. They became slightly more metacognitive in the later module, but this change was not yet strong. Interactions with others during learning were not common, and the use of technology resources and library books was quite rare. This broad picture of how polytechnic students learn mathematics is not surprising, especially when considered in terms of the objective of doing well in traditional assessment.

However, the implementation of the CDIO Initiative requires re-thinking of the learning experiences provided by the faculty to the students, beginning with enriching the curriculum with more experiential, industry-related tasks. For mathematics modules, this should include showing students how to solve real problems taken from modules outside of mathematics by using standard mathematics procedures as well as modelling using technology. This will sensitise the students to the need to exploit appropriate resources in their learning.

Standards 2 and 3 of the CDIO Initiative emphasise teamwork and communication skills. More modules at SP should provide learning activities that involve other partners. The above findings about Involving others and the study by Struyven, Dochy and Janssens [10] suggest that students at polytechnic may prefer direct instruction to the more interactive modes of learning. It is not a straightforward case of catering to their preferred learning style because what they prefer may not be optimal. Indeed, the working environment of the 21st century requires team work, and students who have not learned this social style of learning need to be properly inducted to acquire the necessary skills. For effective implementation, however, care must be taken so that students who are familiar with the traditional transmission mode of learning will have time to adapt to the new learning strategies [24]. These new activities need to be infused slowly to give students lead time to familiarise themselves with a learning approach that is not their usual practice. These activities need also be introduced explicitly so that students will perceive the efforts made by their lecturers [14, 15], and to appreciate the helpfulness of these study behaviours.

Teaching staff should be encouraged to conduct action research about their teaching practices as part of Standard 10 of the CDIO Initiative. One feasible area of action research is to gather data on student learning in order to better match the planned learning experiences to student preferences of learning [14, 15], and to challenge learning approaches that are not particularly beneficial.

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STUDY OF CDIO WORKSPACES IN SINGAPORE POLYTECHNIC

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ABSTRACT

The CDIO Framework calls for the development of appropriate workspaces that support and encourages the learning of product or system building, disciplinary knowledge and social learning (Standard 6). A study of different workspaces used in the teaching of Design & Build and CIE project modules in the Singapore Polytechnic was undertaken. These workspaces are primarily used to teach modules which have Learning Designs that involve students working in teams to Conceive, Design, Implement (prototype) group projects. Particular focus was placed on how such workspaces contribute to and enhance student learning and social behavior which leads to desired learning outcomes. Students and teaching staff were surveyed to find out their satisfaction with each workspace with respect to their teaching and learning outcomes. The merits and demerits of each workspace were also discussed. Lessons drawn from this study were abstracted and recommendations made regarding the design of future workspaces.

KEYWORDS

Workspace, Learning Environment, Design-Build Experiences

CDIO PROJECTS

Many institutions invest huge amounts of resources building workspaces to support project work. While some like the Integrated Learning initiative at Queen's University, Yumekobo at Kanazawa Institute of Technology (KIT) and MIT have well equipped and large infrastructures; many projects are built in smaller laboratories. How then do we design a workspace that incite and support the CDIO project? Can the project workspace provide a refuge that systematically cultivates teamwork and synergy amongst members?

A close examination of workspaces reveals that most projects happen amidst 4 elements:

- CDIO process
- Environment
- Tools used in projects
- Students' interaction

These elements interact in different intensity at various project stages with students' interaction residing at the heart of all these elements as shown in Figure 1.

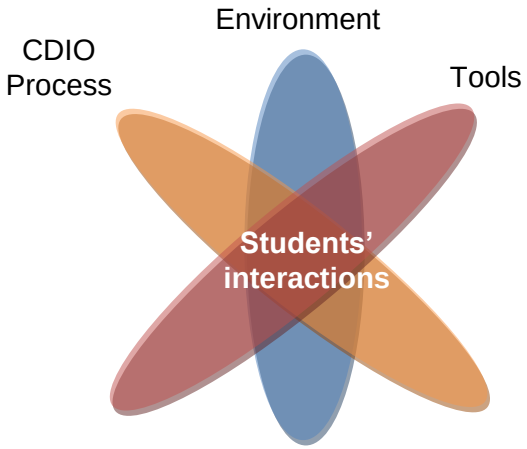

Figure 1. Elements available in CDIO Projects

To understand how workspaces can be better designed, it is useful to first dissect the activities that transpire in the workspace and how they interact with these elements. Understanding the activities that take place during the different phases of the project is thus useful as it helps to map out the students' interactions and thereafter translate them into the different needs of the workspace.

CDIO Process

Table 1 shows the activities that take place at the various stages of the CDIO process. It can be seen that some of these activities involve more group work while others are carried out by individuals.

Table 1
Project Stages and Activities

Project Stages	Activities
Pre-Project	Form effective teams
Conceive	Research Create concepts Generate and share ideas
Design	Translate concepts into tangible design Develop potential solutions Combine building blocks Prototype ideas using simulation or other means
Implement	Fabricate parts Assemble parts Test integrated project Troubleshoot project
Operate	Demonstrate workability Execute tasks

In the conceive stage, students typically discuss and generate ideas. Thus, the workspace needs to provide furniture and resources that support collaborative work. In contrast, the design and implementation stages require students to work individually while keeping tabs on what other team members are doing. Many problems arise if students fail to communicate effectively over these stages as they may end up with completed parts that cannot be

successfully assembled or integrated. Workspace infrastructure to support information sharing and communication is very important to ensure the success of these 2 stages.

While some students can continue to use the same workspace to operate the project, others may require another space. In one Year 2 CDIO project, the completed aircraft model had to be operated in a stadium as the enclosed workspace cannot handle this activity.

ENVIRONMENT & TOOLS (WORKSPACE DESIGN)

Many papers have stressed the importance of flexibility, 24/7 access, availability of tools etc, in workspace design. We will focus instead on designs that facilitate the interaction among project team members while conducting projects. Three parameters found to be crucial in promoting interaction are :

- Furniture
- Vertical visualisation support
- Information management

Furniture

As mentioned previously, students work in groups during some stages of their project work and individually in others. The workspace has to offer sufficient flexibility so that where both collaborative and individual work can be carried out. This can be implemented using reconfigurable furniture. However, if furniture has to be rearranged, it should be ensured that this can be carried out smoothly without too much time being expended.

Another important consideration is for project workspace to be flexible enough to be used for secondary purposes like the conduct of lectures, seminars, tutorials etc. Many a time, project workspaces are designed for students to work in clusters. They may not be ideal places for lectures.

Vertical Visualisation Support

A picture paints a thousand words. It is therefore essential for students to be able to share ideas and discuss using images besides words. Vertical visualisation using a whiteboard or flipchart is very useful for students to express and discuss their ideas.

A common problem encountered in a project workspace used by many groups of students is in capturing and storing information discussed. Students usually capture notes from whiteboards after discussion by copying them on pieces of paper. With the advance of technology, some workspaces have digital smart boards that can store data and print information drawn on them easily.

Students' Information Management System

Throughout a project, students generate a lot of ideas and information. Since the CDIO process is linked and activities carried out in successive stages are highly related to previous ones, it is crucial that documentation is properly and effectively kept. Failing to do so will result in students making mistakes and having to repeat their work.

There are generally two streams of information that flows throughout the project; the recording stream that is generated based on analysis and the creativity stream that is based on generative activities such as synthesis and exploration as shown in Figure 2.

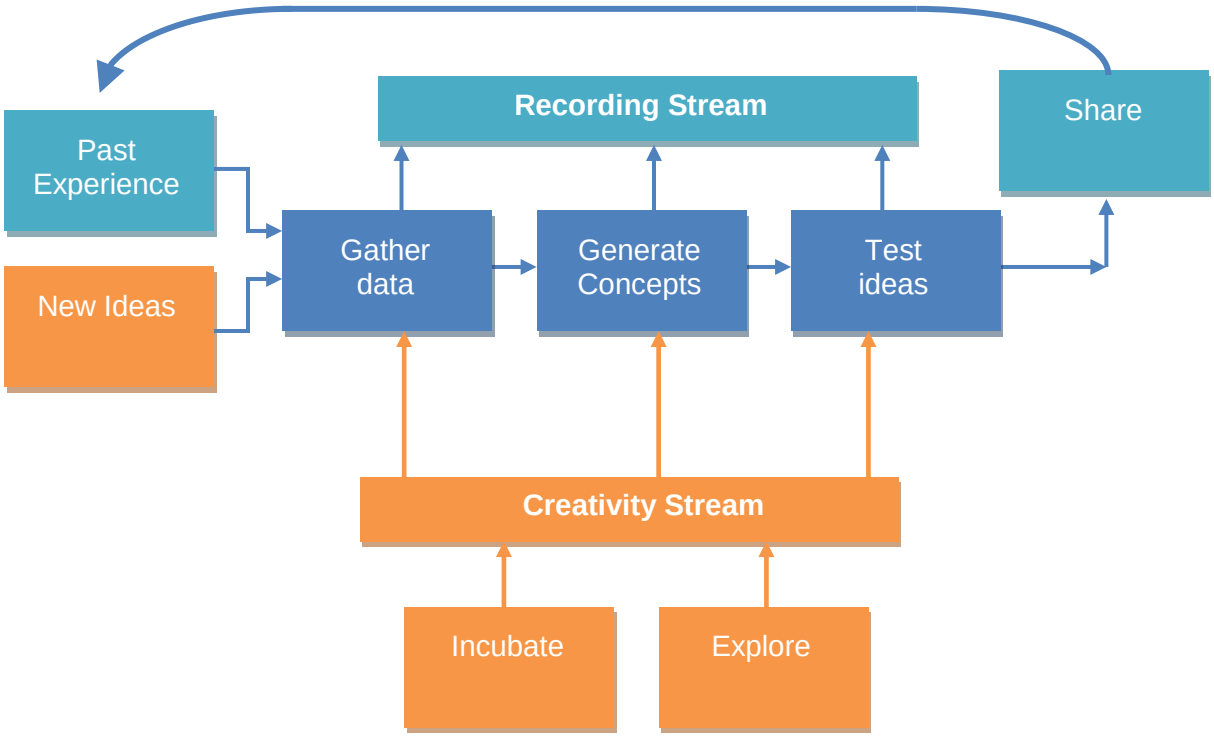

Figure 2 Streams of data derived from project

It is important that project workspaces facilitate these streams of information and is also able to capture them effectively for students to refer to them in subsequent stages of project.

WORKSPACE DESIGN FOR ELECTRONIC PROJECT FABRICATION

DESIGN & INNOVATION PROJECT (D&I) LAB AT T822

The lab at T822 was designed for Year 2 Design & Innovation Projects. Three groups of students from the Diploma in Electrical and Electronic Engineering made use of this lab to build their projects. Depending on the options that students had subscribed to, the projects could be aerospace, microcontroller or bio-electronics related. Activities carried out in the lab ranged from conceiving what the final artefact should do, to the fabrication of chassis and electronic circuits.

The workspace was designed to support students operating in clusters of 4 to 5 students. In each cluster, there was some standard furniture and equipment such as power supply, oscilloscope and soldering iron available for students to complete their projects. Students generally made use of their assigned area as their base stations that also included storage areas and also some vertical spaces for discussion usage. Wireless LAN is available in this lab to allow students to surf the internet for information related to their projects. Lab PCs were also made available for students to program their projects with the necessary software such as Labview and C pre-installed.

Besides clustered areas, there were also several centralised locations for project use. Some of them were for keeping items such as electronic components and space with bigger equipment that could not be so easily duplicated. There was also a centralised location for students to test out their projects such as the playing field for the micro-controller robots. While most of the project activities could be carried out within the individual cluster, many students were also required to make use of an adjacent workshop to fabricate their chassis. Many machine tools for fabricating chassis were made available. The Technical Support Officer had to brief the students before they may make use of the machines. As safety is a major concern, a staff member had to be present whenever students worked in the workshop.

In addition to Year 2 students working on the D&I Projects, many final year students also made use of the workshop and workspace at T822 for free access. We noticed that third year project students liked to use this space as it had been equipped with the necessary mechanical and electronics equipment to support their projects. On the other hand, this workspace had not been successfully used as a lecture or tutorial venue.

Conceive. Students generally gathered around their clusters to discuss and generate project ideas. However, it was noted that students did not usually discuss with all their group members. It was observed that most students discuss in pairs or trios. The board that was catered for students to sketch their ideas while they discussed was not used as extensively as we originally envisaged. The workspace in T822 may not have been designed well for the conceive stage.

Design. During the design stage, students need to discuss about how they want to fabricate their projects. However, most of them did not plan their project in detail before they start. Many students just proceeded to the implementation stage and many of them encountered problems as they started to develop their projects.

Implement. Programming and fabrication were obvious activities that students carried out while they were in the implement state. Students made use of the computers in the lab and also the instruments found within their clusters to build their projects. The workspace was well designed for this stage and in fact, many students who have proceeded to their third year of course continue to use this lab due to the user-friendliness of the space. The space supported individual work where students built their hardware and carry out programming.

Operate The lab space could be used for demonstrating that the project worked as planned. As the lab was a confined space, some students who built the aeroplane models had to test their aeroplane models in the stadium. The lab space was good for students testing out their microcontroller robots and Labview biomedical projects.

So far, we noted that the space at T822 had been designed well to support the Implement – Operate stages. However, we felt that it might not have been as effective for the Conceive – Design activities as the space does not encourage face-to-face interaction and discussions.

INTRODUCTION TO ENGINEERING & IDEA (IE/IDEA) LABS AT T12601-T12606

The IE/IDEA labs were designed to teach 1st year students the creative idea generation process through a module called IDEA, and to allow them to design, implement and operate simple projects through the IE module. In both these modules, students work in teams of varying sizes at different points in time. They engage in activities that are varied, including brainstorming, pair-share-square and larger group discussions, class presentations and the designing, simulation, building and troubleshooting of electronic circuits. To accommodate this, trapezoidal-shaped furniture was selected that could easily be reconfigured for different group sizes and activities. A raised floor was installed in the lab so that electrical power can

be flexibly supplied to each table cluster wherever in the room they may be. Lighting installed ensured uniform brightness and minimum shadows throughout the workspace.

The IE/IDEA labs were designed to be self contained – a one stop centre where students can go through the 2 modules in one location. Because these labs were also used by students to build and test physical projects, they had to accommodate the use of different tools and equipment required. Adequate space had also to be available for sufficient amounts and variety of electronic components to be stocked and projects-in-progress to be stored.

Another important consideration for the IE/IDEA workspaces was that they had to be attractive, vibrant and youthful in appearance. This will enable students to identify emotionally with the workspace and be proud to be associated with it. Bright colour schemes, warm lighting and an attractive ceiling grid were installed. Whiteboards were placed in strategic locations for students to cluster around and discuss ideas. An electronic SMART board was installed to up the cool factor and give flexibility to the lecturer teaching in front of the class. It also provided the option of storing discussion ideas etc easily. Wireless internet access and a wireless projector were also made available. With the latter, students are able to present their ideas to the class from where they are seated using their Notebook computers.

While the primary use of the labs is described above, the workspace had to be flexible enough to accommodate other secondary uses. This included being able to be a venue for seminars, short courses, tutorial classes and other project modules. They were also to be used as alternative venues to host our outreach programs to secondary school students.

The workspaces hosted up to 8 student classes. The following is a description of how the workspace was used in the Conceive-Design-Implement-Operate cycle.

Idea Generation (Conceive). Students formed groups of 5 to learn about the creative process and tools required for the creation of new product ideas. For this activity, tables were arranged in a configuration that could accommodate larger group discussions. They were placed next to white boards which we envisaged would be used in the discussions. However, like in T822, whiteboards provided in the lab were observed to be seldom used. Students did not like that they were unable store information on the boards easily for future use. They preferred instead to gather around a piece of paper and discuss their ideas there. The whiteboards were extensively used, however, when the instructor was involved in the group discussion – giving inputs and fresh ideas to the groups. The seating arrangements were observed to be satisfactory and it encouraged group discussions and dynamics. The deliverable of the idea generation process was a class presentation of a new and novel engineering based product or service. Students were observed to present from either the front of the class or from their discussion tables using the wireless projection system.

Design. 2 projects were prescribed to students in the IE module. They were required to work in pairs for the 1st project and in groups of 4 in the 2nd one. The projects were carefully selected to integrate knowledge learnt in supporting 1st year technical modules like Digital Electronics, Principles of Electrical & Electronic Engineering and Teamwork & Communication Skills. While the projects are prescribed, students nevertheless have the flexibility to design the projects' circuits in different ways. They were expected to verify the workability of their designs using circuit simulation and/or breadboard testing. Circuit simulation software was available in the polytechnic's servers and students can run them using their own Notebook computers through the campus wireless network. The tables in the lab were arranged to accommodate the smaller group sizes in this activity. It was observed that the design process involved mainly individual or paired work. This worked well in the 1st project as it was done in pairs. In the 2nd project, it was found that half the group was not active in the activities.

Implement. Implementing the IE projects involved the fabrication of prototype circuits on strip-boards and troubleshooting them. After that, different boards were integrated together and tested to ensure that the whole project works. This involved soldering work and the use of test equipment like power supplies, multi-meters and oscilloscopes. Heat resistant boards were used during soldering to protect the workbench from heat damage. Suction fans were installed to suck poisonous solder fumes out of the room. To avoid cluttering the workbench, students go to equipment stations at the corner of the lab to obtain and carry required test equipment back to the workbench to use. They are returned back to the equipment station when done. Despite this arrangement, overcrowding of the workbench often occurred, especially in the 2nd IE project when students work 4 to the group. Like in the design stage, project implementation was observed to be either individual or paired work.

Operate. Unlike in T822, operating of the IE projects was done exclusively in the IE/IDEA labs. One of the IE projects involved a vehicle going under and counting the number of gantries encountered. The lab was flexible enough to be configured to accommodate the testing track for this. The other IE project could be operated from the workbench. Nevertheless, projects that were not suitable to be operated from the lab, e,g, a solar car project, could be operated from venues adjacent to these labs.

Other important considerations for the IE/IDEA workspace include easy access after scheduled hours and the availability of a wide variety of electronic components and tools. All the IE/IDEA labs were treated as a common resource and were made available for free access regardless of where students are timetabled for their formal lesson. The labs were kept open in the evenings provided more than 10 students requested for the service. Each lab stocked a good quantity and variety of basic electronic components which students can draw with the approval of their lecturers. Lab technicians were also authorised to draw more uncommon components for the students from the main EEE store. Mail order component catalogues were also made available in labs should students wish to purchase them for themselves.

WORKSPACE DESIGN IN MECHANICAL & MANUFACTURING

MACHINE DEVELOPMENT CENTRE (MDC) AT W1112

Design should be learnt in a dual environmental setting; 1) in an academic and 2) in an environment simulating industrial realities. The latter is important because conceiving and designing systems and products is a creative process that is best endeavoured in a realistic environment. The MDC at W1112 was renovated precisely to engage industrial realities. The workspace is compartmentalised into sections where disciplines like design, assembly, logistic, electrical and programming take place. Infrastructures like an engineering workshop, store, meeting room and office equipment are also present to facilitate the centre's activities. Equipment in the workshop are permanent fixtures and the student and staff activities are centred on achieving the physical outcomes. This workspace design is shown in Figure 3

Students are assigned to different parts of the workspace at stages of their project where teaching staff teach them about industrial automation systems.

Conceive. The conceive and design workspace in the MDC comprise of two rows of tables equipped with computing and general office equipment. Students sit as they would in an open office system. They are surrounded by cubicles where the centre's staff are located (see Figure 4 for layout). Machining concepts and design details are the main components shared and discussed at this stage. The setting here emphasizes objective teaching where guidance is given in a formalised way. Blue sky conceiving exercises are not required as work in mechanical engineering designs are renovated or reused from known systems

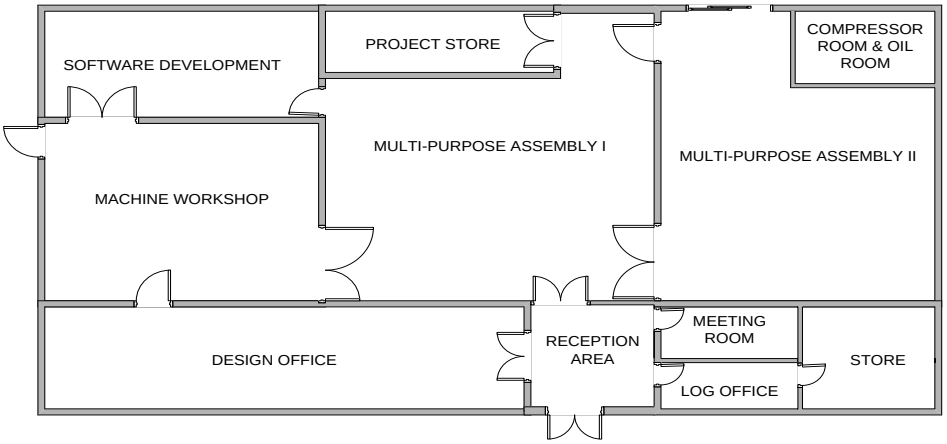

Figure 3 The MDC workspace in W1112

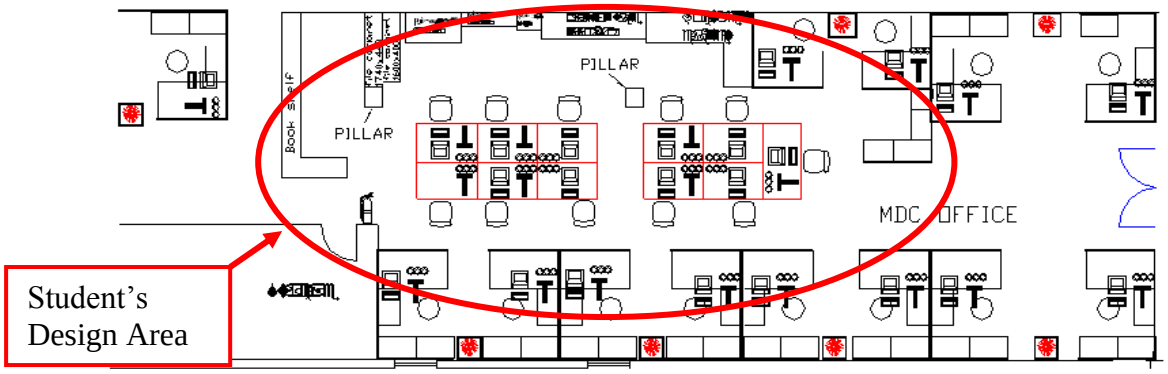

Figure 4 Layout of Design Office

Design. Students are required to learn appropriate design software before they proceed to the design stage. Computing systems in the workspace are loaded with design software such as AutoCad from Autodesk, Pro-E and Solidworks. Students remain in the Design Area and are given 2-3 weeks to pick up the required software skills before they are asked to model and extract parts from an assembly drawing assignment. Deadlines are given and students work out their own schedules which they must adhere to strictly.

Implement. In this stage, the physical artefact arising from the conceived machine specification is built. This takes place in the multi-purpose assembly areas in Figure 4. Students have to manage the space allocated effectively because although individual components are built in a modular form, the physical outcomes of the design can be as long as 25 metres. Each of the MDC's machines assembled rarely comes in the same configuration, complexity and size. The centre is equipped with enough flexibility to cater to this diversity. The predominant form of learning here is skill-based learning. See Figure 5 for the type of machines that it can accommodate.

Figure 5 Workspace accommodating different outcomes in Industrial Automation.

Operate. Students have to equip the machines built with configurable programs which can be customised using computing interfaces like touch screens. They have to master the controls and operational aspects of their machines and are expected to impart their knowledge to end users during the commissioning period. The operate stage of the project is done in the multi-purpose assembly areas

INTEGRATED PROJECT CENTRE (IPC) & PROJECT LAB AT W1113 & W1218

The IPC at W1113 and the Project Lab at W1218 are used as workspaces for the School of Mechanical & Manufacturing Engineering's IDEA and Introduction to Engineering (IE) modules. Note that this is different from the IE/IDEA labs in T12601-T12606 above which used by students of the School of Electrical & Electronics Engineering.

The conceptualising and design stage is done in the IPC while the Project Lab is used to Implement and Operate the projects. The layouts of both workspaces are shown in Figure 6 and 7.

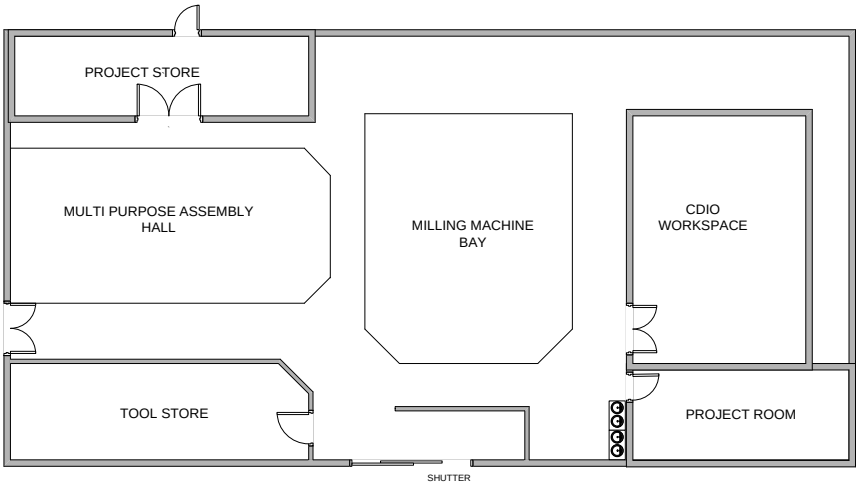

Figure 6 Project Lab in W1218 (Workspace for Implement and Operate)

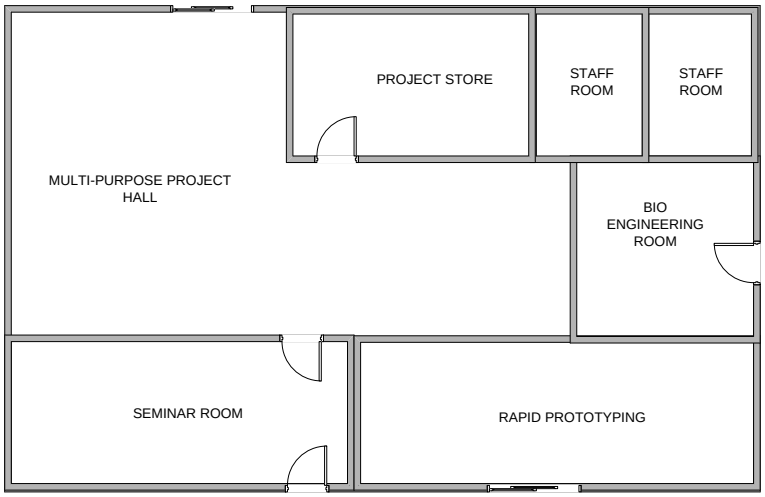

Figure 7 IPC in W1113 (Workspace for Conceive and Design)

Following the early success of the MDC, the IPC was built as a flexible workspace that supports several modules and functions including being used as an exhibition area for Final Year Projects. As such, it is not equipped with heavy and fixed machinery and can only support the Conceive and Operate stages of the IDEA and IE modules. This takes place in the Multipurpose Project Hall (see figure 7). A pictorial view is also illustrated in Figure 8.

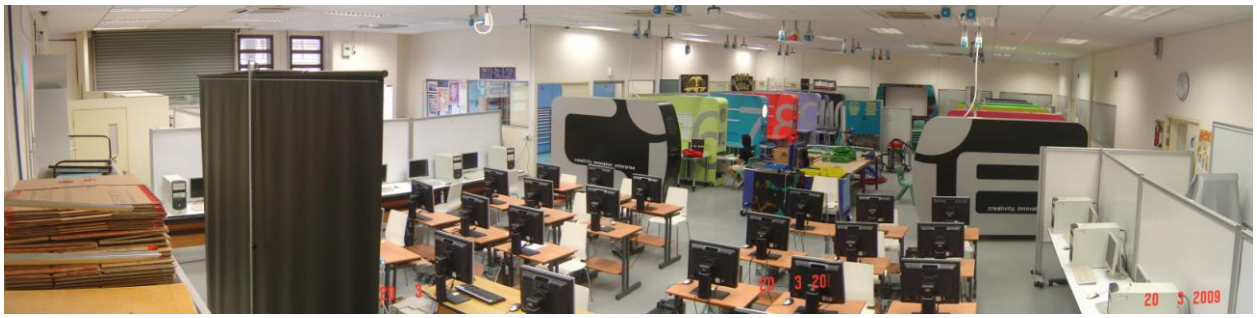

Figure 8 IPC Multipurpose Project Hall (Workspace for Conceive and Design)

Conceive. The IPC accommodates one class of 20 students at any one time. A total of 160 students or 8 classes of the IDEA and IE module are timetabled here. In addition, this workspace also accommodate about the same number of students from a different module. Students using the IPC are assigned an area designated for team usage such as discussions and project launch. Each area has facilities like PC point and chart pin up wall for their projects. These cubicles are configurable into different forms depending on needs.

Design. Students are provided with and are expected to use Studio Max and AutoCad software in the design stage of their project. The predominant activity here is team discussion and design work. This can be done either on or off campus as students now own their own laptops. The design work will be reviewed in this workspace by the module lecturer for the class.

In contrast to the IPC, the Project Lab at W1218 has many fixed supporting infrastructure like machine shop equipment including lathes and milling machines. It is also equipped with fabrication equipment for various engineering materials like Aluminium, Steel, Engineering plastic and many others. This makes it suitable for Implementing and Operating projects.

However, it is not as flexible a workspace as the IPC. The workspace layout can be visualised in Figure 9.

Figure 9 Project Lab in W1218 (Workspace for Implement and Operate)

Implement. Implementing the IDEA and IE project involves fabricating mechanical parts using machine tools and assembly work. As the IPC is not designed to house these machine tools, the project lab in W1218 is used instead.

Operate. Students also use W1218 to operate their projects. As the student artefacts derived from this module are generally no bigger than an A3 paper, they can be tested and operated upon in the limited space available in the lab. The facility has also an auxiliary storage space or cabinet to allow students to keep their projects. However this storage space is scarce and priority is given to final year project students.

User information for the MM Workspaces

School of Mechanical and Manufacturing				
Workspace Name	Location	Sq Area (M^2)	Courses (CDIO)	No. of Students
Integrated Project Centre	W1113	245	SP0502 IDEA MM1028 IE	160 160
Machine Development Centre	W1112	1125	MM3008 Teaching Factory	80
Project Centre	W1218	812	EC1166 Design & Fab Project MM305Z Project Part II	80 400-500

LESSONS DRAWN

3 lessons can be drawn about the design of project workspaces from the above survey of workspaces in the Singapore Polytechnic. These are categorized as follows:

- Subliminal Messages
- Specialisation vs. workspace flexibility
- Space required and throughput vs. artefact size

Subliminal Messages

Project workspace can be designed to send subliminal messages to students using it. In the case of the IE/IDEA labs at T12601-T12606, the emphasis was to provide a vibrant, flexible and even "cool" workspace that students can identify with and enjoy using. The aim was to project a casual hobby club atmosphere where good, innovative ideas are welcomed. As such, vibrant colour schemes were used and modern equipment like wireless projectors and Smart boards were installed. Tables could be easily moved and reconfigured in different shapes to suit different learning activities. Various surveys of both staff and students have consistently shown that students enjoy using these labs.

In contrast, the MDC at W1112 is designed to be a formal workspace. It is used to conceive, design and fabricate industrial automation systems that meet industry specifications dictated by our industry partners. The layout and work environment in the MDC is hence deliberately designed to simulate what students are likely to find in the industry.

Specialisation vs. workspace flexibility

Depending on the type of projects built, specialised equipment may be necessary. When such equipment is required, the workspace loses its flexibility to be used in other ways. There is also less chance of the entire C-D-I-O process being housed in the same venue.

In the case of D&I Lab in T822, 2nd year students build an electronic project which has to be housed in a chassis. A dedicated workshop area in an adjoining lab equipped with drilling machines, metal cutters etc is available for students to do this. This workshop area cannot be flexibly used for other purposes. If the electronic portion of the project requires a microprocessor, then dedicated supporting equipment like emulator boards may be required. The bigger and bulkier these supporting equipment are, the less flexible the workspace becomes.

Another example is the requirement for machine tools in the Mechanical & Manufacturing Engineering School's IE module. Machining in the Implement and Operate phase of the IE module is done in a dedicated machining workshop housed in the Project Lab in W1218. Because of the heavy investment in setting up the infrastructure, this lab is used for other modules requiring the same equipment as well. To free up the lab time, the Conceive and Design portion of the project is housed in another lab – at the IPC in W1113.

On the other extreme, students taking the School of EEE's IE/IDEA module build simple electronic circuits and projects which involve mainly simulation, soldering and testing. The equipment required to run these projects are modest and portable. Students go to the equipment station and carry the equipment required to their work area and return them when they have finished. The artefacts that they build are also small in size. As such, the entire C-D-I-O process of these projects can be housed in the same place – at T12601 to T12606. Moreover, these workspaces are also flexible enough to be used for other purposes like conducting meetings, tutorials, lectures, seminars, school promotion activities etc.

Space required and throughput vs. artefact size

The amount of space and labs required for projects also depends on the size of the project artefact. Where project artefact size is large like in the case of Industrial Automation projects housed in the MDC in W1112, only a few projects can be housed in each multi-purpose assembly area at a time. This is because there has to be sufficient space to house the artefact-in-progress. If more than 1 team of students are doing similar projects, another

venue has to be found for the second team even though the existing workspace may be free and is used for just storing the project. This problem can be mitigated somewhat if an effective storage system could be devised such that work in progress can be stored (perhaps in a vertical ASRS), freeing up the work area for other groups.

Where project artefacts are small, e.g. the ones built by School of EEE IE/IDEA or the D&I module students, each workspace can be timetabled for use repeatedly over the course of the week. In the case of T12601-T12606, a maximum of 8 4-hour sessions can be timetabled in each lab per week. Projects-in-progress can be simply taken home by the students or stored in relatively small storage spaces in the labs. The throughput of these labs is hence much higher.

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TEACHING AND LEARNING CREATIVITY IN ENGINEERING EDUCATION

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KEWORDS

Creativity, Creativity learning, Defining creativity, Basic course, ReAction, CreAction

ABSTRACT

The development of engineering education must in the future take into consideration a broadening of the students' awareness of the true Space/Time nature of our world. By accepting and using the world-view that Einstein defined we have been able to achieve an enormous scientific and technological development during the past century. In the field of human resources development, however, we still have only to a small extent utilized this new science and we mostly continue to live and work as if the traditional Space+Time reality is the only one existing. In order to achieve sustainable development and true progress in our projects and find real solutions to our problems, we must increasingly make use of the untapped creative resources, which can be generated from the Space/Time reality.

Accordingly, we present here new tools and procedures for generating creative actions in engineering work as well as a basic Operating System for all human actions. We also make suggestions for how Creativity learning can be introduced in the CDIO syllabus and how it can be taught as a basic common subject in all engineering education and training.

INTRODUCTION

Creativity is considered to be one of the most important qualities of productive people in industry and business. The CDIO initiative has played a vital and outstanding role in promoting and enhancing engineering education in the world and creativity has a central part in all facets of the work in….

Graduating engineers who are able to
conceive-design-implement-operate
complex value-added engineering systems
in a modern team-based environment.

So far, creativity has not been introduced as a distinct subject in the CDIO syllabus and that is mainly due to the fact that the subject, up to now, has had no scientific definition and the result of creativity research has had little scientific relevance. In our research we have found that there are a great number (>50) of different definitions but none are science-based and universal, which is the prerequisite for determining the origin and nature of creativity.

From the science-based definition of creativity that we present, we can now establish a base for a Creativity Science and, in turn, develop tools and procedures for teaching and learning how all of us can be creative and generate creative actions. Creativity can now be introduced as a basic common subject in all education and training.

We propose that Creativity be introduced as a separate subject in the CDIO syllabus and presented as a basic common course for all students. This will have a profound positive effect on their learning and their future engineering profession.

UNDERSTANDING AND DEFINING CREATIVITY [1]

Our True Reality And Our Perceived Reality

Using the properties of the new world-view that Einstein's Theory of Relativity presented, we can now make a distinction between an external Space/Time reality, which is the true description of our reality and the Space+Time reality we can perceive with our five limited senses. In the same way we can describe our two corresponding inner realities as the original and true domain of Being and the one by us designed and developed domain of Knowing, graphically represented in figure 1 below.

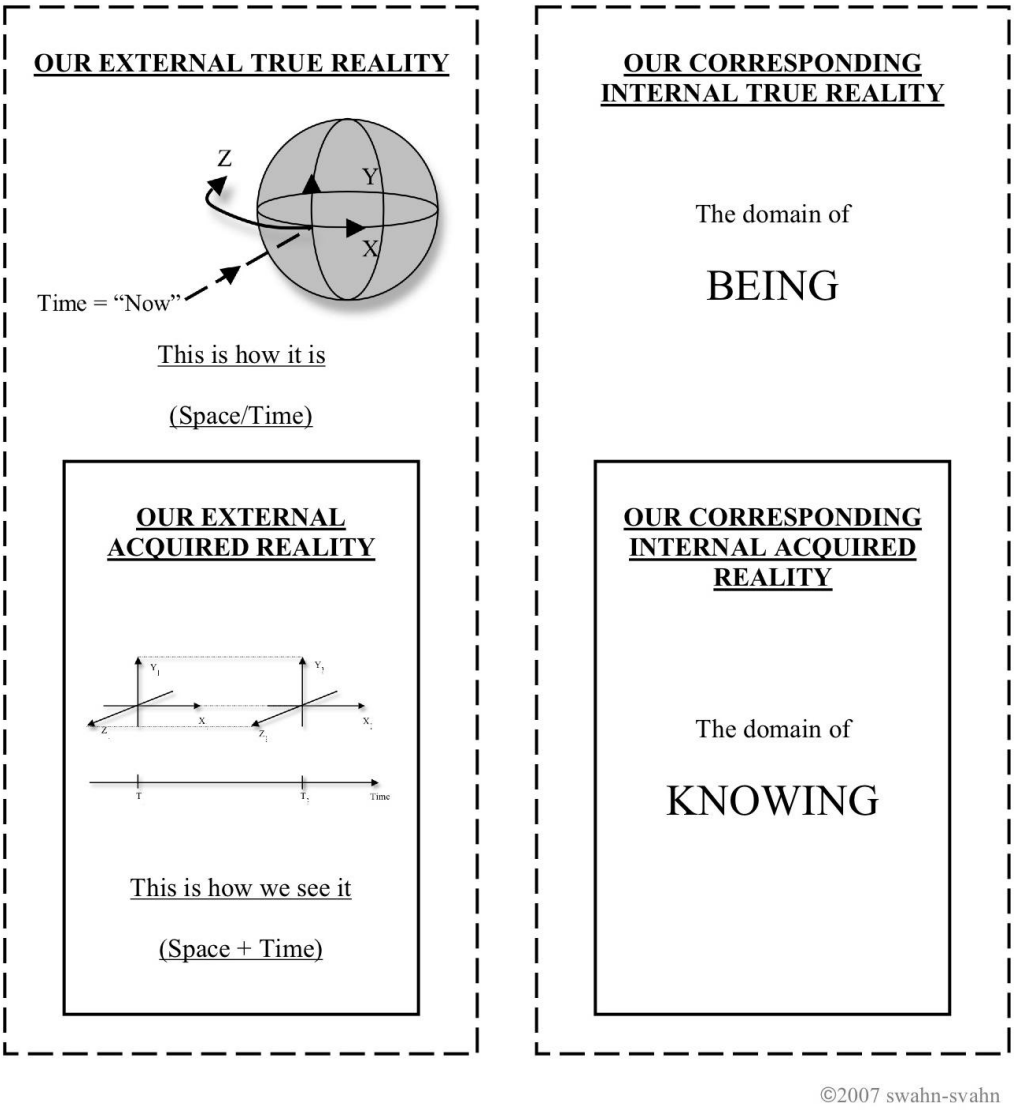

Figure 1: Our corresponding outer and inner realities

Knowing

The domain of Knowing is the part of our inner self that we have designed and constructed with the help of our limited five senses. Here we have stored all that we have learned since

birth; all our knowledge, skills, experiences, beliefs, opinions, thoughts, reasoning and emotions. The properties of its content are expressed in relative values (e.g. from warm to cold, from good to bad, etc., with the full scale in between), and information is processed in an analog way; it can be considered our analog inner domain. In Knowing, all information and all processing are related to the past. From Knowing we generate ”changing actions”, or actions that makes something that already exists into something else, often with bigger, better and /or different content. These types of actions we have defined as ReActions.

The domain of Knowing represents the summary of all we are, our personality or our EGO, and our ReActions are ultimately aimed at protecting and preserving its survival.

Being

An understanding of the content and workings of the domain of Being can only be reached by drawing parallels between our outer true reality, and its corresponding inner reality. In Being, the three space dimensions and the time dimension appear in a unified interdependent system eliminating time as a separate dimension. This means that “time does not exist” or as Einstein expressed it: “The distinction between the past, the present and the future is only an illusion”. This presents a possibility that information from Being can be related to the past, the present or the future.

In Knowing, our five senses are limited to obtaining and processing only a narrow spectrum of information and can therefore provide us with a limited or incomplete picture of our outer reality. In Being our senses can be assumed to be unlimited and they can provide us with a true and full picture of our reality.

The possible content of Being includes three important properties; Intuition, which informs us of our true reality received from the unlimited expansion of our five senses; Integrity, which expresses the absolute value and the truth about our reality; and Intention, which is the intrinsic life force and the driving force in using intuition and integrity to create something new. It is from the domain of Being that we generate creative actions that can bring into our reality something that did not exist before. We call these actions CreActions.

The result of our CreActions is sustainable development, progress and success for enterprises, organizations and societies, and flow, aliveness and well-being for the individual.

Defining Creativity

In reference to our previous reasoning we can now define creativity:

> *Creativity is the ability to bring something into existence that was not there before – from a possibility in the future. It is generated from our inner domain of Being*

Generating Actions

All actions are generated through a Communication for Action.
All our actions are a mixture of the two actions that we have defined - ReActions and CreActions. They are distinctly different because they are generated from different domains, and therefore we must analyze, investigate and deal with them as separate entities and in their most refined and extreme forms.

ReActions

ReActions are generated from a Communication for ReAction. The Source of the communication for ReActions is all that we have accumulated in the domain of Knowing in form of knowledge, skills and experience etc. and is verbally expressed through an order, accompanied by explanations and/or descriptions. A communication for ReAction is a one-way communication that changes something already exists into something else, often with better and/or different content or properties. The most refined ReAction process is automatic and repetitive symbolized by the light grey circle in figure 2 on the next page.

CreActions

CreActions are generated from a Communication for CreAction, which brings into existence something that has never existed before from the domain of Being.

The Communication for CreAction has to;

1. express a definite goal in the future;
2. have absolute, not relative values;
3. be guided by Intuition;
4. express the truth with Integrity and with Intention.

The future-based Communication for CreAction has three components;

Declaration – which defines the goal in exact qualitative and quantitative terms at a precise time in the future: I declare that X is true by Y

Promise – A Promise to reach the declared goal at the precise time, and

Request – A request for support at a precise time to reach the declared goal.

It is in this oral communication, in the speaking of declarations, promises and requests that creative actions are generated. A Communication for CreAction is always a two-way communication between at least two persons as there must always be somebody who is aligned with our declarations, listens to our promises and answers to our requests.
A CreAction is always generated with a committed intention and will never occur automatically, as often ReActions do.

It is important to know that we can always choose to be creative and generate CreActions, and that it is done through a deliberate communication.

The Operating System for all Human Actions

From these assumptions and deliberations we have developed and designed the following model that explains a basic Operating System for all human actions. It shows how communication for actions are transferred from our domains of Knowing and Being into our actual external world in forms of ReActions and CreActions, which we also call Doing, (Figure 2)

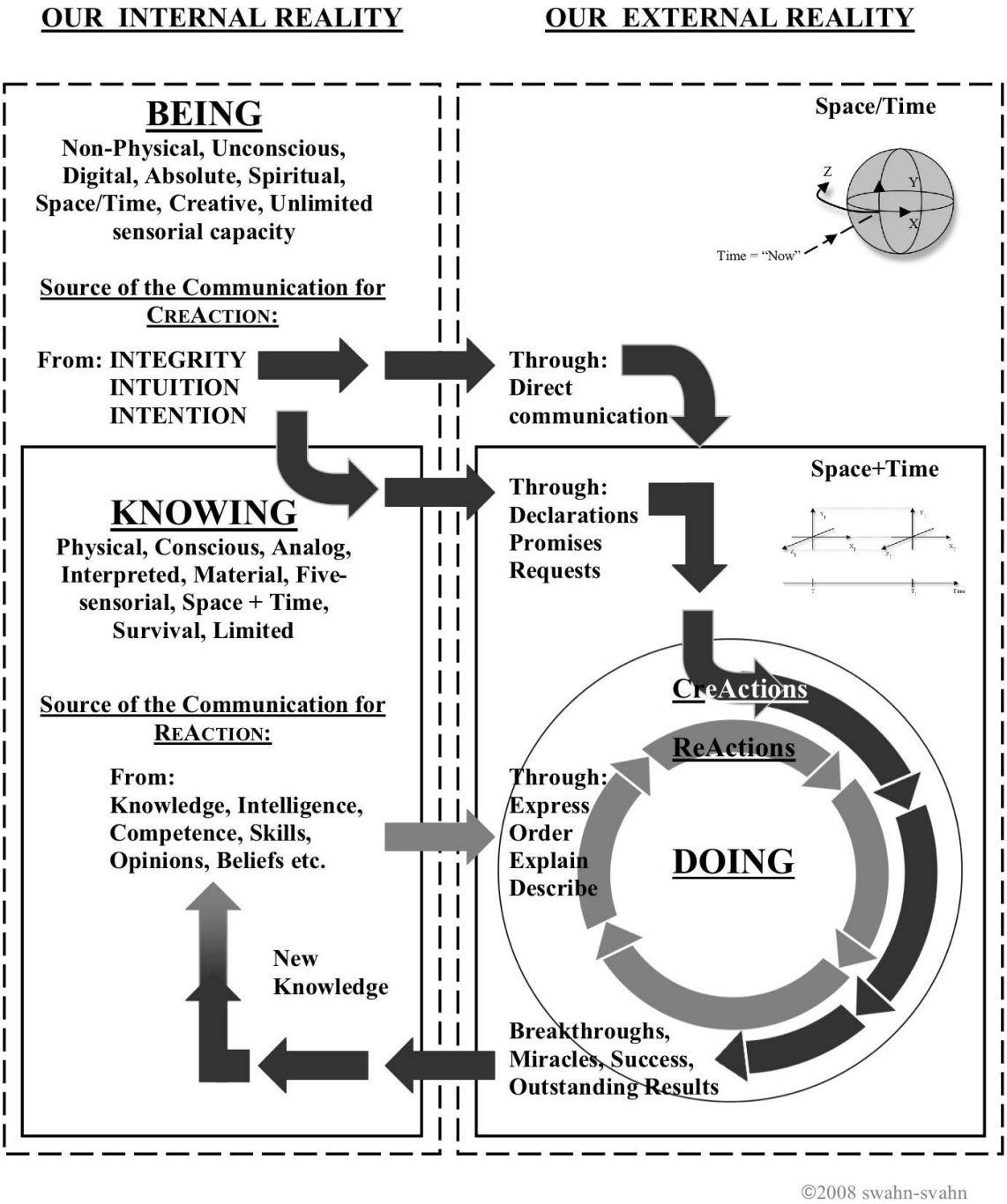

Figure 2: The basic Operating System of all Human Actions

Brief Comments On The Operating System

Two routes from Being to Doing.

CreActions can take two routes from Being (Space/Time) into our perceived reality (Space+Time). The first is direct. Artists and musicians use this route, for instance, when

they create and translate their art from Being directly onto a canvas or through an instrument. They have a special language that they use to communicate directly from Being

The second route is indirect. As we still have not invented a verbal language for a direct communication from Being the communication for CreAction must always be channeled through Knowing. This causes big problems, which we must realize and counteract.

The Importance of a Support Function

When the Communication for CreAction is channeled through Knowing it is strongly influenced by the survival forces inherent there. The Communication for CreAction (formulated through declarations, promises and requests) is such a strong intention to reach new bold ideas and possibilities, that our ego will perceive this as risky, uncertain and insecure. As our ego's primarily function is to secure our survival and to preserve and protect everything we have achieved and obtained so far, it will view our new project as a major threat to it's survival and will try to convince us that it was unwise to get involved, that it isn't going to succeed, that it will become problematic and risky for our career, etc. It will oppose everything that it sees as a threat to our physical, social, or mental survival.

To counteract this we need to establish a support function that assist us in going through with our projects, in keeping our word and in acting within our integrity. (The Communication for CreAction, which is formulated through a Declaration, Promises and Requests, establishes the prerequisites for this support function to work) A good support function is necessary in all creative projects and is essential for them to be successfully completed.

Creativity only shows up in cooperation between people supporting each other.

Cost and Benefits of the Different Actions

In figure 3 on the next page we present a Costs and Benefits analysis of the use of the two types of actions. The Costs and Benefits for using ReActions are shown to the left and for CreActions to the right. In the middle we show the two ultimate and extreme results of using solely one action.

The ultimate and extreme benefit and purpose of ReActions is the preservation, maintenance and "survival" of what already exists, both physically and mentally.

The ultimate benefits of CreActions are Progress, Development and Success for projects and aliveness, "flow" and wellbeing for individuals.

The benefit of utilizing the preserving ReActions is that they bring us security and material advantages at the cost of a decrease in feelings of well-being, aliveness and joy. The cost of CreActions is increased risk, insecurity, lack of material rewards etc. that is a threat to survival, and a loss of material possessions. The cost of CreActions is the same as the benefits of ReActions. With the same reasoning we can conclude that the Cost of Reaction is the same as the benefits of CreAction.

All our actions are a mixture of ReActions and CreActions. We can distinguish between them by analyzing the communications that generated them and the quality of the result they produce.

CreActions are normally a very small part of our actions and almost all our daily actions are ReActions. By increasing the CreActions in relation to the ReAction we can improve our progress and development and increase our aliveness, flow and well-being. This is always a choice that is open to us.

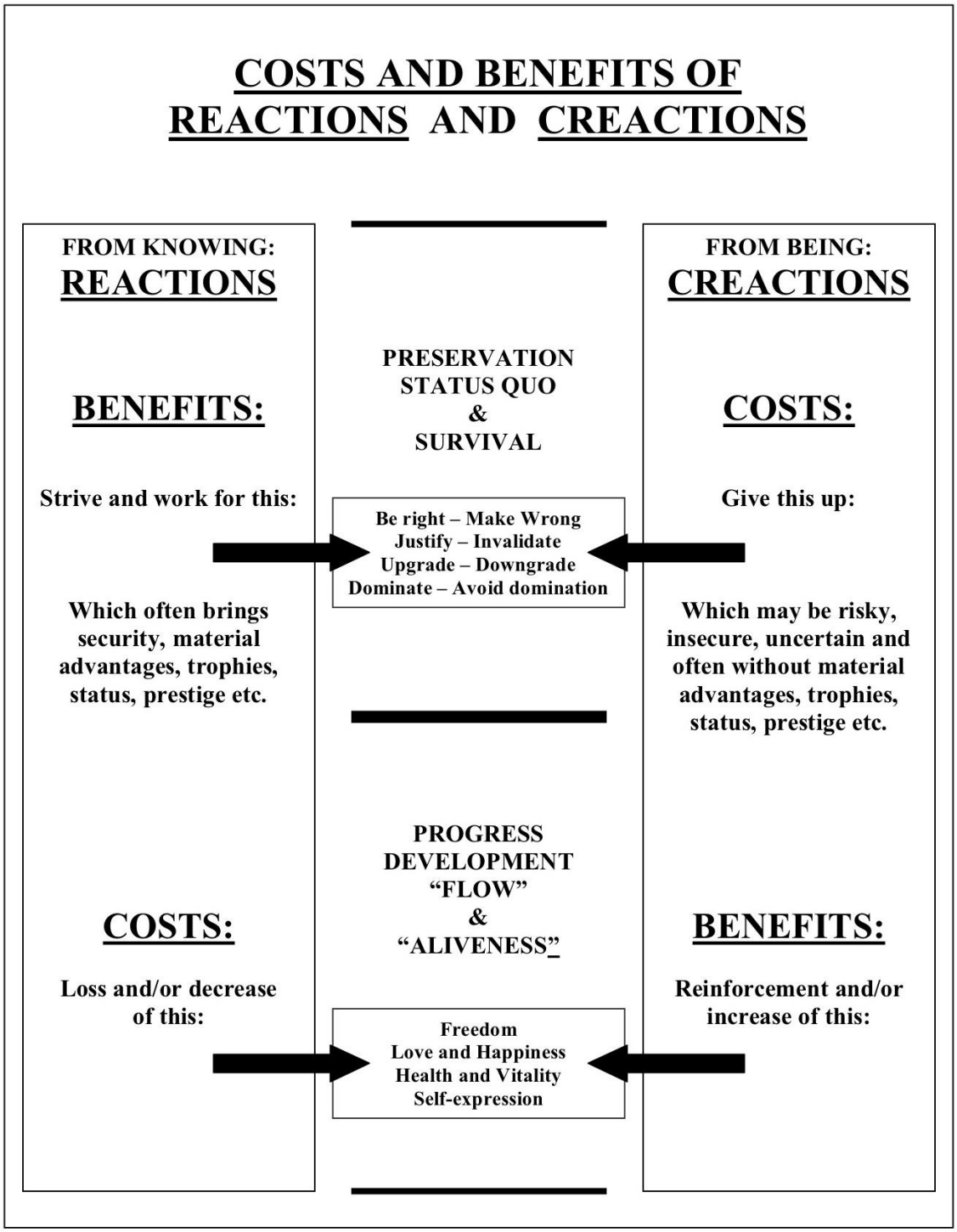

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Figure 3: Cost and Benefit Analysis of Action

Why is it then so important to generate CreActions? In addition to the obvious advantages mentioned above, it is of utmost importance to find sustainable solutions to the problems of our time. One prominent statement by Albert Einstein about problem solving is worth remembering.

"The world we have made as a result of the level of thinking we have done thus far, creates problems we cannot solve at the same level at which we created them"

Translated into our vocabulary this can be expressed as follows:

Problems can be solved and situations improved by changing the communication for ReAction that caused them to a communication for CreAction.

When things go wrong and when results are unsatisfactory: *Change the communication for ReAction to a communication for CreAction.*

INTRODUCING CREATIVITY INTO ENGINEERING EDUCATION

General Considerations

Human resources development will in the future to be made up of three fundamental parts:

1. The Pedagogical part: the further development of the domain of Knowing, which consists of adding new, more, better and different knowledge, experience, skills etc.

2. The Psychological part: consists of unlearning and correcting the misinterpretations and/or the misunderstandings of our reality, which our five senses have stored in our domain of Knowing, and which distorts and prevents the learning process.

3. Creative part: explaining how to generate creative actions from the domain of Being. It is from the Creative part that development; progress, success, flow and aliveness will emerge.

Today's engineering education and training concentrates mainly on the pedagogical part with the objective to provide the job market with skilled, knowledgeable and competent engineers.

The psychological part is touched in varying degrees during the education when the students are introduced to training in personal, interpersonal and communication skills and when they are confronted with the complexities of teamwork.

The Creative part will introduce a new possibility of utilizing the great, untapped human ability to create from the domain of Being. The development of this part has just started, but within a few years it will, and must be introduced in all learning institutions from upper secondary school to university level.

The Consequences for the CDIO and Engineering Education

The understanding of the origin and nature of creativity and the application of the basic Operating System for all human actions will affect and augment all the building blocks of the CDIO syllabus. Creativity learning pervades all levels of the second and third building blocks. (as shown in figure 4).[2]

QuickTime™ and a
decompressor
are needed to see this picture.

Figure 4: Building blocks of knowledge, skills, and attitudes necessary to Conceive, Design, Implement, and Operate Systems in the Enterprise and Societal Context (CDIO). [2]

Creativity is more then just a characteristic that can be attributed to a person, a team or a process. It is present and apparent throughout all human activities. It will therefore also have a strong positive impact on the Technical Knowledge and Reasoning building block. (Figure 4)

Creativity is accessible to all and can be consciously generated through a special, science-based and future-based communication, which everybody can learn and use. This will give students both an excellent tool and a new outlook on life and work, which will profoundly enhance and strengthen their professional, personal and interpersonal skills. (Figure 5) [2]

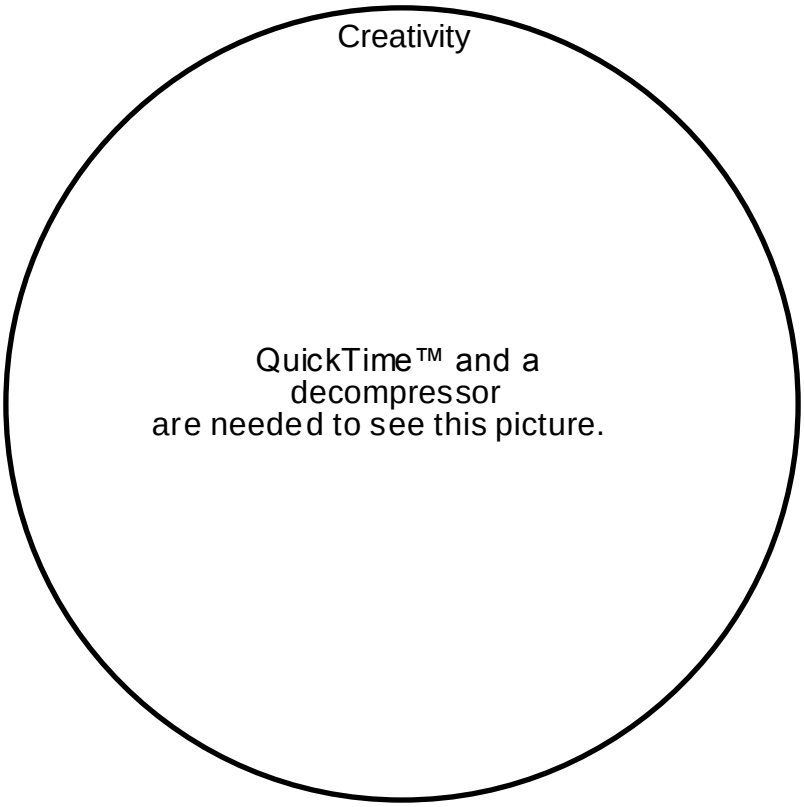

Figure 5: Venn diagram of Personal and Professional and Interpersonal skills. [2] (Modified)

Proposal for a Creativity course program

The introduction of a Creativity learning program in the CDIO syllabus could start immediately with test and pilot projects in one or more of the collaborating learning institutions.

Tentatively we suggest that a basic course in creativity should be offered to all students at the beginning of their first year of study. The first module of such a course would consist of a series of lectures in which the basic concepts are presented and explained leading up to the presentation of Operating System for all human actions. In conjunction with these lectures, lessons, exercises and workshops of both theoretical and practical nature will take place. For the general layout we refer to the textbook CREATIVITY – A Science-based Outlook on Life and Work. [1]

Creativity learning should also be open to students in the second year and above in form of refresher courses as well as lectures in special topics related to the development of a new Creativity Science.

The experiences gained from these pilot projects shall then be presented to all collaborating institutions and a new Creativity section of the CDIO syllabus will accordingly be developed and introduced.

CONCLUSIONS

The CDIO initiative of collaboration between leading engineering learning institutions in the world has provided for and achieved a great breakthrough within technical education.

We are now entering a new phase where Creativity will be offered as a basic subject to all students. This leading-edge initiative will be an even further breakthrough in engineering learning.

We provide here a science-based development program for Creativity learning as a part of presenting a basic Operating System for all human actions. We are confident that this will be the start of a new era, not only in engineering, but also in all human resources development.

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BIOGRAPHICAL INFORMATION

Anders Lennart Swahn (M.Sc. in Civil Engineering, CTH, Göteborg, Sweden, 1958) has a distinguished global career as engineer, technical education expert (UNESCO, ILO, World Bank), industrialist and creativity teacher and researcher.

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Teaching and Learning through Projects in the Course *DSP*

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ABSTRACT

In order to improve the ability of combining theory with practice, herein we introduce an idiographic teaching and learning methodology, which has been successfully employed in the course of Digital Signal Processing (DSP). How to formulate the course syllabus is discussed, involving the motivations and details. The key point is to incorporate relevant elements of EIP-CDIO into the teaching and learning activities. Our three-year's results demonstrate that the reform of EIP-CDIO improves student's comprehensive abilities efficiently. Most students have learned more than their expectations from the course DSP.

KEYWORDS

EIP-CDIO, Course syllabus of DSP, Active and experiential learning, Teaching and Learning through Projects

INTRODUCTION

Theory learning without any assistant practice is ineffective because there are many nuances, exceptions, and subtleties to be learned in practical environments [1]. Therefore, learning from practice is the same important as acquiring knowledge and applying it into practice for engineering students. Currently, one of the shortcomings in traditional engineering education is lack of sufficient Conceive-Design-Implement-Operate (CDIO) training. The Engineering College of Shantou University has proposed EIP-CDIO education mode which further emphasizes EIP (Ethics-Integrity-Professionalism) considering the specific circumstance of China [2]. Under this education mode, theory course and seminar are fused with project practice by teams, and the humanism spirit is carried through the course. The objective of EIP-CDIO is to make students have diatheses, such as professional morality, honesty, acuity, creativity, and so on.

Since 2005, our teaching and learning reforms directed by EIP-CDIO have been firstly explored in some courses. And then, the complete reform was put in force for all the courses in 2006. The course digital signal processing (DSP) is one of the first pilot courses, and we have never intermitted our efforts to enhance the teaching and learning level. The concrete measures for teaching and learning reform of the course DSP are introduced in this article. We are greatly pleased to share the experience with other colleagues engaged in electronic engineering education.

ENACTING THE COURSE SYLLABUS ACCORDING TO EIP-CDIO

Our method to enact the syllabus is: Firstly, the kernel of the course must be grasped, and then the projects by which students perform their experiential learning are constructed according to it. The kernel contents of DSP are shown in the followings:

1. Digital processing of analog signals procedure
2. Digital spectrum analysis algorithms
3. FIR digital filter design and their realization algorithms
4. IIR digital filter design and their realization algorithms

According to the aforementioned contents, the project constructed by us is the "Designing and implementing a digital filter system to filter analog signals". The project includes the following units:

1. Generation of an arbitrary analog signal and digitization
2. Spectrum analysis of the generated analog signal by DSP algorithms
3. Designing an FIR or an IIR digital filter to satisfy the given specifications
4. Designing a block diagram to realize the digital filter
5. Writing program and performing numerical calculation according to the block diagram by sample processing methods
6. Constructing the analog signal from the digital filter output
7. Spectrum analysis of the output analog signal by DSP algorithms
8. Evaluation the filtering effect by comparing the output signal spectrum with the input signal spectrum

Evidently, the project covers the kernel contents of DSP. Five to ten students are grouped together to do the project. Cooperation and competition among groups are encouraged. Compared with the traditional course syllabus of DSP, our syllabus is more detailed and explicit in terms of teaching contents and objectives. Only the kernel contents are instructed and discussed by interactive strategies in class, and the others are completed by students' experiential learning. In this way, the total contents are covered by 42 credit hours. Students understand the knowledge and improve their practical abilities through the idiographic teaching and learning methods.

To incorporate the relevant elements of EIP-CDIO into the teaching and learning, our methodology is the followings:

1. Active teaching and learning
2. Experiential learning through projects
3. Emphasizing critical thinking
4. Complete analysis of the kernel contents in interactive pattern
5. Scientific research aided teaching
6. Cooperation and competition spirit training
7. EIP edification

Our faculty previous efforts have already set up the EIP-CDIO mode for engineering education [2]. In general, each course should play its role in developing students' ability of EIP-CDIO. Fig. 1 shows the teaching and learning methodology of the course DSP directed by EIP-CDIO education mode. To match this mode, we propose projects of three levels:

1. First-level project is the main thread, serving the education program
2. Second-level projects are of comprehensive design-implement, serving the corresponding course group
3. Third-level projects are specialized, serving the corresponding kernel courses.

Employing Bloom's Taxonomy, our syllabus of the course DSP is detailed and explicit in terms of the contents and objectives. The contents are divided into memory, understanding, practice and integration analysis, marked by four-level degree, i.e., A, B, C, D.

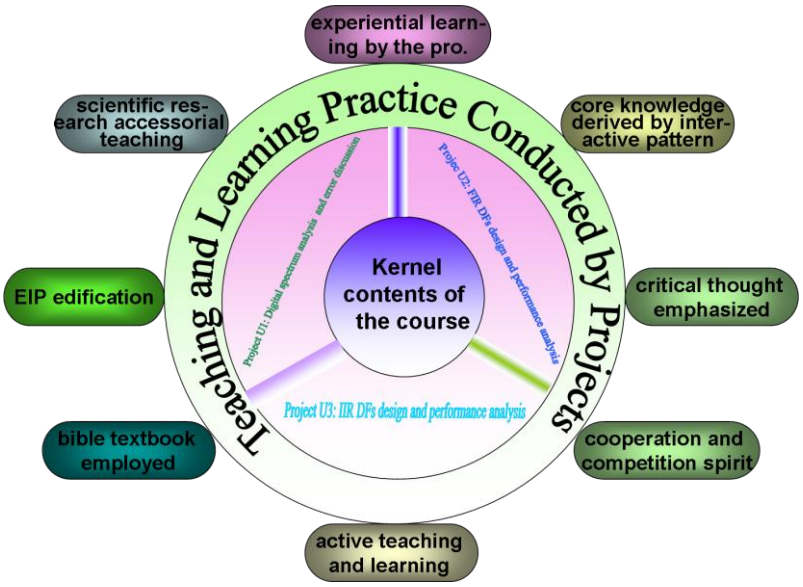

Figure 1. Teaching and learning methodology of EIP-CDIO in the course DSP

INCORPORATING THE RELEVANT ELEMENTS OF EIP-CDIO INTO TEACHING AND LEARNING

Teaching and Learning Method 1: Active Teaching and Learning

It is said that interest is the best teacher, and we try our best to inspire students' interest in the course of teaching. At the first class, we prefer to introduce some practical examples regarding the course, in order to let students understand the motivation of the course. When discussing the kernel contents, we firstly introduce what kind technical problems are met in typical application, and give the solution to increase students' desire of active learning.

For example, we show students the following observed signal in Fig. 2 when discussing "Digital spectrum analysis algorithms", and then ask students what information concealed in the signal. Most students say "Just noise, without any information", then we show students the spectral amplitude of the signal in Fig. 3 by digital spectrum analysis algorithm, and ask the same question again. Now students understand that there is a periodical signal hidden in the noise, then we explain furthermore that the signal is observed under the strong noise background, therefore it is hard to find the hidden sinusoidal signal by waveform in time-domain or by hearing. However, the hidden sinusoidal signal can be easily found by its spectral magnitude. In practice the sinusoidal signal hidden in strong noise sometimes is the behavior of device trouble. If we can find it earlier, larger loss can be avoided.

Teaching and Learning Method 2: Experiential Learning Through Projects

In order to let students learn more from practice, we design the third-level project of course DSP named "Designing and implementing a digital filter system to filter analog signals", which consists of eight units introduced in section II. Our teaching and learning program is guided by the project. Specifically, we prefer to arrange the third-level project in the first class, and let students learn the course with thinking the problems in the project. The third-level project should be as specific as possible, making students be able to apply what they have

learned to solve the specific problems in the project. Fig. 4 shows one solution of the project by students.

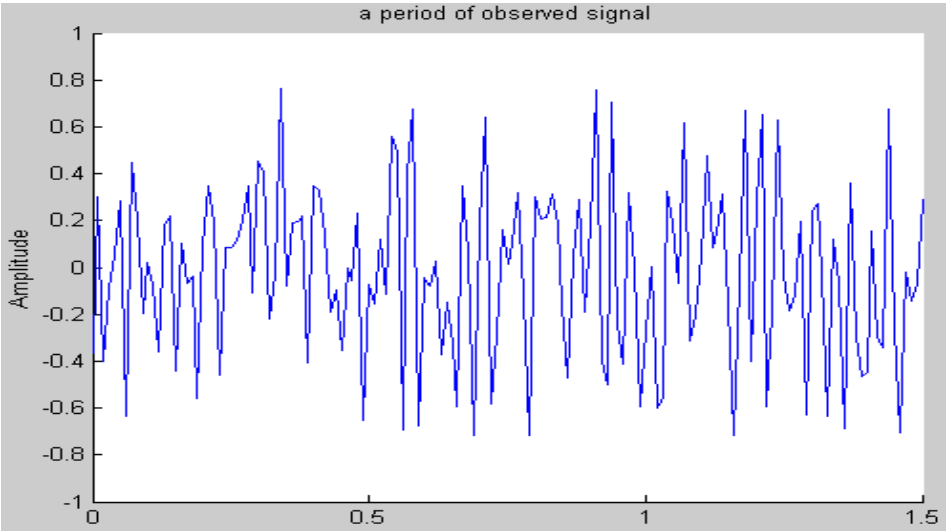

Figure 2. Observed signal

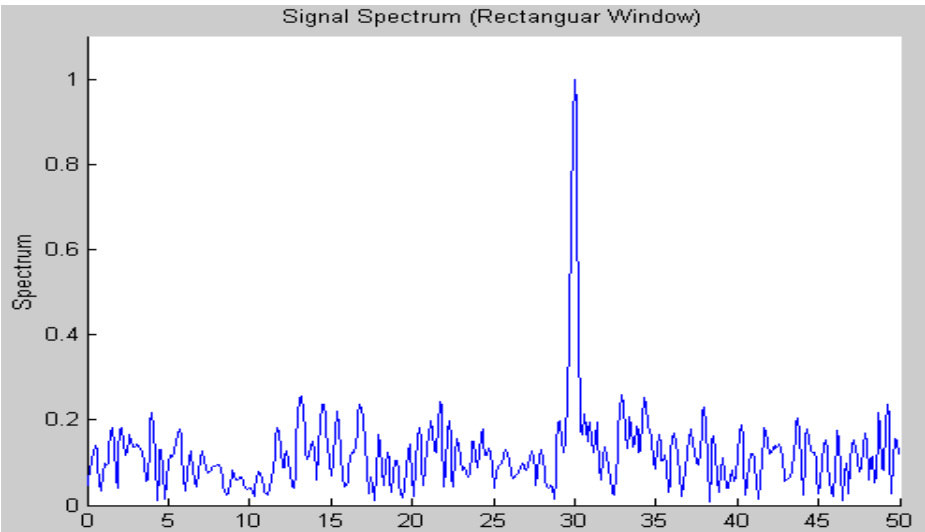

Figure 3. Spectral amplitude of the signal in Fig. 2

Teaching and Learning Method 3: Emphasizing Critical Thinking

We prefer to encourage students to ask why as frequently as possible. and tell them not to blindly follow teachers and textbooks. When discussing the algorithm of digital spectrum analysis, most textbooks directly give DTFT algorithm as

$$X_d(\omega) = \sum_{n=-\infty}^{\infty} x_d(n) e^{-j\omega n}$$

then present the relationship between digital frequency and analog frequency as

$$\omega = \Omega T = 2\pi f T$$

We ask students: “Why does the textbook hold this relationship? ”. Some students answer: “This relationship is only a regulation”. We then ask: “Why does this relationship exist? ”. With the interactive form, students recall the CTFT of an ideal sampled signal:

$$x_{is}(t)=x_a(t)\sum_{n=-\infty}^{\infty}\delta(t-nT)\xrightarrow{CTFT}X_{is}(\Omega)=\int_{-\infty}^{+\infty}\sum_{n=-\infty}^{\infty}x_a(nT)\delta(t-nT)dt=\sum_{n=-\infty}^{\infty}x(n)e^{-j\Omega Tn}$$

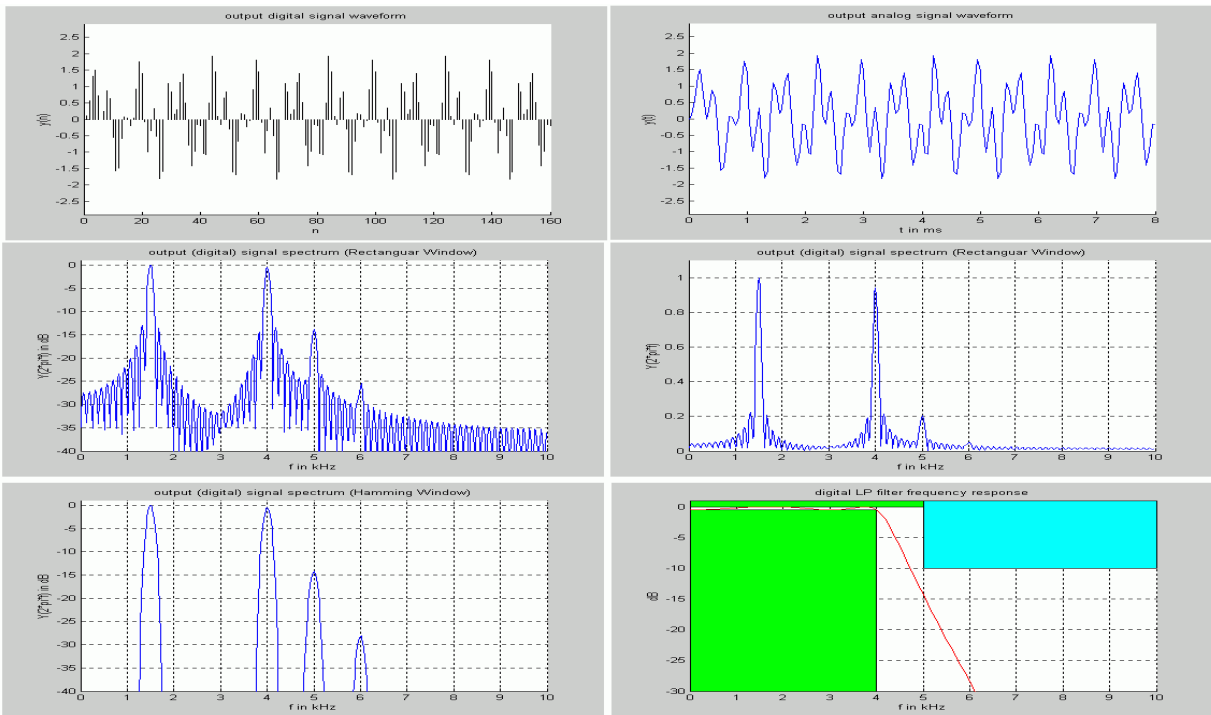

Figure 4. One solution of the project by students

Additionally, according to the sampling theorem, we get

$$X_{is}(\Omega)=\frac{1}{T}\sum_{n=-\infty}^{\infty}X_a\left(\Omega-m\frac{2\pi}{T}\right)$$

This equation indicates that there exists periodical expansion relationship between $X_{is}(\Omega)$ and $X_a(\Omega)$. When the digital frequency $\omega=\Omega T=2\pi fT$ is defined, the spectrum of a discrete-time signal is the same as that of the ideal sampled signal. By the above interactive discussion, students not only understand why the digital frequency ω is defined as $2\pi fT$, but also master the relationship between $X_a(\Omega)$ and $X_d(\omega)$.

Teaching and Learning Method 4: Complete Analysis of the Kernel Contents in Interactive Pattern

According to the requirement of "*Course syllabus of Digital Signal Processing*", the credit hour of the course is sharply reduced. In the classroom, only the kernel contents are taught and discussed, while the others should be actively learned by students themselves through the project. The kernel contents must be deduced and analyzed completely. On the one hand, students must grasp the kernel contents. On the other hand, we impart the method of analyzing and solving problems, i.e., giving the method of fishing is better than giving fish.

CONCLUSION

According to the EIP-CDIO education mode, we have formulated "*Course syllabus of Digital Signal Processing*", and the syllabus has been performed since 2005. Three-year's teaching

and learning activities indicate that the CDIO reforms enhance students' ability of combining theory with practice. Students' study enthusiasm has been aroused effectively, and they have learned more than their expectations from the course.

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TEACHING INTERPERSONAL SKILLS - THE CONCEPT OF SOCIAL RISK ANALYSIS

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ABSTRACT

In addition to the traditional learning outcomes for technical disciplinary knowledge, the CDIO-syllabus also specifies personal and interpersonal learning outcomes. The argument for teaching interpersonal skills rest upon the team-based working environment that is typical for engineers, where knowledge and skills in teamwork, leadership, and communications are highly required. Thus, the practice of interpersonal skills need to be implemented in engineering teaching, not only in terms of learning objectives, but realised in practical teaching activities and as an integrated part of the examination. This study aims at presenting and reviewing a practical approach to teaching of interpersonal skills, referred to as the Social Risk Analysis, which has been applied and integrated into the curriculum of two engineering courses. The Social Risk Analysis encourages and imposes a critical review of the social interaction in a small group of students and thus facilitates communication and teamwork operation. Students find the Social Risk Analysis being easy to apprehend and meaningful in engineering teaching, and most significantly, they perceive that the Social Risk Analysis facilitates the work performance. The study found it possible to successfully implement the Social Risk Analysis into the course curriculum of the two engineering courses. The implementation required, however, refinement of the pedagogical approach by integrating the Social Risk Analysis into the learning objectives, teaching activities and assessment of the course, and further, redesign of the engineering work assignments in order to impel cooperation, communication and participation of the students in a team. The establishment of an engineering context provides an important basis for the teaching of interpersonal skill using the Social Risk Analysis.

KEYWORDS

Interpersonal skills, social risk analysis, teamwork, CDIO

INTRODUCTION

The CDIO framework for engineering education rests upon the expressed need "*to educate students who are able to Conceive – Design – Implement – Operate complex, value-added engineering products, processes and systems in a modern, team-based environment*" [1]. The context of conceiving, designing, implementing and operating depicts the professional

role of engineers and it provides a realistic framework for teaching engineering skills which facilitates the understanding of the technical disciplines and imparts learning in personal and interpersonal skills [1]. The required professional engineering skills go beyond the down-right technical disciplinary knowledge and include the personal and interpersonal skills that are required when operating in the team-based environment that characterises professional engineering work to day.

Engineers are challenged by the ongoing globalization and they encounter problems of cross-disciplinary nature which e.g. requires team working skills with awareness and respect for other competencies [2]. The recognised competitive advantage of companies that succeed in creating cross-disciplinary team environments, in which engineers work side by side with other professions [3], [4], brings forward the argument and need for cross-disciplinary team learning for engineering and other university students in processional programs in order to qualify for a globalised marketplace [5]. Thus, team collaboration in cross-disciplinary environments includes social as well as technical skills [6]. Schaffer *et.al.* [7], Reichlmayr [8] and others conclude that the skills of communication with people with different skills backgrounds, to understand more that one discipline, are important in any teaching program preparing professional engineers. These knowledge areas apply to the skills inquired by industry, e.g., interdisciplinary skill, softer people-oriented skills, project-based experiences and creativity and critical thinking besides profound knowledge of engineering theory [2].

Derived from surveys of contemporary engineering practices, reviewed and validated from industry and academic stakeholders, the CDIO approach presents a comprehensive syllabus of knowledge, skills and attitudes which is well adapted for a variety of engineering educational programmes [1]. The guiding principles and features of a CDIO program are compiled in 12 standards which serve as a guideline and framework for redesign of engineering programs. The learning outcomes of engineering education, following the CDIO syllabus, are recorded in Standard 2 and includes *"…personal and interpersonal skills, and product, process, and system building skills, as well as disciplinary knowledge…"* [1]. The personal learning outcomes refer, in this context, to the students' individual cognitive and emotional development, e.g. engineering reasoning, creative and critical thinking and professional ethics while the interpersonal learning outcomes consider individual and group interactions which include teamwork, leadership and communication.

Problem Statement

The implementation of an integrated curriculum of technical and personal, professional and interpersonal skills, of which the CDIO initiative provides a thorough and comprehensive example of an approach to engineering education, implies a change and reformation of existing engineering education programs. The emphasis on personal and interpersonal skills provides a new challenge for the existing teaching staff of the technical disciplines in consideration of the new subject fields, but also from a pedagogical perspective. The teaching of non-technical skills e.g. teamwork and communication skills require appropriate teaching methods different to the traditional didactic methods [9]. Besides, how can personal and interpersonal skills be implemented into an existing curriculum without detracting the technical disciplines?

Purpose and Objectives

This study takes on the challenge of creating an integrated curriculum in which teaching of the technical disciplines is integrated with teaching of interpersonal skills. The objective is to introduce a simple approach for teaching of interpersonal skills and to review the outcome on basis of two different cases, i.e. two different courses. The approach is in this context

referred to as the Social Risk Analysis. The definition of interpersonal skills refers directly to the CDIO syllabus, paragraph 3, Interpersonal Skills: Teamwork and Communication.

METHOD

The presentation and review of the Social Risk Analysis described in this context rests upon practical experiences from two different cases, i.e. two different courses, where case 1 took place at Lund University, Faculty of Engineering, in Sweden in the time period of 2003 to 2005 and case 2 refers to The Technical University of Denmark, Department of Management Engineering in 2009. Despite the different origins, there are a number of common denominators in the two cases. For example, the subject field is about construction management in both courses, the teaching is project based and includes industry involvement, the courses are optional for students in their final year of education, the course credits correspond to about 30% of full-time studies for a semester, there is about 15 students from different engineering programs in the class, the students work in groups of about four to five students and the groups are divided by the teacher.

The differences to be mentioned about the two cases concern the duration of the courses in which the course in case 1 ranged over seven weeks while the course in case 2 extends over 13 weeks. Civil-engineering students constitute the main target group for both courses, but both courses are characterised by a cross-disciplinary selection of students. In case 1, the group of civil-engineering students was supplemented by students from the architectural and land surveying programs. In case 2, the group of students were constituted by equal shares of civil-engineering and architectural-engineering students and the whole group represented three different nationalities.

The review of the practical application of the Social Risk Analysis rests upon, in case 1, course evaluations from 2001 and 2005 and, in case 2, a questionnaire survey that was carried out halfway through the course.

The structure and fundamental principles of the Social Risk Analysis was established with help and support from the department of Cognitive Science at Lund University, Sweden.

THE CONCEPT OF SOCIAL RISK ANALYSIS

The initial fundamental argument for introducing interpersonal skills in the curriculum of the engineering courses of case 1, and later in case 2, rests upon the conception that the teaching of interpersonal skills not only represent an important topic of its own but also facilitates the learning process of the technical skills, see figure 1. This line of thought accords with the CDIO concept in which the importance of interpersonal skills are emphasised besides the technical disciplines and other professional skills and it corresponds to the FIRO-theory of interpersonal relations which, among other things, explains how collaborative relationships in a team influence the work performance of the team, see Blackman [10] referring to the original work of Schutz [11] from 1958. Crawley *et.al.* [1] call for a better preparation of engineering education as the basic intent of the CDIO initiative and address, in this matter, not only the knowledge and skills that engineering students should learn but also how engineering students should learn these skills. Thus, the implementation of an integrated curriculum includes pedagogical considerations at all levels down to the design of individual courses, which e.g. corresponds with the findings of Varkey *et.al.* [9] and others.

A basic condition for the pedagogical design of the courses in case 1 and 2, was the context of the course, i.e. the scenario or the situation in which the students team up and act in the

role of professional engineers solving technical problems and, consequently, in the context where the interpersonal skills become authentic and relevant.

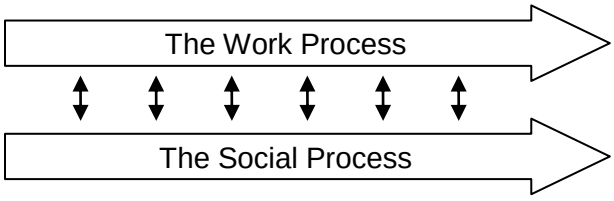

Figure 1. The Interaction of the Work and the Social Processes

The pedagogical design of the courses in case 1 and 2 in this context were based on a project assignment in which the students worked in teams, compelled to interact in order to complete the project. Further, the interpersonal skills as well as the technical subjects were included in the course curriculum, which was designed so that the learning activities and methods of assessment were aligned with the learning objectives of the courses. Thus, the curriculum design of the two cases followed the concept of constructive alignment as presented by Biggs [12]. The introduction and explanation of the Social Risk Analysis was done early on in the two cases, just after the project assignment was introduced and groups were established. The initial preparation, instructions and clarification on the rationale for the teamwork and in this case, the Social Risk Analysis, are essential for the student's view towards teamwork [8] and the team capacity for growth [7].

The Social Risk Analysis – Step by Step

The operation of the Social Risk Analysis, described step by step in the following section, constitutes a generic framework that follows the same procedure irrespective of the group composition or the group assignment. However, the issues of analysis derive from the individual members of the group and from the characteristics and context of the group assignment and, consequently, the issues of analysis can vary between different groups in the same project. Further, the new issues of relevance can be found during the work process as the group dynamics develops. In the first step of the Social Risk Analysis, the group identifies and agrees on some common issues of analysis.

Step 1: Identification of Common Issues of Analysis

The identification of some common issues of analysis provides the starting point for the Social Risk Analysis. As mentioned above, this step should be initiated at an early stage of the work process in order to provide an early opportunity for the group members to familiarise and to get to know the work assignment. Thus, the group assignment should be introduced and explained before the Social Risk Analysis, as it can influence the choice of relevant issues of analysis in the Social Risk Analysis.

The issues are identified with a traditional brainstorming within each group. The following list provides examples of relevant issues for the Social Risk Analysis described from an individual point of view:

- Priorities. How do I prioritize my loyalties? What is most important to me, e.g. my family and friends, my professional carer, my income, appreciation, duty, etc.?
- Conditions. Under which circumstances do I work and perform the best? Is it when I work against the clock, with great responsibilities, on my own, as the underdog, early in the morning, after lunch, at night etc.?
- Personality. How do I perceive my own personality type?
- Cooperation. Which type of personality do I prefer to cooperate with? Why?
- Cooperation. Which type of personality do I find it difficult to cooperate with? Why?
- Behaviour. What kind of behaviour do I appreciate from my team members? Why?

- Behaviour. What kind of behaviour do I dislike among my team members? Why?
- Ambition. What level of ambition do I have with this group assignment?
- Success criteria. Which are my success criteria for the performance of the group?
- …

Step 2: Self-Conception

The list of issues of analysis from step1 provides a common starting point for the second step of the Social Risk Analysis, namely the self-conception. This step implies a meta-cognition, which accounts for the personality, set of values and qualities of each individual student in the group. Each student makes the self-conception in light of the given context, i.e. the team and the assignment that is to be carried out, and decide for them selves how open-hearted they like to be. Thus, the Social Risk Analysis does not require a total mental revision that reveals and explicitly express the student's innermost thoughts and values to all the other members of the group. It is, however, of greatest importance that everyone is honest and holds on to the truth in the self-conception. If that is not the case, it is likely that the Social Risk Analysis will impair rather than facilitating the teamwork. The results of the self-conception are presented to the other team members.

The role of self-conception is introduced and explained with reference to the Johari Window, developed by Luft and Ingham in 1955, which provides a framework for understanding and improving self-awareness [13] and describing the process of human interaction [14]. The self-conception part of the Social Risk Analysis aims at increasing the personal awareness of each student as well as the other team members and helps the students to better comprehend the interpersonal communication and relationship of their team. Self-conception represents, together with feelings and behaviour, three levels of human interaction according to the theory of FIRO, which posits that self-concept drives feelings, feelings drive behaviour and behaviour drives results [10]. The Social Risk Analysis is introduced when the groups are recently formed, the stage of Inclusion referring to the FIRO theory, and when insecurity and questions about acceptance characterises the individuals of the team. In this context, the Social Risk Analysis will help building self-respect, trust and a sense of group solidarity in order to facilitate the work performance of the team.

Step 3: Identification of Potential Conflict Areas

In step 3 of the Social Risk Analysis, the group jointly analyses the self-conceptions that has been accounted for by each team member in step 2, with the purpose of identifying potential problems or situations in which conflicts between team members may occur.

Step 4: Agreement on Fundamental Principles for the Teamwork

The list of potential problems prepared in step 3 is analysed by the group in order to elaborate suitable and preventive measures and policies for the teamwork in order to delimit the risk for conflicts and guidelines for how to handle conflicts that do occur.

It is important that the whole working process of the Social Risk Analysis, from the initial identification of common issues of analysis in step 1 to the concluding assessment and report in step 6, is well-documented by the members of the group. The documentation preserves the discussions and agreements of the group and constitutes kind of a social contract in the team.

Step 5: Recurrent Review the Social Risk Analysis

The Social Risk Analysis is to be considered a continuous process that, similar to the Social process illustrated in figure 1, should be run in parallel to the work process of the group. The

recurrent review of the Social Risk Analysis monitors the development of group dynamics over time. Besides, when students are new to the conceptions of interpersonal skills in general and/or the Social Risk Analysis in particular, it is likely that the initial analysis needs supplements and refinement when the work has commenced. Thus, step 5 of the Social Risk Analysis implies a recurrent update and review of step 1 to 4, see figure 2.

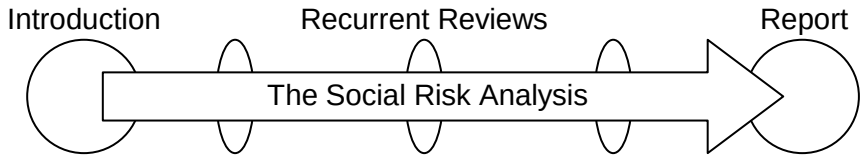

Figure 2. The introduction, reviews and report of the Social Risk Analysis

The initial introduction, the recurrent reviews and the final report of the Social Risk Analysis correspond to the approach to a course curriculum represented by constructive alignment, [12], in which the Social Risk Analysis can be included in the course objectives, implemented in learning activities and assessed as part of the course requirements.

Step 6: Assessment and Concluding Report of the Social Risk Analysis

The final step of the Social Risk Analysis, step 6, includes a critical assessment and debriefing of the interpersonal experiences and development of the team. Step 6 should be done after the work process has been concluded and eventual reports has been handed-in, in order to create some distance to the work process and allow for a review of the teamwork in some perspective. The documentation provides an excellent reference to the final evaluation of the group performance and its development.

EVALUATION OF THE SOCIAL RISK ANALYSIS

The Social Risk Analysis has been applied and tested in the two different cases, i.e. courses, described above and there is an overall positive attitude towards it among the students. In the course evaluation from case 1 in 2001, the students were asked to write down their own positive and negative judgements about the course and then, the other students could either agree or disagree to the total list of student judgements. The Social Risk Analysis was given four positive comments and a range of 84 to 95 percent of the students concurred with those positive comments. The same evaluation had no negative comments at all about the Social Risk Analysis. In the course experience questionnaire, CEQ, in case 1 from 2005, the students fully agreed to the statement, by a score of 95 out of 100, that their ability to work in groups had improved due to the course. The Social Risk Analysis was also mentioned in the list of personal comments to the best parts about the course and, in the same CEQ, there were no negative comments about the Social Risk Analysis.

In the questionnaire of case 2, which was specifically directed at the Social Risk Analysis, all students agreed to the opinion that the Social Risk Analysis had a positive impact on the work performance of their group (Positive: 50%, 50%, 0%, 0%: Negative). There were no explanatory comments to this question by the students, but it ought to be obvious that the students perceive a useful connection between the social aspects and the work performance, which constitutes the basic hypothesis and argument for the Social Risk Analysis in this context. Almost 90 percent of the students found it easy to understand the structure and content of the Social Risk Analysis (Easy: 38%, 50%, 13%, 0%: Difficult), which of course is of importance to the successful implementation.

An evident majority of the students agreed to the question about whether the Social Risk Analysis has made it easier and more acceptable to talk about interpersonal relations, potential conflicts or other relevant social issues in the groups (Agree: 13%, 63%, 13%, 13%: Disagree). This provides, together with the previous question about the relation between the Social Risk Analysis and the work performance, decisive arguments for the implementation of an integrated curriculum. Further, all students consider that teaching of interpersonal skills are of important relevance for engineering students at technical universities (Relevant: 75%, 25%, 0%, 0%: Irrelevant). However, to the question about whether any of the students have used the Social Risk Analysis or any similar teaching methods related to interpersonal skills in other courses during their previous university studies, the answer was clear (Yes: 0%, 100%: No). None of the students, despite being in their fourth or fifth year of university studies, could direct to any previous experience of explicit teaching activities in the field of interpersonal skills.

Even thought the results from the evaluations and questionnaire of the two cases announce some generally positive and interesting aspects of the teaching interpersonal skills in an engineering context, the empirical data in this study must be considered limited and imperfect for comparisons or more profound conclusions. For example, the course in case 1, which represents an intensive seven week course, must be considered too short for the group dynamics to develop into the role seeking phase during which the risk for interpersonal conflicts increases. Thus, the impact and importance of the Social Risk Analysis is delimited when the course is too short to allow the group dynamics to develop.

The course in case 2 runs for a period of 13 weeks, which should provide better conditions for group development. However, the total workload of the two cases are about the same, which implies that the 13-week course is less intensive and consequently, it delimits the need for a consistent team effort and allows for the students to work more individually. Thus, the review of the two cases indicates that the design of the work process, i.e. the design of the engineering assignment that the students should solve as a team, is of the importance to the conditions for learning of interpersonal skills, and thereby, important to the relevance of the Social Risk Analysis or any similar method. The engineering assignment should be designed so that is requires the commitment and participation of the whole team, and consequently, facilitates the teaching and learning of interpersonal skills.

CONCLUSION

The Social Risk Analysis, as described in this context, provides as a tangible approach to the teaching of interpersonal skills that can be integrated in the curriculum of an engineering course as part of its learning objectives, teaching activities and assessment. The Social Risk Analysis encourages and imposes a critical review of the social interaction in a small group of students and thus facilitates communication and teamwork performance. Students find it easy to apprehend and consider it being meaningful in engineering teaching.

On basis of the experiences from the two cases reviewed in this context it is concluded, however, that the successful application of the Social Risk Analysis is dependent on the pedagogical approach and on the design of the work assignment. Generally, the implementation of interpersonal skills into the curriculum should follow the general pedagogical requirements regarding clearly stated learning objectives, learning activities and assessment. In this case, the implementation of the Social Risk Analysis is done according to the concept of constructive alignment. More specifically, it is concluded that the work assignment should be designed so that it impels cooperation, communication, commitment and participation of the whole team in order to facilitate the active experience and learning of interpersonal skills. The work assignment provides an engineering context in which the incentives for teamwork can be articulated and explained and thus, justify the introduction of the Social Risk Analysis.

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Biographical Information

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TEACHING TEAMWORK AND PROJECT MANAGEMENT USING VIRTUAL PROJECTS

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ABSTRACT

Project management is one of four "management" modules taught in Liverpool science and engineering programmes. One of these modules is taken each year. The module described here is usually taken by second-year students. The problem was: The class typically contains 200-300 students from six or more major disciplines across engineering and science. It is not possible to assume a common set of interests or experiences, as would be the case if the class contained, for instance, only aerospace engineering students. Very few students (perhaps less than ten in a typical year) will have had any experience of project management and many will not have worked or studied in a team. There is usually a diverse range of cultural and ethnic backgrounds. For many years the class was taught by lectures only, with no formative assessment and no "active" element at all. Although of course most students passed the exam, they had never used any of the techniques described to them. The solution was: Without changing the intended learning outcomes very much, the material was re-cast into half the original number of lectures, supplemented by a virtual team project with five assessed deliverables at two-week intervals. The key characteristics of the revised module, and its associated virtual projects, are described in more detail in the paper along with feedback from the students who have taken the module.

KEYWORDS

Teamwork, project management, virtual projects, large classes

INTRODUCTION

Project management is one of four "management" modules taught in Liverpool science and engineering programmes. One of these modules is taken each year. The module described here is entitled "Project and Risk Management" (PM, in brief) and is usually taken by second-year undergraduate students and Masters (taught MSc) students.

This class was traditionally taught using lectures only, with no formative assessment and no "active" element at all. Although of course most students passed the exam, they had never used any of the techniques described to them. It was decided to make the module much more active, by halving the number of lectures and creating a virtual project for every student, so that PM techniques could be put into practice. One problem was: The class typically contains 200-300 students from six or more major disciplines across engineering and science. It is not possible to assume a common set of interests or experiences, as would be the case if the class contained, for instance, only aerospace engineering students. Very few students (perhaps less than ten in a typical year) will have had any experience of project management and many will not have worked or studied in a team. There is usually a diverse range of cultural and ethnic backgrounds and several levels of prior educational or work experience.

The approach to a solution was: Without changing the intended learning outcomes very much (see below), the material was re-cast into half the original number of lectures, supplemented by a virtual team project with five assessed deliverables at two-week intervals and a set of question and answer (Q&A) sessions. This resulted in the same number of timetabled "contact" hours but in less than half of them is a lecture delivered. Only seven formal lectures are now delivered.
To the original learning outcomes (listed in the appendix) was added a further small but important set relating to team and project working, viz:

- use the basic functions of Microsoft Project
- ability to work in a team
- ability to deliver work to a deadline

The virtual projects themselves were devised and developed, under the guidance of the author, by two students who had recently taken the earlier version of the module. The topics were chosen to be equally accessible to all students, regardless of their prior experience, and the projects were constructed so that every team could use a different set of quantitative data. The topics selected were the setting up of a specified type of restaurant in a specified location in the city of Liverpool and the building, by a charity, of a facility for a village in a developing country. In the first two years, among 500 students, only one has proved to have had direct prior experience of either of these tasks, while no team has found it difficult to understand the requirements. The two students developing the virtual projects worked for ten weeks over a single vacation, so the effort required was approximately 20 person-weeks plus about one week of the author's time.

The projects were designed to have five deliverables (called "tasks"), at two-week intervals, each of which required one or two team meetings. The tasks, which are generic so that they apply to all projects, are listed in Appendix 2. Every task had to be submitted to the students' virtual learning environment (VLE), on a pro-forma, to a firm deadline. The importance of the new learning outcome "ability to deliver work to a deadline" is that this module over-rides the university practice for late submission, which defines a mark penalty for lateness of up to five days. In order to meet the LO, no late submission is possible (except for good, usually medical, reason). The *quid pro quo* for this aspect of the contract with the students is that the module teachers undertake to mark the tasks within 3 days and to deliver feedback at the meeting of the class in the same week as their submission. In practice this has meant a submission deadline of 5pm on Monday, with feedback to the students at 11am on Thursday. Feedback (see below) indicates that it would be preferable to have a midnight deadline, but this removes one evening from the short time for marking. In the first year sixty teams of five students were established while in the second year forty teams of six were used. Marking the work of 200-300 students in this period is a challenge, and the way in which it is met in described in the following sections:

MODUS OPERANDI

The lectured material principally relates to definition of terms, explanations of concepts (such as Discounted Cash Flow) and anecdotal examples of the management of specific projects. The students are offered a weekly class with a lecture every two weeks, in which the next task is defined, followed by a consultation class in the intervening weeks. Each task explicitly involves applying the material covered (albeit briefly) in the preceding lecture. Most of the students have had no prior training in team work, although as the CDIO approach is embedded in their programme they will usually have experienced one team-based design-build-test project. The students are told that team selection will be at random, defined by the lecturer, who in fact attempts to prevent the formation of teams from a single ethnic background or with a single female. In the first year mixed teams were constructed from all

subject cohorts, and this remains the educational ideal. However in response to student feedback (see below) teams in the second year of operation were constructed from within a single discipline cohort (e.g. from Aerospace Engineers, or from Civil Engineers) in order to facilitate team meetings, by only using students who share a common timetable.

All content and assessment is via the local VLE. The students are given access to a lecture handout one week before each lecture, the lecture Powerpoint presentation is released immediately following the lecture and (second running only) a video of each lecture is mounted within two hours of the lecture. On-line guides are available to:

- Team working and the role of the Project Manager and Secretary (who have to be different for each of the five tasks)
- Pro-formas for team meeting Agenda and Minutes
- The use of Microsoft Project
- FAQs

In addition to the five tasks, there is a short multiple choice question (MCQ) on-line test in week 7 (or a slightly longer one for Masters students). A summative MCQ examination is held at the end of the module. These elements contribute in the following way to the whole module mark:

- Tasks 1-5, 6% each
- On-line test 10%
- MCQ examination 60%

Each task is assessed in the following way, designed to minimise staff effort while retaining rigour and useful feedback: It is the responsibility of the PM for the task to coordinate the deliverables and distribute them to all team members. Every member of the team must submit an identical set of deliverables, but only the PM's submission is marked and feedback is only given to this submission. Feedback is then shared by the team members, usually at their next meeting. Other team member are given the same mark if, and only if, they submit the same set of deliverables. This means that only one-fifth of the students' work has to be marked while the remaining 80% is simply verified as being identical. In the case of serious malingering, recorded in the meeting minutes, staff reserve the right to adjust downwards the mark of any specific student. This has proved necessary in only a handful of cases.

Students are instructed that if they experience problems in the operation of their team they should first attempt to solve them themselves, that they should always record them in their meeting minutes, and that if they call on staff intervention, staff will only act on problems for which there is a written record trail.

FEEDBACK FROM THE FIRST COHORT

Student responses were sought to three specific questions:

1. What were the aspects of this module which were particularly effective and why?
2. This module could be changed in the following ways to improve my learning …. , and
3. What do you think you learned from undertaking this virtual project?

From a response of 264 student (90% of those registered for the class) 91% of students were pleased with the module and 87% claimed to enjoy the virtual project. In response to question 1, 104 students mentioned team work, 97 mentioned the virtual project and 74 the use of VITAL (the University of Liverpool virtual learning environment). Some comments include:

"I think use of VITAL was exceptional and that the team projects were an interesting and practical way of learning."

"The virtual projects were useful because it enabled us to apply what we learnt in the lectures to a real-life situation. It also enabled us to build on our team working skills and allowed us to use industry-standard tools for project management"

"The virtual projects were beneficial as they gave an insight into how engineers might interact in the real world while managing an important project. The module reinforced my group skills."

"It has to be the virtual projects and team work. By working on a project totally unfamiliar from our own comfort zone enables us to learn something different and understand what sorts of things involves in any project. And in the case of the team work I would have to say that, it gives great bit of knowledge how to handle and maintain a group work."

"Team work and virtual projects. Team work allows you to think in different ways."

"The high weighting of the Virtual Project (and the use of VITAL) were the most effective parts of the module. This was because it greatly encourages you to spend the necessary time on the project, therefore increasing understanding and knowledge of the subject."

"I believe that the virtual projects gave a very good insight into how a management project is run. I thoroughly enjoyed these projects and would like a career in the management sector. However the lectures themselves could have been made more interesting."

"Enjoyed the team work as normally I do not do the extra work but because other people depended upon me I worked much harder and learnt much more. I also like the use of VITAL as all the information needed is in one place, and allows me to get in contact with both the lecturer and my team members easily."

But also:

"Very little of this project was particularly effective. Given the nature of the subject, management is a very vague subject area and the overwhelming use of jargon to describe common-sense financial decision making behaviour I found to be more of a hindrance than a thorough explanation of the processes behind them."

The responses to question 2 (This module could be changed in the following ways to improve my learning ….) did not show any dominant attitudes, but 36 students commented unfavourably on the large class size for lectures (almost 300 students). However 23 students asserted that no change or improvement was needed. Specific comments included:

"Increase the deadline from 5 to mid-night on VITAL submission."

"Due to people being from different areas of university, ie ..maths , engineering, we all have things to do at different times of the week and it was sometimes difficult arranging times to meet up, maybe putting groups of civils with civils and maths with maths would mean people could meet easier."

"By making it more real , i.e. by introducing the students to real projects and having discussions with project managers of related fields so that we understand more deeply how a medium or large scale project is carried out in the industry."

"Submitting work on VITAL, very easy but deadline should be made to midnight to submit, then less arguments can occur about being in lectures or work."

"The lectures were quite boring to be honest, but I have no suggestions how to improve it because it's not the most interesting of subjects to learn or teach, I'd imagine."

"Less emphasis on team work, it would not have made much difference if I had done all of the tasks on my own as I did the majority of the work anyway and wasted a lot of time organising and then re-organising meetings."

In responding to the third question (What do you think you learned from undertaking this virtual project?) students most often commented on their acquisition of soft skills such as team working and time management (78 responses). Specific comments included;

"I just realised that management is not easy as I thought."

"I never thought that building a well could be that complicated and need precise planning. I learnt that no matter how small the project seems to be, we need to put serious effort on it as failing will give big consequences to community."

"I have learnt the real time problems faced in a project, and the importance of team work.2

"It illustrated to me that even a minor project (in our case was the village barn) can be complex and highlights the importance of planning, management and control to the success of the project ."

"Definitely learned the importance of project management and organisation. Perhaps more importantly the fact that a project manager needs a good team behind him/her as well ."

"We learned how to create and set up a project, from identifying risks etc. to basic costing for a project. As I have never taken a module or class like this one before, I have learned a vast amount of information regarding cost and management of a project."

"I did enjoy the project and it was the first time I had considered any of the project management/costing issues associated with a project. It was also a good learning experience to consider how one would go about setting up a restaurant. I felt like I learned a lot from this virtual project. It made me consider the management and financial side of things. I also learned a great deal about critical paths and how to professional manage a project to ensure it is delivered on time."

"What it would be like to have our own business, dealing with real life situations etc. Very interesting, and thoroughly enjoyed."

But three students actually responded: *"Nothing."*

In response to the student feedback, several changes were made for the second running of the Virtual Project module. Some of these were pragmatic, in response to local conditions, while a few were for pedagogic reasons. The principal changes were: Team size was increased from 5 to 6, in order to enable the students to better cope with student absence and illness 9and to slightly reduce the number of teams). Teams were restricted to students from a single degree programme, instead of being selected from a range of programmes of study. This was simply to make team meetings easier to arrange – a pedagogical approach would suggest that mixed teams are preferable. The class size for lectures was reduced to about 120 by offering the lecture twice. In this second year the two identical lectures each fortnight were given by different people, providing a seamless transfer from one lecturer to another. These changes were all popular but it remains to be seen whether they were educationally effective.

Apart from student evaluation of the module it is also possible to see the impact of the changes, and the virtual projects, on the assessment outcomes. The mean marks for the last seven years are shown in the table (every cohort was at least 200 students, so the means are quite reliable). These results are largely comparable because the majority of learning outcomes have not changed over this period. The additional outcomes detailed above are only 3 among 26 LOs, 23 of which remain the same (see Appendix 1).

	2002	2003	2004	2005	2006	2007	2008	2009
Class average (%)	**62**	**57**	**60**	**55**	**61**	**64**	**71**	

The rise in 2008, the first year of the virtual project scheme, seems significant. The 2009 data will be inserted at the conference.

OTHER ISSUES

This module is offered to students at two levels, second year undergraduate (Level 2) and Masters (Level M). For the vast majority of both sets of students the material is new, but it is necessary to differentiate between the outcomes expected at levels 2 and M. This is done in three ways:

1. The on-line test is 50% longer for the M level students, but worth the same number of marks;
2. The pass mark for the module is 50% at M level but 40% at Level 2;
3. M level students have a sixth task, which is more reflective in nature. This is an individual (not a team) task and is described as follows. "In the context of your virtual project, write:
   a) A substantial discussion of the lessons you learned from your team's SWOT analysis, followed by a set of recommendations.
   b) A requirements document, i.e. the document you would use to brief the project team about the purpose of the project.
   c) A critical analysis of the effectiveness of your project team in delivering the five tasks, followed by a de-briefing document which is intended to give advice to next year's teams."

These three differentiating elements require a significantly enhanced effort and depth of understanding from M level students.

CONCLUSIONS

The active module, with its virtual project, is popular with students. It succeeds in delivering its learning outcomes, including teamwork and delivery on time. The outcomes are much more completely met than under the previous "chalk and talk" delivery regime. It is a bit more expensive in terms of staff time, requiring team marking of the tasks but a computer-marked multiple choice examination. Using students to devise the virtual projects was a successful experiment.

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Biographical Information

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APPENDIX 1: LEARNING OUTCOMES FOR THE MODULE

On successful completion of this module, students should be able to demonstrate knowledge and understanding of:

- the meaning of a given set of common acronyms and terms
- the nature of a project, its planning and key elements of its management
- SWOT analysis and SMART objectives
- the breakdown of a project into tasks
- the management of risk
- the construction and interpretation of Gantt charts and critical path networks
- the nature of costs and how to apportion them
- the difference between direct and indirect costs, and fixed and variable costs
- the estimation of overheads and their absorption
- depreciation and several methods of costing
- break-even analysis
- DCF and NPV methods to appraise an investment.

Intellectual Abilities: On successful completion of the module, students should be able to demonstrate ability in applying knowledge of the above topics to:

- carrying out a SWOT analysis and developing SMART objectives
- constructing and interpreting Gantt charts and critical path networks (determining critical paths, slack and opportunities for crashing, etc)
- evaluating project risks
- estimating and analysing costs
- carrying out an appraisal of potential investments.

Practical Skills: After studying this module, students should be able to:

- use the basic functions of Microsoft Project
- manipulate straightforward cost procedures
- calculate net present value
- construct and use network diagrams
- construct a risk evaluation

General Transferable Skills: On successful completion of the module, students should be able to demonstrate the following aspects of key skills:

- manipulation of numerical (financial) data
- written presentation of management information
- ability to work in a team
- ability to deliver work to a deadline

APPENDIX 2: THE PROJECT TEAM TASKS

Task 1: Devise a SMART objective for your project and prepare a SWOT analysis (from a defined perspective)

Task 2: Devise a work breakdown structure for your project and present it in a Gantt chart using Microsoft Project. Identify the critical path

Task 3: A work change order has been issued: revise your WBS and Gantt chart; comment on changes to the critical path; identify the slack in your project plan.

Task 4: Identify the stakeholders in your project. Construct a risk register, calculate the severity of each risk and discuss how to mitigate the most serious risk.

Task 5: Calculate the depreciation of your equipment, the net present value of your predicted cash flows, and the overhead absorption rates applicable to your project.

Task 6 (Masters students only, as individuals, not as a team): With the benefit of hindsight and reflection: Devise a requirements document, a reflective discussion of the lessons you learned from your team's SWOT analysis and your analysis of the operation and effectiveness of your team.

THE ASSESSMENT OF ENGINEERING REASONING RECORDED IN STUDENT ENGINEERING DESIGN JOURNALS

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Ecole Polytechnique de Montreal

Robert Niewoehner

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ABSTRACT

An engineer's journal, also known as a *logbook,* is a key document where the individual contributions to a project and the evolving design rationale are made explicit. The development of project-based learning at Ecole Polytechnique Montreal is an ideal setting for students to use an individual or project journal. In the 1st year design project, a strong emphasis is put on the information elements and structure that must be present in the student's journal. In the 2nd and 3rd year projects the journal's content builds on this structure. This paper focuses on methods used to assess the contents of a 4th year student's journal. In this assessment model, the evaluator grades the journal content and provides feedback to the individual students according to three key parameters, namely: content diversity, critical thinking demonstration and project management information. The critical thinking abilities are assessed by reading through the journal content using a predefined analysis grid. This grid contains 11 "Critical Thinking intellectual standards" reformulated as questions so students and evaluators alike can get a better understanding of how the criteria applies specifically to journals. The paper discusses how the implementation and assessment of journals provides a formalized assessment structure to an empirical engineering practice. Moreover, a number of unexpected outcomes from the journal assessment process are also reported, such as: the increase of reusable information, the identification of an individual's contributions to a project, the sparse use of sketches to solve complex spatial problems, etc. Finally, the authors conclude on new perspectives to increase the efficiency of the journal assessments along with new opportunities for collaboration and exchange of information in a project context through the use of electronic journals.

KEYWORDS

Critical thinking, designer's journal, engineering reasoning, professional skills

CONTEXT OF JOURNAL USE

In January 2004, Ecole Polytechnique Montreal launched a major reform program for all its engineering curricula. The Mechanical Engineering department adopted the CDIO (Conceive-Design-Implement-Operate) approach to foster the changes needed to prepare its future engineers for the realities that the industry of the 21st century is facing [1]. One of the

important CDIO standards is to encourage project-based learning where students participate in active and experiential learning through real product development situations.

The Mechanical Engineering curriculum is articulated around four integrated learning projects, which constitute a cohesive chain of learning experiences [2]. A brief description of these four major design projects is provided in Table 1.

Table 1
The four integrated learning projects at Ecole Polytechnique Montreal

	Description
Year 1	▪ 1 semester cornerstone project: 3 case studies and design exercises ▪ Set in a controlled design solution space in time and scope
Year 2	▪ 1 semester cornerstone project, presented in the form of a design contest ▪ Work focussed on conceptual design and prototype building/testing
Year 3	▪ 1 semester cornerstone project ▪ Individual assignment submitted by local companies or research laboratories
Year 4	▪ Capstone project covering 2 semesters with industrial partners ▪ Teams of 20 students from Ecole Polytechnique, the School of Industrial Design, and the School of Business and Management. ▪ Work focuses on Integrated Product Team functions.

ENGINEERING JOURNAL TRAINING

In the first year engineering learning project, students are presented with an engineering journal writing guide. The guide presents different notebook contents from famous scientists but also from past students (Figure 1, Figure 2 and Figure 3).

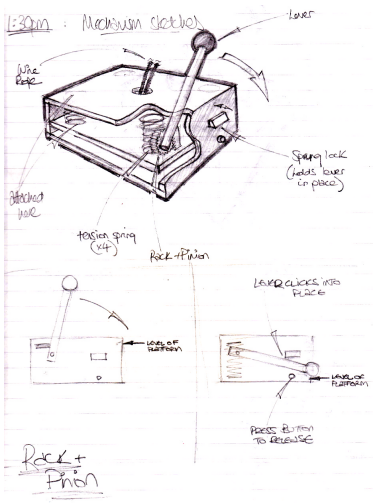

Figure 1 Journal sketches

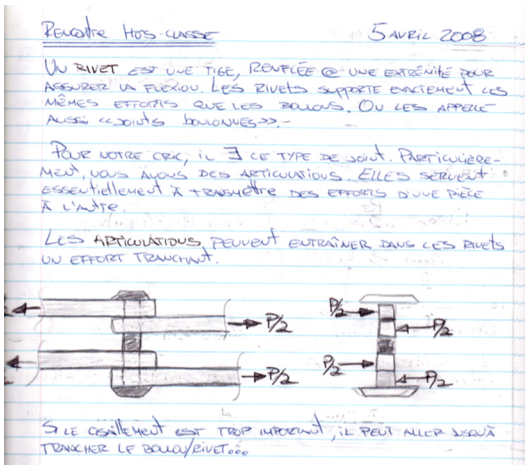

Figure 2 Journal calculations

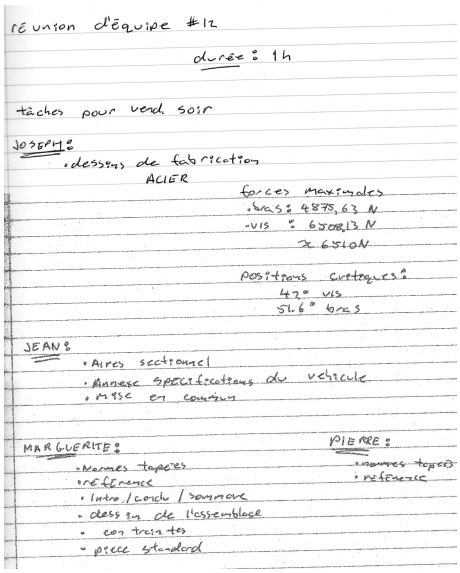

Figure 3 Journal meeting entry

The guide also defines the information expected to be found in an engineering journal detailing the structure and format it must adhere to as shown in Table 2. In this introduction to journals, the main goal is for students to become accustomed with the structure and the use of the journal more than to work on the actual journal technical content.

Table 2
Journal Tag types

Tag type	Why?	How?
Date and week number	Simplify navigation in the journal.	Clearly indicate the day's date and week number at the beginning of each entry in the journal.
Time spent	Conserve individual time sheet to be compiled by the team project management	Write down the time spent to complete each documented activity in the journal.
Page number	Ease information finding in the journal	Write down page numbers in each page corner in the journal (if not already printed).
External source reference	To conserve critical knowledge, identify where the information is with a brief summary for future project use.	Use standard reference formats as in scientific articles and books. File names, Internet hyperlink, consultation date, etc.
Meeting minutes	Conserve project team meeting conclusions, progress and justifications for decisions.	Note the location, date, time and complete with the meeting's subjects, decisions and actions.

This training is immediately followed by the active use by the students of journals in their integrated learning project. Students are closely followed by the teaching staff to assess if the journal structure respects the minimal information requirements defined in the journal writing guide.

ENGINEERING JOURNAL ASSESSMENT

Building on the first three years of journal writing and use, the 4th year project focuses more on the actual content of the journals than the information structure as illustrated in Figure 4.

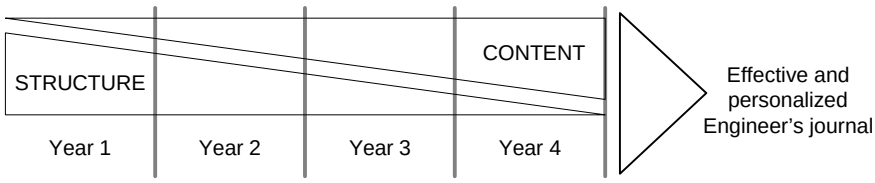

Figure 4 Focus of the journal assessment across the 4 year program [3]

In the 4th year project, the assessment of journals is part of the project grading system. During these capstone projects, students are asked for their journal on three occasions during the project. The teaching staff assesses the journal on the spot, grades and submits written comments. Only the final evaluation is kept on record for the grade awarded to the journal content. Students are hence given multiple opportunities to get feedback so they can correct their weaknesses in journal writing accordingly. The actual journal assessment process is in continuity with the previous training the students received.

Three main criteria are used to evaluate an engineering project journal:

- Variety of information types (*types of content*)
- Critical thinking demonstration (*critical thinking*)
- Project management information consignment (*project management information*)

Types of Content

The variety of information types in a journal is an indicator of the richness of approaches taken to solve problems. From an engineering journal content study [4, 5] the important information types were defined as shown in Table 3.

Table 3
Journal content types

Type	Class	Description
Textual	Hand written notes	Personal notes taken during individual or collaborative work.
	Meeting notes	Notes taken during a meeting.
	Contact details	Names, phone numbers, e-mail, addresses.
	Hand calculations	Simple or complex hand calculations used for evaluation of a situation.
	Tables and figures	Hand drawn or printed.
	Completed forms	Copy of official document.
Graphical	Sketch	Hand drawn, from pencil sketch to high quality rendering.
	Graphics and diagrams	Hand drawn
	CAD drawings	Printed and inserted in the journal.
Graphical and textual	External documents	Report sections, product information, pictures inserted in the journal.
	Annotated external documents	As above with manual notes added
	Annotated CAD drawings	Manual add-ons to existing drawings
	Memorandums	Post-it notes, highlighted notes, memory aids

The diversity of content is evaluated by paging through student journals and identifying occurrences for the different content families. More content types indicate that the student uses more ways to approach, document and solve difficult problems.

Critical thinking

The journal is also used as an open door to evaluate a student's problem solving processes. A properly used journal consigns in writing all problem solving steps, good or bad. This gives a unique insight to how students solve problems. To better use these observations the "Critical Thinking" approach to engineering reasoning was used to better structure the student problem resolution processes. In the Critical Thinking approach, 9 basic intellectual criteria are defined ([6] and Table 4). To be more specific to project work the questions were slightly reformulated and two other criteria were added, namely: Concision and Risk.

Table 4
Critical thinking in student Journals

Criteria	**Examples**
Clarity	Can you elaborate further? Can you give me an example? Can you illustrate what you mean?
Accuracy	How can we check this? How can we find if this is true? How can we verify or test this?
Precision	Can you be more specific? Can you give me more details? Can you be more exact?
Relevance	How is this linked to the problem? How does this weigh on the question? How does this help us to solve our problem?
Depth	What factors make this a difficult problem? What are the complexities of this question? What are the difficulties we must address?
Breadth	Do we need to look at this from another perspective? Must we consider another point of view? Should we look at this in other ways?
Logic	Does this make sense together? Is your first paragraph coherent with the last one? Do your conclusions come from the presented evidence?
Significance	Is this the most important problem to consider? Is this the central idea to focus on? Which of these facts is the most important?
Fairness	Do I have a personal interest in this problem? Do I support other's ideas too easily? Do I represent other's viewpoints sympathetically?
Concision	Is your message complete? What can you take out without losing the meaning?
Risk	What is the present risk level? Is this risk level acceptable? What could you do to reduce it?

The formulation of the criteria as questions in line with project work, gives students and the teaching staff a more pragmatic grasp of what the criteria mean in a project context. By reading through a student journal and using the intellectual criteria it becomes easier for the teacher and student to describe and discuss the strength and weaknesses of the contents of that specific journal.

Project management information

Journals must also document meeting tasks, responsibilities and decisions. Students from the previous 3 years of journal writing should have acquired these elements. The presence of the following critical items is evaluated without imposing on the students a journal template.

- Are there personal meeting minutes and notes present?
- Are individual tasks assigned to the student during meetings clearly identified in the journal?
- Are there written elements that show the student has worked on his assigned tasks?
- Is there a sufficient demonstration of progress over time towards completion of the tasks?
- Is there a compilation of all hours spent on the project?
- Are all entries to the journal dated?
- Are empty pages identified as intentionally left blank?
- Are there ripped out pages?

OUTCOMES

It is difficult to convince students that the use of journals in project work is essential. The starting point is to make journal writing a key component in a student's evaluation. Giving frequent feedback on the logbook content helps ligitimize the journal as a key engineering ool for students. But ultimately, it is while doing project work students truly understand the value of maintaining a journal.

Indeed, in a project-based learning context, students frequently retrieve older information that supported a decision that was not completely documented in reports but is needed later in the design process. They reuse other student's notes to continue their work when the project staffing is reorganized due to time constraints. They collaboratively sketch in each others journals during ideation and brainstorming. Reading the completed student journals at the end of the project by the teaching staff is a complete rerun of the project process flow; all decisions are in writing, good and bad. It is a great opportunity to better prepare the mentoring support provided by the teaching staff for the following projects.

Students appreciate feedback given through the journal. The written comments by the teaching staff become a starting point for constructive discussions about individual contributions to project work (ethics, responsibility, accountability, knowledge management, etc.).

FUTURE DEVELOPMENTS

In collaboration with the University of Bath (UK), where engineering logbooks have been the topic of extensive research over the past few years ([4], [5], [7]), a reflexive process will be proposed to the students next year. After they submit a report, they will be asked to go through their journal and tag the critical elements (Table 5) in their journal that were used to build the report. This exercise, illustrated in the example provided in Figure 5, highlights the link that exists between the ideas expressed in a journal and the final conclusions presented

in a report. With this new approach, the journal will propose a richer context to evaluate the detailed process used to come to the conclusions that are published in the project reports.

Table 5
Journal content type proposed tags

Tag type (tag)	Description	Associated documents	Tag examples
Actions (A)	Tasks to be completed by a team member	Meeting notes	A, [E1_CR_21.doc]
Calculations (C)	Hand calculations	Report, Matlab, Excel	C, §(section), p(page) C, §A6, p73
Diagrams (D)	Hand drawn diagrams, org and flow charts, graphics, etc.	Report, Visio, Excel	D, §4.5, p18
Notes (N)	Personal notes	Report or meeting notes	N, §4.5, p18 N, [E1_CR_21.doc]
Sketches (S)	Sketch	Report	S, §2, p7 S, [part_name.prt]

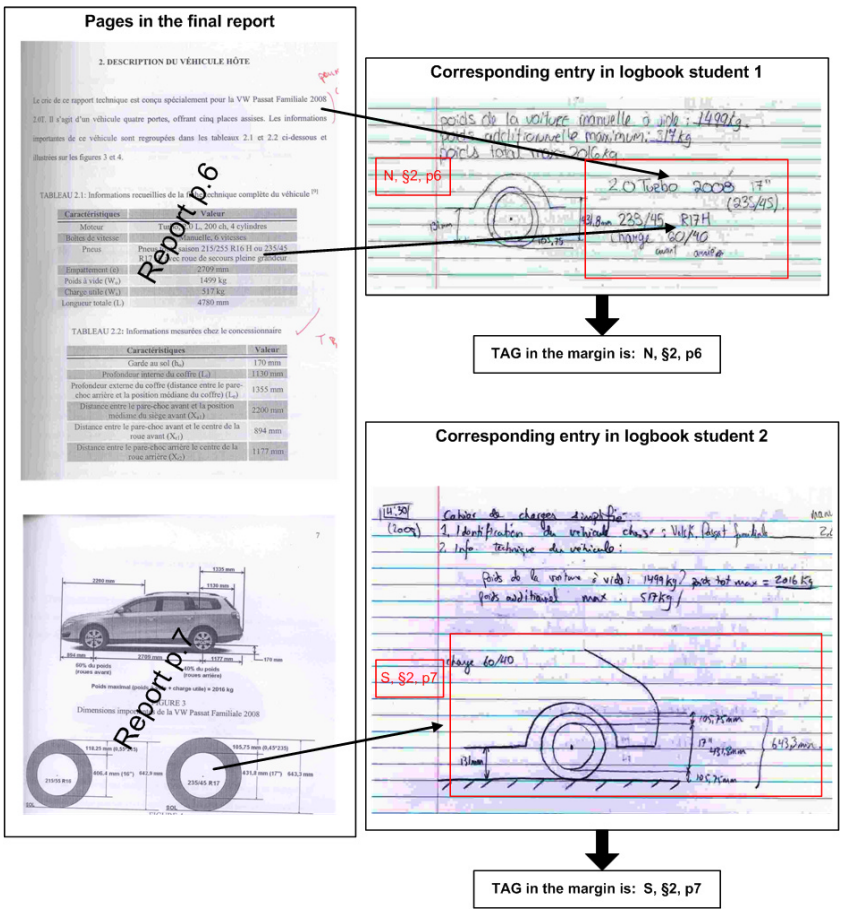

Figure 5 Journal tagging example

The paper based journal remains the most flexible support for project information [7]. Archiving journal information for rapid information retrieval remains a difficult mostly unsolved issue. Presently, no previous journal based team knowledge is passed on to future teams. This proposed tagging method is a first step in making paper based journals a searchable tool.

New tools (database, wikis, tablet PC's and Product Data Management) can enhance or even maybe replace paper based journals. A research project at École Polytechnique Montreal is currently underway to test the transition of information between three successive student teams working on a single project over three years without an actual face to face meeting between teams [8]. The present team is actively preparing the legacy information for the first transition in September 2009.

CONCLUSION

The proposed method to evaluate student engineering journals has helped the teaching staff to give structured feedback to students. High quality feedback promotes the use of journals and increases the amount of documented work done by students in project-based learning situations. Evaluating a properly written journal gives a unique view of the problem solving skills and difficulties students experience; this in turn helps the teaching staff to provide focused support to individuals or teams in need.

The theoretical teaching framework provided by the CDIO reform, the incubator environment for technology and teaching methodology integration at MATI Montreal, the close involvement of industry, and the multidisciplinary context in which the initiative has grown help support project-based learning. To further enhance the students' experience, the capstone projects now take place in a new state of the art 1000 m^2 Multimodal Learning Environment (MLE) [9].

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Biographical Information

Daniel Spooner is an engineer-in-residence at Ecole Polytechnique de Montreal (Canada). He also teaches at the University of Montreal's School of Industrial Design. In the last 15 years, he has lead development teams for more than 60 products in the transport, consumer, medical, and telecommunication industries. He also operates his own product design and engineering consulting firm involved in complex system design. He contributes actively to structure the CDIO capstone project initiative at Ecole Polytechnique.

Greg Huet is a research associate at Ecole Polytechnique de Montréal (Canada). He completed his PhD thesis in 2006 in the field of "design information and knowledge management". Greg is currently working on a number of research projects involving the use of new PLM tools to support collaborative engineering design activities. He is also one of the teachers/supervisors for the first year design project.

Clément Fortin is Professor at Ecole Polytechnique de Montréal (Canada) and the current Director of the Mechanical Engineering department. He was the Mechanical engineering program chair from 2004 until 2005 and has been involved in the CDIO initiative since 2004. His research interests include product and manufacturing process development, engineering change management, virtual environments for product development, and computer aided tolerancing.

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Rob Niewoehner is Director of Aeronautics at the US Naval Academy. Prior to joining the Naval Academy faculty, he served as a fleet F-14 pilot, and then as an experimental test pilot, including Chief Test Pilot for the F/A-18 E/F Super Hornet, throughout its development. His particular pedagogical interests include the promotion of Critical Thinking skills in engineering students.

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THE CREATION OF CDIO WORKSPACE FOR ENVIRONMENTAL MANAGEMENT AND WATER TECHNOLOGY

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ABSTRACT

Fostering active learning and creation of workspaces are central to pedagogic principles in the CDIO initiative. Workspaces are seen as vehicles to create conducive learning environments, which enable a wide range of active and social learning. By creating a common workspace, active learning elements can be effectively infused into modules of the course program.

This paper presents the creation of a CDIO workspace at Hydraulic and Environmental Engineering Laboratory for students from the diploma course of Civil Engineering & Management as well as Diploma in Environmental Management and Water Technology at the School of The Architecture and the Built Environment, Singapore Polytechnic. It outlines the present utilization of the workspace, which includes time-tabled teaching and learning, preparation work for projects such as group brainstorming and model building, organization of activities like competition, as well as self learning.

Positive acceptance was concluded according to the feedback from both staff and students concerning perceived usefulness and effectiveness in enhancing teaching and learning. Some issues for further development and improvement are also discussed in the conclusions.

KEY WORDS :

Learning Space, Hydraulic, Environmental, Engineering Education, CDIO

INTRODUCTION

Fostering active learning by creation of workspaces is central to pedagogic principles in the CDIO initiative[1]. Work spaces are conducive learning environments, which enable a wide range of active social learning. By creating a common learning space, active learning elements can be effectively infused into relevant subjects of the course program. CDIO Workspaces, as rationalized in Standard 6 [2], are believed to be the most conducive learning environment as they are student-centered, user-friendly, accessible and interactive [3,4].

Driven by the concerted efforts in a constant search for a more effective education model in an ever changing world, the School of Architecture and the Built Environment (ABE) at Singapore Polytechnic has taken concrete steps to adapt and implement CDIO initiative for the Diploma for Civil Engineering & Management (DCEM) and Diploma in Environmental Management & Water Technology (DEWT) courses. In the coursework for students from the DCEM and DEWT courses, there are capstone projects for year 1, year 2 and the final year. Workspaces are needed for students to conceive, design, implement and operate the product. As a result, an integrated CDIO Workspace for teaching and learning of subjects such as Hydraulics and Hydrology, Environmental Engineering, Water and Waste Water Technology was created within Hydraulic/Environmental Engineering Laboratory.

This paper presents the creation of a learning space within Hydraulic/Environmental Engineering Laboratory at the School of Architecture and the Built Environment, Singapore Polytechnic.

The observed usage patterns of the learning space are identified and evaluation of effectiveness on students learning as well as the impact on the delivery of the subject content are made in comparison to the teaching and learning approaches before the creation of the workspace. Positive feedback was received from both staff and students concerning perceived usefulness and effectiveness in enhancing teaching and learning. Some issues for further development and improvement are also discussed in the conclusions.

PARADIGM SHIFT FROM CONTENT TO CONTEXT OF ENGINEERING EDUCATION

As in any engineering education, new technology and learning styles of students change. At the School of Architecture and the Built Environment, Singapore Polytechnic, the teaching of Hydraulics and Hydrology, Environmental Engineering, Water and Waste Water Technology can be supplemented by internet technology and resources available in the library and many other resources. Classroom teaching in a didactic form as a means for acquiring new knowledge is becoming less critical to students. Therefore, in the modern day education, it is paramount to engage students in their learning or they will be engaged by something else.

Traditional approaches in the teaching of engineering subjects are typically built around lectures, tutorials and laboratory experiments. The fundamental concepts and basic theories are normally taught in a classroom or lecture theater setting. The tutorial classes are normally conducted as problem solving sessions for dedicatedly crafted questions within the topics taught. Practical experiments in laboratory, which are normally not within close proximity of classrooms and lecture theaters, only play a limited role in supplementing the teaching and students' understanding of core concepts. Overall the focus is on the transmission of content of engineering knowledge. Whereas this type of approach is well structured, it inherits many drawbacks such as lacking active and student-centered learning. It tends to inculcate passive learning and is dominated by the imparting of technical knowledge rather than an active discovery of knowledge. The change in the patterns of students learning requires the emphasis in engineering education to be shifted from content to context, from traditional teacher-centered to student-centered learning. The CDIO initiative provides a convenient framework to meet the challenges of engineering education.

Creation of learning space by integrating different teaching and learning resources into a conducive environment was identified as one of the key infrastructures for answering the call for paradigm shift in engineering education. Within ABE, the earlier experiences of creating engineering workspaces and learning spaces[5,6] have build up the case to create additional learning space for hydraulic and environmental engineering education.

THE CREATION OF LEARNING SPACE IN HYDRAULIC /ENVIRONMENTAL ENGINEERING LABORATORY

According to CDIO Standard 5 – Design-Implement Experience [2], the curriculum has to include two or more design-implement experiences, including one at a basic level and one at an advanced level [2]. For DEWT course, in year 1 the students have to design and re-assemble a mobile water treatment working model for their capstone project. Students will have to propose water treatment processes, prepare 2D and 3D drawings, and build the physical model.

CDIO Standard 6 requires engineering workspaces and laboratories to support and encourage hands-on learning of product, process, and system building, disciplinary knowledge and social learning. There are different criteria for learning spaces for conceiving, for designing, for implementing and for operating [3].

There have been earlier successes in creating learning spaces in Singapore Polytechnic [5,6]. Since the implementation of CDIO framework for DCEM and DEWT courses, new learning paces have been created at T3A03 and W515 for CDIO activities. Table 1 shows engineering workspaces for CDIO activities adjacent to existing laboratories.

Table 1
Engineering Workspaces in the Existing Laboratories

	Stages	Location	Adjacent laboratories	Engineering workspaces for CDIO activities
1	Conceive	W515/T3A03	Material Testing/ Geomatics	Design and other general discussions
2	Design	W417/T304/T305	Structural Mechanics Lab/ e-studios with application software	Design, testing of structural models, virtual design and computer simulation of civil engineering models
3	Implement	W515/W514	Project lab	Blueprint reading/Trellis construction, concrete beam casting
4	Operate	W511 (Hydraulic/Env. Engg Lab)	Environmental engineering and geotechnical laboratories	Hydraulic equipment & channels, Soil testing, design of water treatment model/operation of Desalination Working Plant and MBR model

The learning space referred to in this paper was created within the Hydraulic/Environmental Engineering Laboratory as shown in Table 1 as item 4. The plan view for the layout is shown in Figure 1. A total of S$195,000.00 was invested into the creation of the infrastructure for the learning space excluding costs for tools, equipments and facilities. It was hoped that the creation of new learning spaces in the hydraulics/Environmental Engineering Laboratory will help supplement more engineering workspaces for CDIO activities.

A typical interior view of learning space is shown in Figure 2. Besides the conventional laboratory tools and facilities around, major equipments such as desalination plant and membrane bio-reactor (MBR) for capstone projects are also at the close proximity of the learning space.

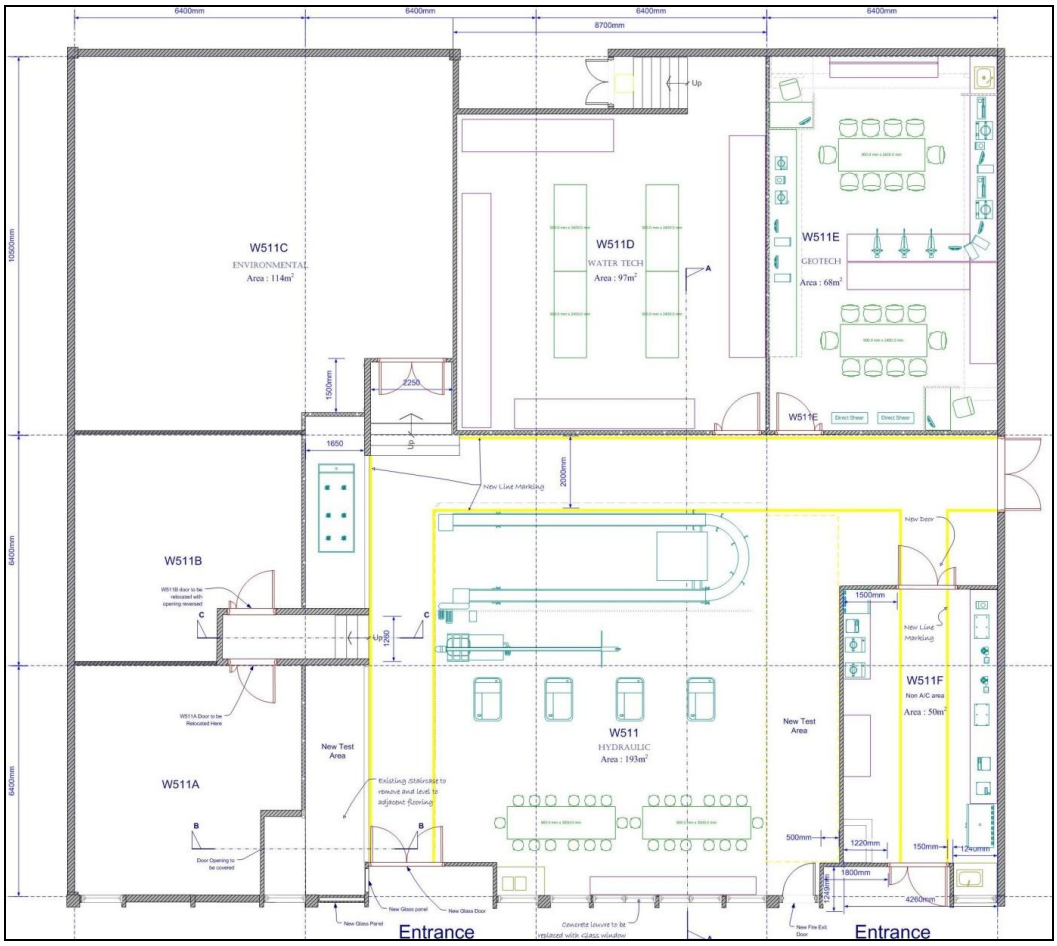


Figure 1. Layout of Work spaces in Hydraulic / Environmental Engineering laboratory

Figure 2. The learning space showing discussion tables in Hydraulic /Environment Engineering Laboratory

Figure 3. DEWT students are working on the year 1 project of mobile water treatment model in the learning space

Figure 3 shows a group of year 1 students working on their capstone project in another part of W511. This is a capstone project for DEWT year 1 students. It requires them to design and assemble a simple working model of water treatment kit for treating storm water to drinking water standard. Figure 4 shows the picture of Desalination plant which is the major equipment for year 2 capstone project. Students are required to understand the desalination processes based on reverse osmosis and to operate the working desalination plant in the laboratory. The MBR, as shown in Figure 5, has been designed, implemented and operated by final year students for one of the final year projects. It will be used as for teaching waste water treatment. As test kits and other equipment are at the close proximity to these working models, students can also learn in context when they collect water or waste water samples for analysis.

Figure 4. Desalination plant in the laboratory

Figure 5. The Membrane Bio-reactor

THE OBSERVED USAGE OF THE LEARNING SPACE

Teaching and learning in the learning space as compared to the traditional ways

Engineering concept is traditionally taught through lectures in classrooms. Theoretical concepts and calculations may be illustrated on white boards. With the creation of learning space at the Hydraulic/Environmental Engineering Laboratory, students have more hands-on learning experience in designing and operating the engineering systems to assimilate, digest and utilize the contents covered in class room setting at the context level. This is evident when the reverse osmosis desalination process is taught by using a mini desalination plant installed in the laboratory. Not only do the students see a real-world reverse osmosis desalination plant, they can identify the physical components in the plant and relate the symbols indicated in the process flow chart. They are also are also given the opportunity to operate the desalination plant under different operating scenarios. When fundamental theories and engineering concepts are illustrated with real-world equipment or machines, context learning is playing a more important role than content learning. When a real-world working plant is there for students to operate, the learning is no longer passive.

In addition, the air-conditioned laboratory is accessible to students when there is no ongoing scheduled class. Students are encouraged to do their projects, tutorials and discussions at the laboratory. They are also free to read various environmental and water engineering

journals and magazines which are readily available at the laboratory. Such facilities have provided students with great opportunities for social learning.

The increase of the utilization rate, as shown in Table 2, reflects the actual utilization of the learning spaces by the scheduled classes taking advantage of the enhanced hand-on facilities with the implementation of CDIO framework.

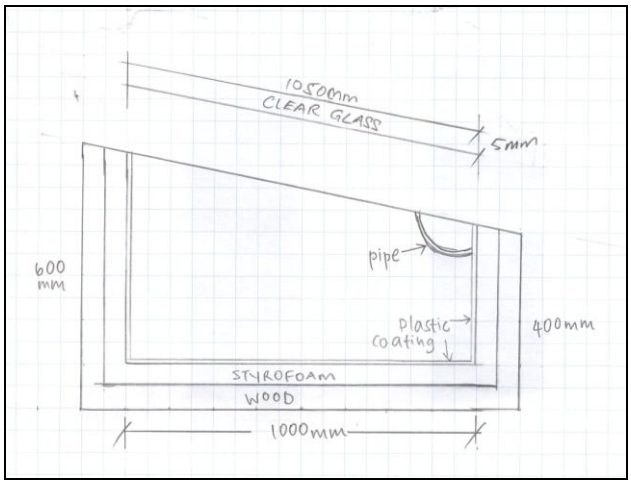
Table 2
Utilization rate before and after implementation of CDIO framework

		Existing Learning Spaces	Before Implementation of CDIO	After Implementation of CDIO	% increase
1	Conceive	W515/T3A03	45.20 %	80.95 %	35.75 %
2	Design	W417/T304/T305	4.80 %	80.24 %	75.44 %
3	Implement	W515/W514	45.20 %	80.95 %	35.75 %
4	Operate	W511	57.10 %	65.40 %	8.3 %

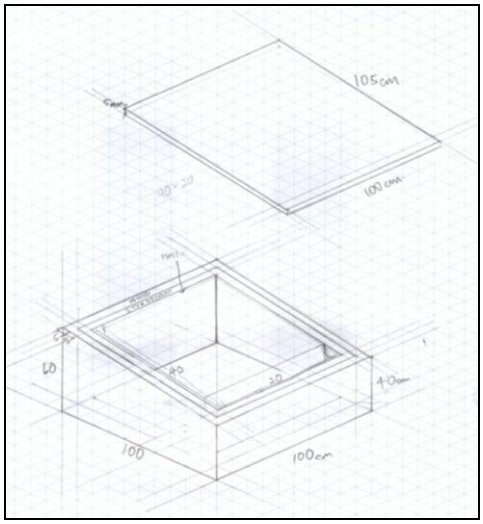
Final year project in CDIO approach

Many projects have been completed in the learning space. As a typical example, a final year project was taken to highlight the functional usage of the learning space in a CDIO framework. The objective of the project was to develop working models for seawater desalination using solar energy.

The brain storming session during the first meeting of the group held at the learning space can be registered as conceiving stage of the project. Preliminary thoughts and ideas were collated and recorded as draft sketches as shown in Figure 6.



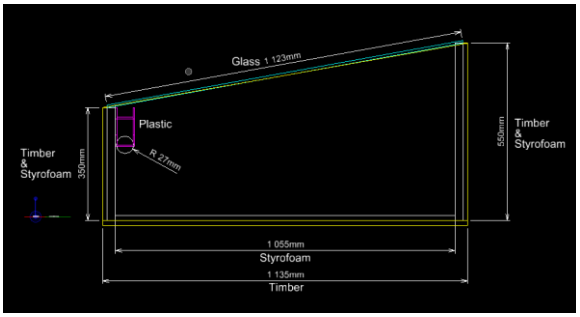
(a) Side view



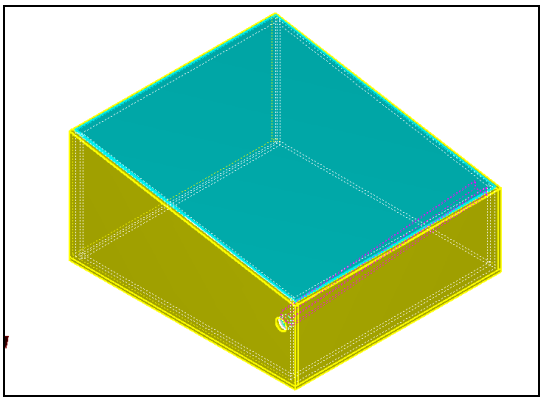
(b) 3D isometric view

Figure 6. Concept stage : Preliminary sketches of the project

During the design stage, the group used another learning space with dedicated software tools, T304/T305 (refer to Table 1) for computer aided design and drafting as well as design for materials and cost estimation. Sample computer drawings are as shown in Figure 7. The estimated material quantities are tabulated in Table 3.



(a) Side view of the proposed model



(b) 3D view of the proposed model

Figure 7. Design stage : Design output from CADD

Table 3
Design/Implementation stage: Materials list and quantities for model building

Materials	Dimensions	Quantities
Aluminum foil	-	1 roll
Glass	L 110cm x B 100cm x Thk 0.8cm	3 pieces
Glass delivery	-	1 time charge
PVC roll	137cm x 68cm	1 roll
PVC roll	137cm x 600cm	1 roll
PVC roll	137cm x 200cm	1 roll
PVC casing	2.5cm x 1cm x 235cm	2 unit
Silicone	-	1 tube
Styrofoam board	L 91cm x B 68cm x Thk 2.5cm	6 pieces
Styrofoam board	L 91cm x B 68cm x Thk 2.5cm	9 pieces
Styrofoam board	L 68cm x B 32cm x Thk 2.5cm	1 piece
Wood	L 240cm x B120cm x Thk 1.5cm	6 pieces

The implementation stage of the project is reflected as model building phase which took place within the learning space in Hydraulic/Environmental Engineering Laboratory. Photos in Figure 8 were taken during this stage of the project.

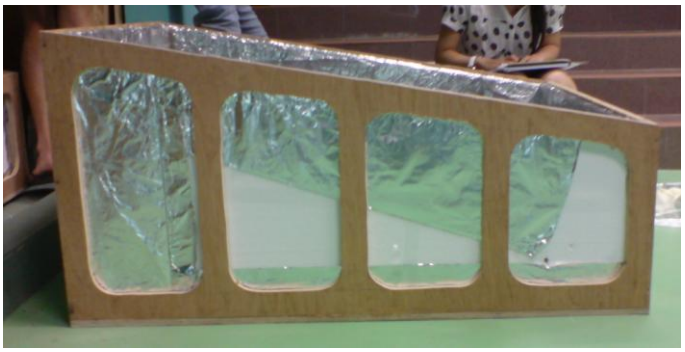


Figure 8. Implementation stage: Product building in progress

The testing on the performance of the finished model can be classified as Operation stage. Though the testing was conducted outside of learning space as it has requires the sunlight. However the proximity of the measurement tools facilitated the testing of the prototype. Figure 9 shows some photos during the Operation stage of the project.

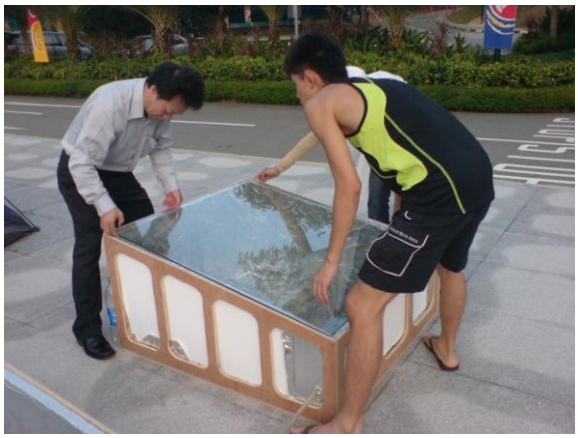
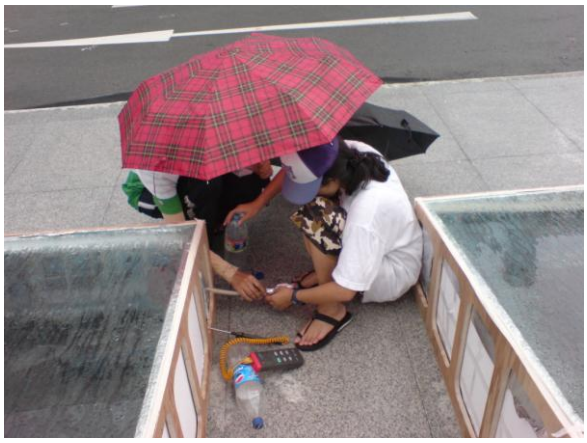



Figure 9. Operation stage : Testing of the product

Learning journey for Schools

CDIO activities have given relevance and meaning to polytechnic students. They can also benefit the students from secondary schools. The School of Electrical & Electronic Engineering (EEE) and School of Architecture and the Built Environment jointly organized a "Clean Energy and Water Challenge" for 180 Raffles Girls' School (RGS) students on 11 Mar 2009. For the RGS girls it was a part of their "Learning Journey." For the clean energy of the challenge, EEE, which has also embarked on CDIO initiatives, organized with a solar boat race competition. Students design, fabricate and race their boats in a water channel.

Figure 10. Students are discussing about the filtration system

Figure 11. Students are building the filtration system

Figure 12. Students are testing the filtration system

For the clean water challenge, ABE organized the CDIO activity at the Hydraulic/Environmental Engineering Laboratory. The clean water challenge involves the design, building up of a simple filtration system to remove fine particles and colour from given "wastewater" samples. The hands-on session had proven to be effective in arousing the interest to water technology and increasing the awareness of water resource management. Figures 10-12 show some photos taken during the event.

PEDAGOGICAL PRINCIPLES AND DESIGN-IMPLEMENT EXPERIENCES

It is well known that lecturing alone is a relatively ineffective pedagogical tool for promoting conceptual understanding. Real learning takes place when there is creation of new knowledge by applying basic fundamental knowledge [4]. There are two distinct ways to transform experience, by reflection or action. When the students work in teams in the engineering work space they take charge of their own learning as compared to working on standardized laboratory experiments. Since learning is both cognitive and motivational, capstone projects in the learning spaces created in the laboratory will cause students to refer to the cognitive processes that have taken place in the classrooms. Moreover they will be more motivated to read ahead and beyond their lessons to be ahead in their projects. There are limited opportunities for students to have "experiential learning" and hands-on from computer-simulation, field trips, community service, and work experience [5][6]. CDIO activities in engineering work spaces will bridge the gap between real-world and classroom teaching.

Unlike consumer gadgets, architecture models, aesthetic design products, environmental and water technology projects require the support of chemicals, test kits, equipment, materials for fabrication and at least a table size space for the realization of product. System testing and improvements require ready access to tools, chemicals and equipment that are available in the newly created engineering workspaces. CDIO workspace is also playing an indispensable role in facilitating students learning as infrastructure for engineering education.

CONCLUSIONS

The learning space in Hydraulic / Environmental Engineering Laboratory was created with the consideration of CDIO model for Engineering education. The creation of engineering workspaces allows students to carry out the engineering processes with the immediate support of testing equipment and facilitation as well as laboratory personnel. There is immediate transfer of laboratory skills that they learn in other modules. Learning within the engineering workspaces is more intensive in the simulated working environments. Tools, equipment, materials and parts of the products can be shared, recycled for the next round of use. It is evident that multiple modes of learning such as active learning and social learning are nurtured, facilitated in the learning space. The creation of such learning spaces within the existing laboratory increases the utilization rate of the laboratory as well.

Feedback from staff and students using the workspaces has been generally positive. Most of the facilities are well used. Industry and public awareness of engineering has been improved through laboratory tours during SP's Open House and by holding of competitions for secondary school students during the annual Engineering Week. The effectiveness of the learning space in enhancing students learning was observed comparing to the traditional approaches as it fosters social learning, active learning and can be easily integrated into project based learning and problem based learning. There are plans to further improve the integration of learning space with lecturing and tutorials so as to create a balanced learning environment that is able to suit the different learning activities and diverse modes of learning.

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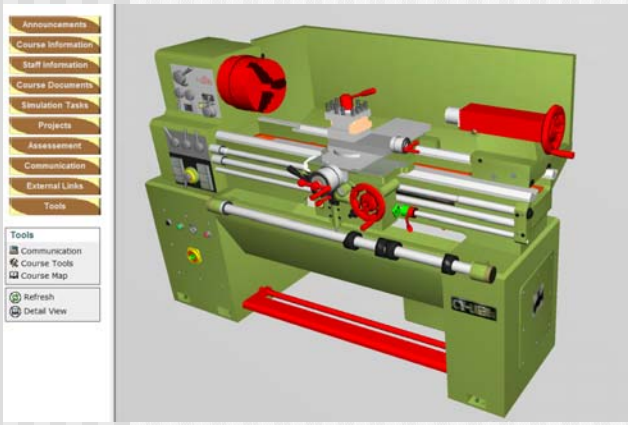

The Effectiveness of Simulation-based Learning for Polytechnic Level Engineering Students

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June 8-10, 2009

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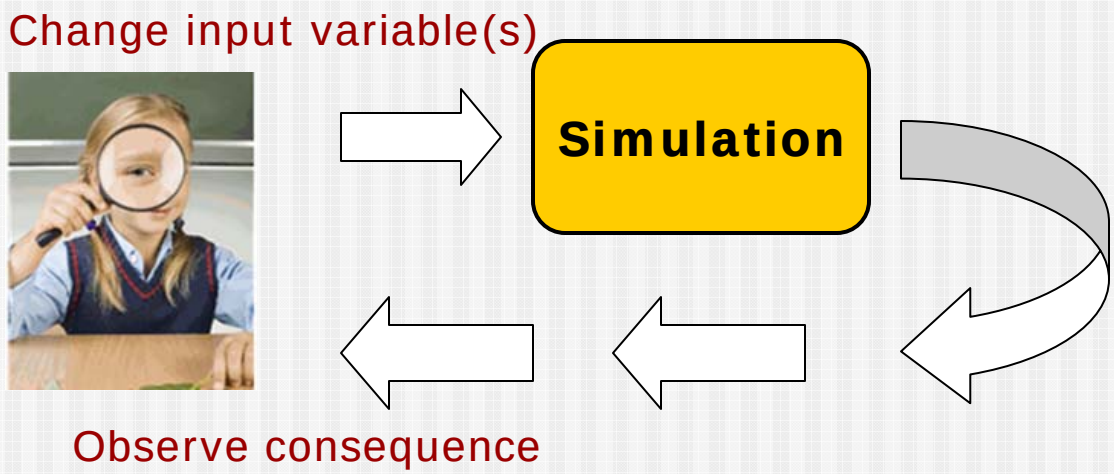
Outline

- Background
- Aim of Study
- Demonstration
- Methodology
- Findings
- Concluding Discussion

Background:
What is SBL anyway?

- Simulation: Closely resembles the physical system while allowing learners to explore, rehearse and to assess themselves.



- Learning by Doing

Background:
What is SBL anyway?

- Academic Settings:
  - Enhance lectures, laboratories
  - Engage students
- Workplace:
  - Cost-effective training
- Could it be used for post secondary engineering education at the Poly level - how effective is it?
- Machining Technology, a year 2 subject was chosen as the study subject as it satisfies most criteria for implementation

Aim of Study

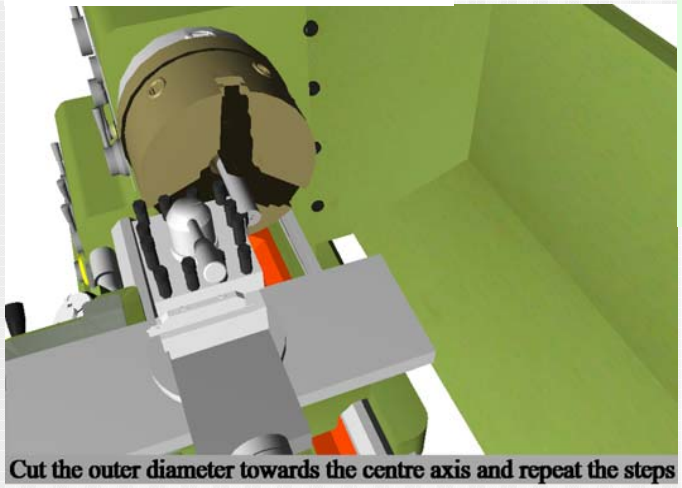
Research Questions

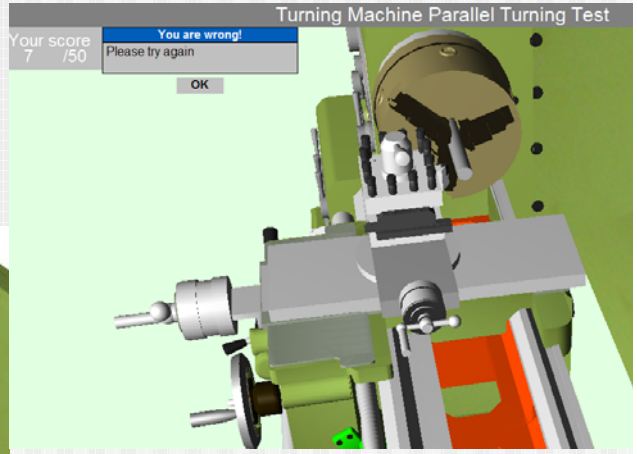
- Could SBL help improve students' learning processes when compared to traditional classroom methods?
- By accessing information in a variety of media formats/interactive fashion, could students make useful associations?
- Were students motivated by the experience?
- Which aspect of SBL assisted student learning?

Technical Devpt & Demo

Explore Machine

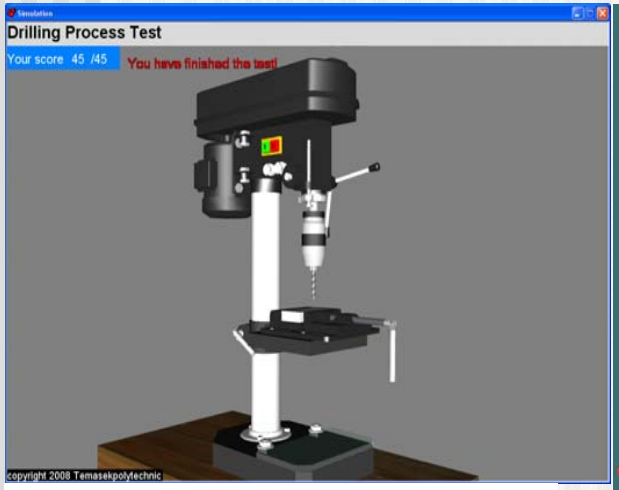
Work on the Machine
Parting Off, Facing, Centre Drilling, Parallel Turning, Deep Drilling



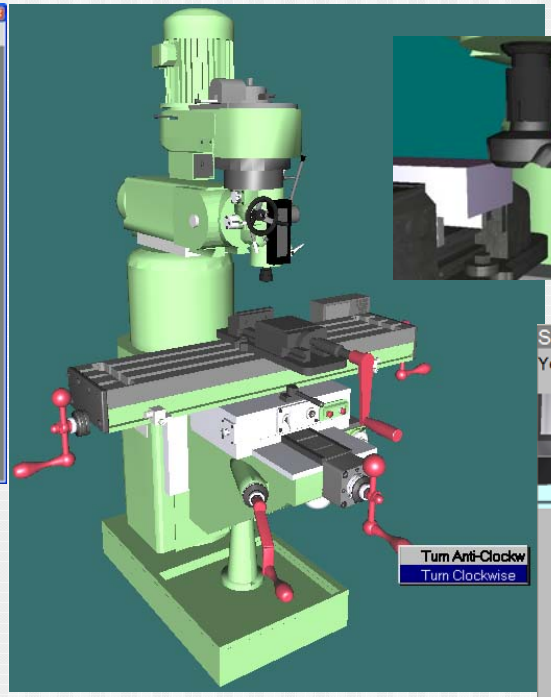


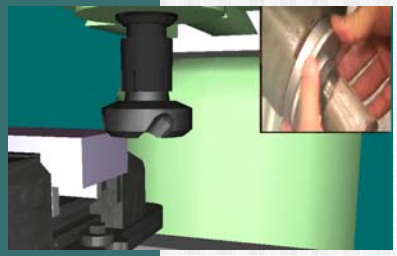
Assessment (Test)

Technical Devpt & Demo

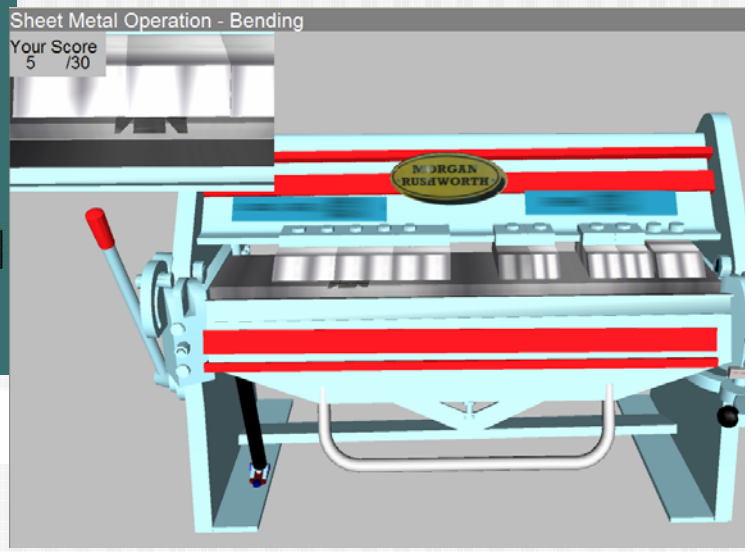


Drilling

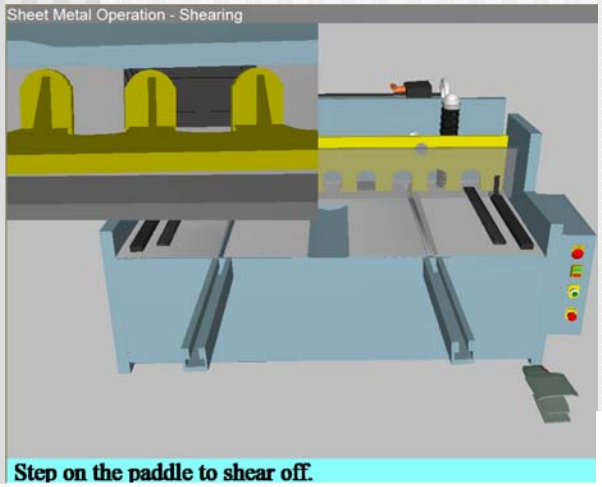




Vertical Milling



Bending Machine



Shearing Machine

Methodology

Subject matter in the study

- Machining Technology
- Complex, common subject
- Students learn fundamentals of machining, including features, functionality, operations & process
- Course instructors observe students have difficulties using machines, students may be intimidated by the complexity, size and complex procedures
- Needs visualisation, manipulation of objects, system variables, planning, understanding of machine system

Methodology

Participants

- 2nd year mechatronics students (age between 17-37, mean age = 21.12)
- 121 students took part (49 in control, 72 in expt)
- Equal variances t test for means of two groups
- No statistically reliable difference in 1st year examination results between the mean CGPA of the E and C group
- Suggests similar initial course knowledge level before they embark on the study

Methodology

Instruments

- Post Intervention Test (Performance)
  - Synthesizing Knowledge on machining operations
  - Produce a part requiring machining operations from different machines
- Survey Questionnaire (Learning/Motivation)
  - Framework based on Self-Determination Theory (SDT)
  - Scoring based on 47 Likert based items
  - 5 point scale ranging from 5 (SA) to 1 (SD)

Methodology

Instruments

Subscales	Items	Adapted from:
Self efficacy	6	Learning
Perceived autonomy	5	Psychological Needs
Perceived competence	5	Psychological Needs
Relatedness	3	Psychological Needs
Intrinsic motivation	5	Motivation
Self regulation	4	Learning
Cognitive strategy use	8	Learning
Extrinsic motivation :		Motivation
- External Regulation	2	
- Introjected Regulation	2	
- Identified Regulation	4	
- Amotivation	3	

Methodology

Intervention Procedure

- Both groups have same number of hours (4 hrs per week)
- C Group (2 hr lecture, 2 hr workshop)
- E Group (1.5 hr lecture, .5 hr lab, 2 hr workshop)

Methodology

Intervention Procedure

Teaching Schedule of Machining Technology (EME2007_ Oct0809) at MCAD Lab EN20-2-93 Rev 1.0

Week Mon - Fri	Session (4 hrs) 1st & 2nd hrs / 3rd & 4th hrs	Assessment
1 20 Oct – 24 Oct 08	**Week 1** Brief Students Workshop Visit TSO: Prepare Demo	
2 27 Oct – 31 Oct *Deepavali (Mon)*		
3 3 Nov – 7 Nov		
4 10 Nov – 14 Nov		
5 17 Nov – 21 Nov		
6 24 Nov – 28 Nov	**Week 7** Survey & Post Intervention Test	
7 1 Dec – 5 Dec		
8 8 Dec – 12 Dec		
9 15 Dec – 19 Dec	(Makeup for Project 1 workshop sessions: 15 Dec 2008 starting at 9.00 am.)** Term Break	
10 22 Dec – 26 Dec	Term Break	

Week 0
- Groupings
- Preparation
- Compare participants CGPA
- Load Models

- Both groups have 4 hrs/week
- C Group (2 hr lecture, 2 hr workshop)
- E Group (1.5 hr lecture, .5 hr lab, 2 hr workshop)

Interviews

Research Findings

Post Intervention Test

- 121 students took part in the Test (91 M, 30 F)
  - 49 Control:36 M, 13 F
  - 72 Expt: 55M, 17F
- Equal variances t-test
- Statistically reliable difference between the mean score of the E Grp and mean score of the C Grp
- Effect Size d = 0.46
- Intervention has a medium effect

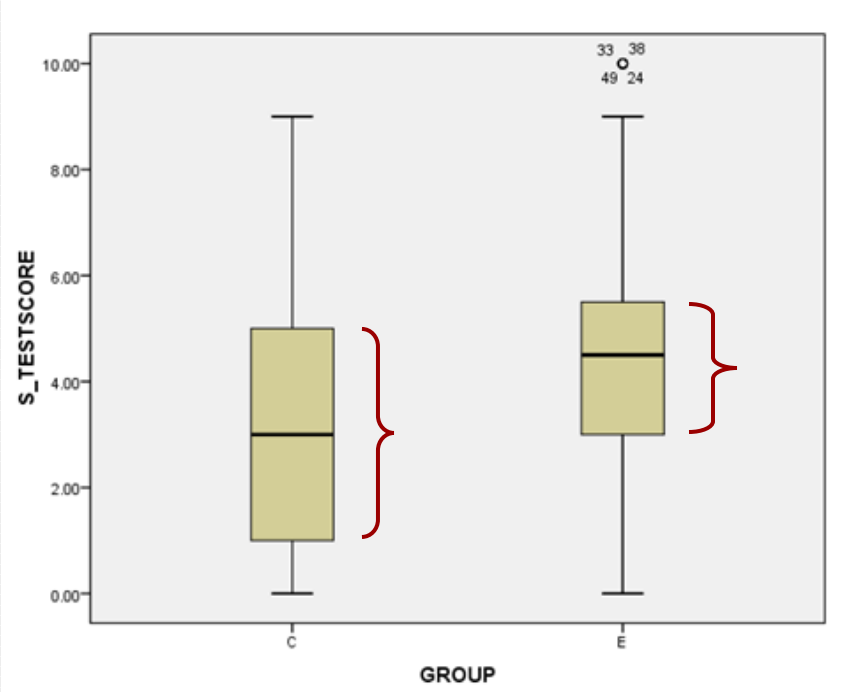
	M ($\bar{x}$)	SD (σ)	t-test * (df = 119, p < 0.05)
Group C (n=49)	3.42	2.51	*t = 2.48* *p= .015* *d=.46* Significant
Group E (n=72)	4.60	2.60	
*assumption on equal variances tested			

E: Experimental Group, C: Control Group
M: mean, s = standard deviation

Research Findings

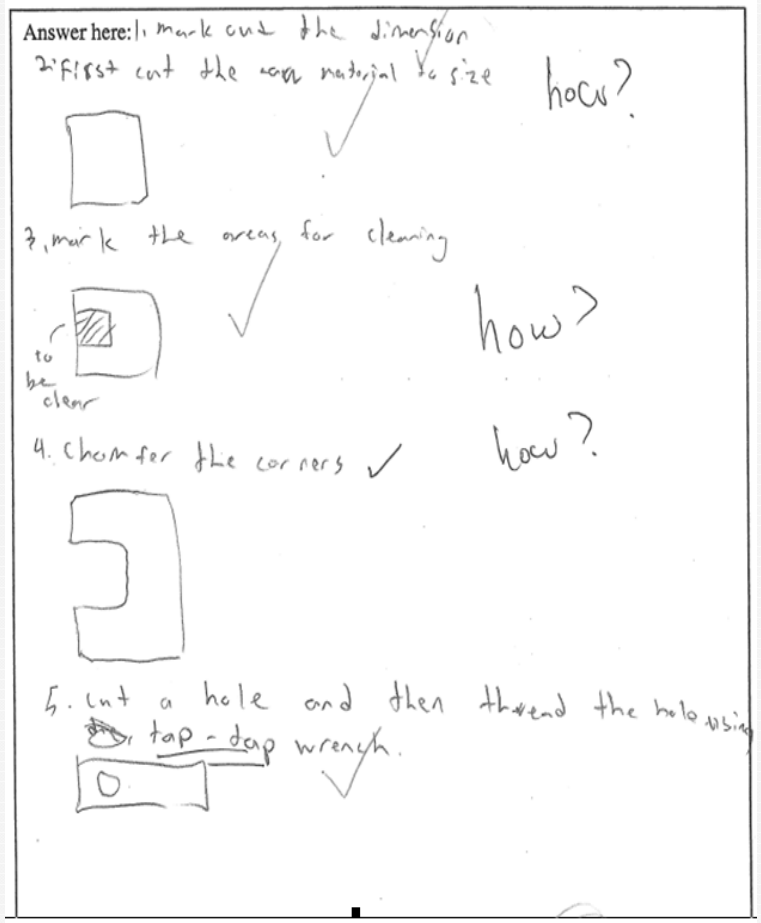
Post Intervention Test

- Box-Plot
  - Inter-quartile range (middle 50% of scores) is narrower for E Group
  - 4.00 vs 2.75
  - Less variation in understanding of subject

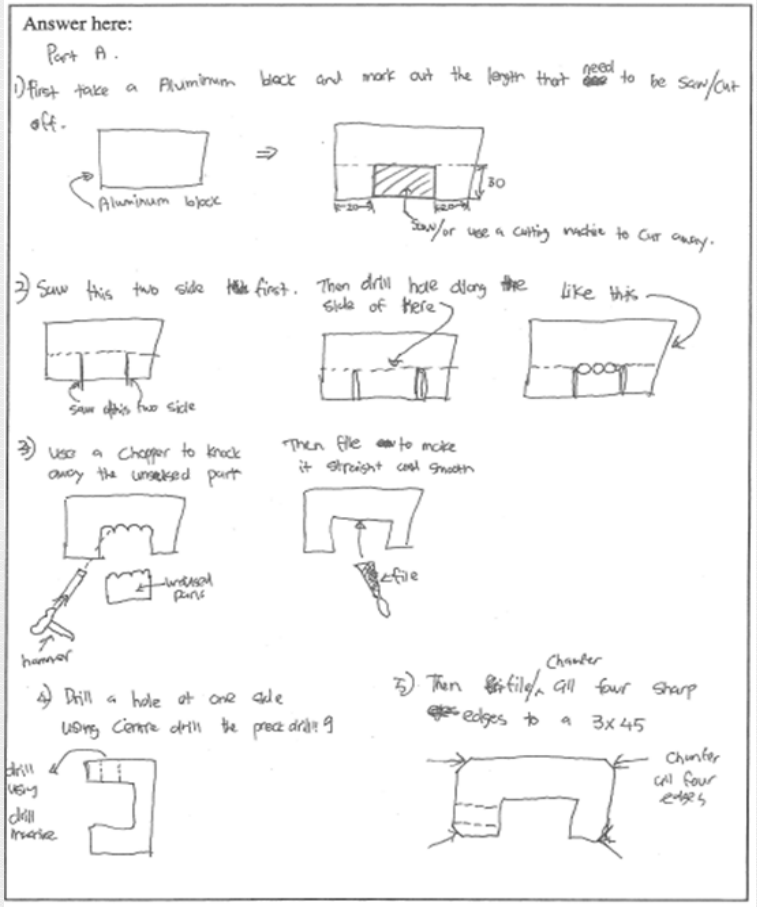


Research Findings

Post Intervention Test



Sample from C Group



Sample from E Group

Research Findings

Survey Results (Descriptives)

- Total of 114 respondents
- 45 from C Group
- 69 from E Group

	Subscale	C Group		E Group		
		M_C	SD_C	M_E	SD_E	Alpha
Learning	Self Efficacy	3.67	0.55	3.78	0.57	0.76
	Self Regulation	3.26	0.64	3.42	0.71	0.75
	Cognitive Strategy Use	3.67	0.44	3.62	0.61	0.79
Psychological Needs	Perceived Autonomy	3.85	0.46	3.58	0.65	0.76
	Perceived Competence	3.74	0.72	3.82	0.64	0.86
	Relatedness	3.50	0.81	3.58	0.71	0.78
Motivation	Intrinsic Motivation	3.88	0.80	3.73	0.69	0.83
	External Regulation	2.71	0.90	2.54	0.99	0.60
	Introjected Regulation	2.21	0.84	2.40	0.91	0.73
	Identified Regulation	4.04	0.58	4.03	0.61	0.73
	Amotivation	2.33	0.85	2.22	0.82	0.75

Research Findings

Survey Results (Descriptives)

- Total of 114 respondents
  - 45 from C Group
  - 69 from E Group
- Except for perceived autonomy, rest of subscale not significant
- However, we could draw some conclusions from looking at the mean value of each subscale

Research Findings

Survey Results (Descriptives)

- Learning (Self Efficacy, Self Regulation, Cognitive Strategy Use)

- E group students perceived that they have better self efficacy & self regulation but not cognitive strategy
  - SBL helped introduce self regulation behavior through strategies embedded into the modules, such as reflection, rehearsal, assessment, “safe” environment
  - Infusion of cognitive strategy (but students are not aware of this)

- Analysis of individual items shows perception that SBL:
  - Helped in connecting concepts and reinforce rehearsals but,
  - Harder to learn from as they have to work doubly hard to mine information and hence,
  - Could have lead to lowering of confidence

Research Findings

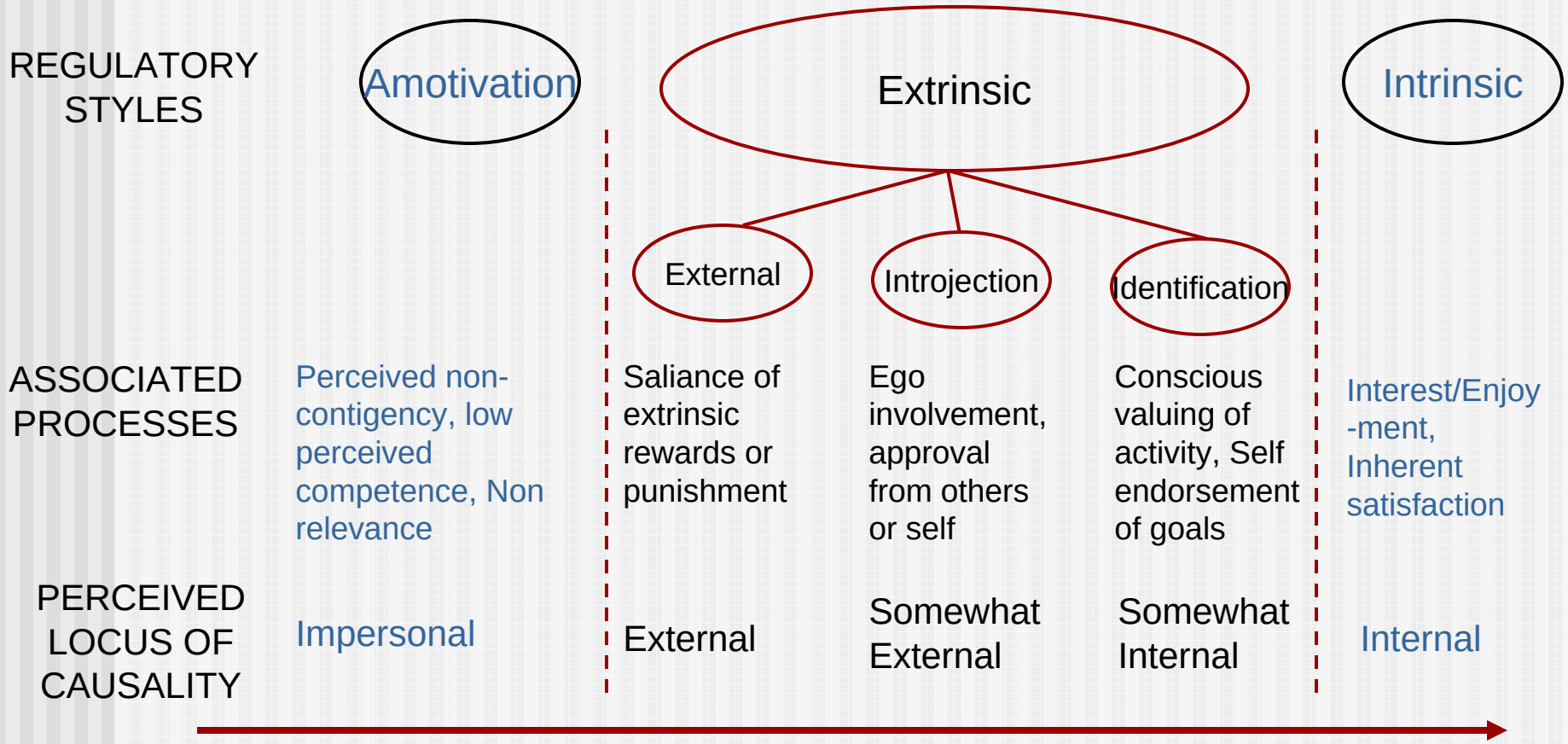
Survey Results (Descriptives)

- Psychological Needs
  - Perceived Autonomy
  - Perceived Competence
  - Relatedness
- E group students perceived that they have higher level of competence and relatedness but less autonomy
  - Students perceived that a number of their suggestions were discounted by instructors (Instructor's view was that students should not deviate from safety procedures)

Research Findings

Survey Results (Descriptives)

- Motivation



Ryan & Deci 2000 [23]

Research Findings

Survey Results (Descriptives)

- Motivation
  - Comparing means, E Group has higher introjected regulation score
    - due to internal pressure – gain some imagined approval
    - Consistent with replies where they perceive tension during learning
  - Both groups have high identified regulation and intrinsic motivation scores
    - Good learning environment is present for both groups leading to needs satisfaction

Research Findings

Survey Results (Correlation E Group)

- Learning
  - Self regulation and self efficacy positively correlated to cognitive strategy use
- Psychological needs
  - Autonomy support, competence and relatedness are significantly correlated
- Motivation
  - Positive correlation between introjected regulation & relatedness

Research Findings

Survey Results (Correlation E Group)

- Learning orientations (metacognition & self regulation) were strongly associated with 3 psychological needs (Competence, Autonomy Support, Relatedness) as well as identified regulation & intrinsic motivation
  - Weak autonomy support should be improved
- High correlates between self-efficacy and competence
  - Competence is a pre-requisite for belief in ability to carry out task to completion

Research Findings

Survey Results (Correlation E Group)

- More Autonomous forms of motivation, (intrinsic motivation, identified regulation) showed strong positive correlations with 3 psychological needs
  - Re-affirms SDT research
- Amotivation correlated negatively with 3 psychological needs, strongest with perceived competence
  - Perceived lack of competence lead to no motivation

Concluding Discussion

- Could SBL help improve students' learning process when compared to traditional classroom methods?
  - Performance has improved
  - Students seems better able to remember details
  - Learning environment to improve on autonomy support
  - Competence is pre-requisite in self belief to learn subject successfully

Concluding Discussion

- By Accessing information in a variety of media formats/interactive fashion, could students make useful associations?
  - Students found SBL to be more difficult to learn from as they have to mine for information in their many forms.
  - Students are not aware that they were using cognitive strategies in their learning
  - Could introduction of learning strategies prior to SBL help?
  - A qualitative analysis currently being carried out will reveal more insight (issues of cognitive overload, etc.)

Concluding Discussion

- Were students motivated by the experience?
  - Learning environment in current study contributed to high needs satisfaction in both groups (both groups exhibit high intrinsic and identified regulation motivation)
  - Students in E Group perceived higher competence but lower autonomy
  - E Group students has higher introjected regulation compared to C Group

Concluding Discussion

- Which aspect of SBL assisted student learning?
  - "Safe" space
  - Rehearsal
  - Prior engagement before actual workshop practice
  - Self Assessment
- Qualitative Analysis will reveal more information

Q & A

The ethos of a study program - a barrier or a springboard for change?

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ABSTRACT

In Sweden, as in many other European countries, vice chancellors and study boards are trying to interpret and adjust to different programs, aiming at enhancing and developing the quality of education. The CDIO-initiative was launched at Linkoping University (LiU) in 1999, in Applied Physics and Electrotechnics (the Y-program), in collaboration with Chalmers and KTH in Sweden and MIT in USA. The initiative was possible due to a generous grant from the Knut and Alice Wallenberg foundation in Sweden (www.cdio.org). In 2007 the implementation of the Bologna structure started at LiU, to some extent in line with the CDIO-initiative, but with a clear focus on learning outcomes at course - and curriculum level. In their national evaluations of Engineering programs in Sweden, The National Agency of Higher Education (HSV) based their quality criteria to a large extent on the CDIO-syllabus.

In this paper I will reflect on the meaning and impact of the "ethos" in a study program. I will review previous research and try to make a distinction between the two concepts, "culture" and "ethos", which sometimes are used synonymously. With that background I will use results and experiences from the change process in the Y-program to reflect on the question of the relation between the "ethos" of a study program and the potential for curricular and pedagogical change. The questions underpinning the outline of the paper are:
What is the meaning of the concept of "ethos" and how is that related to the concept of culture?
Are there previous research about the concept of "ethos" and its´ impact on student learning?
What was the "ethos" of the Y-program and how was it enacted and sustained?
Is the "ethos" of a program a springboard or a barrier for curricular and pedagogical change?
Conclusions

KEYWORDS

Ethos, culture, curricular change, pedagogical change

Background

In changing the curriculum of a study program the question is emerging of what an “ethos” or a “culture” is and its´ impacts on the change process and student learning.

In Sweden, as in many other European countries, there is a great concern about the declining interest in science, mathematics and technology among young adults, the decline in enrolment rates in HE regarding these subject areas and the high drop out rates early in the education in these programs. These issues were the background to a longitudinal study at Linkoping University (LiU). (1; 2; 3;)
In 1998 the study board of the Y-program, initiated a study with the aim of inquire into the students self reported experiences during the first year. The program was marketed as “the toughest” Graduate Engineering program in Sweden and the attrition rate was high but so was also the drop out rate. The study was initiated in order to give the study board some idea of what the problem was. Both students and lecturers were dissatisfied and the drop out rate was *one* indicator of this dissatisfaction.

The results of the study showed that the students were very motivated, experienced an overwhelming work-load but were prepared to work hard and sacrifice a lot in order to manage, but faculty believed that the students did not work hard enough and that they were not qualified for the studies. The results were met with some discussions, but were considered to be of such interest and value for further development of the curriculum, as well as for the improvement of the program, so the project was expanded to encompass the students experiences through the whole study program of 4 ½ years and with a follow up one year after their graduation. In 1999 plans were made to transform the study program from an “elite”- program to a high quality project- based learning environment, where engineering skills would be in focus. These changes were in line with the goal of an international development project, CDIO (www.cdio.org) that Linkoping University and the Y-program were involved in, in collaboration with KTH and Chalmers in Sweden and MIT in Boston. In order to monitor the implementation of planned changes it was decided that the study would encompass four cohorts, those who started in 1998; 1999; 2000 and 2002. Data from the first cohorts (1998 and 1999) were defined as base line data in the study against which the results from the latter cohorts (2000 and 2002) could be compared, with respect to the rolling assessments of the implementation of a CDIO curriculum. Between 1998-2002 the percentage of enrolled, female students varied between 13-20%. During the first two years about 40% of the students dropped - or stopped out (taking a study leave for longer or shorter period of time), but the percentage of female students remained stable in each cohort, despite the drop out.

Three main issues guided the design of the study:

a) The students experiences from college and their expectations when they started the Y-program
b) The students experiences of the curriculum and study environment at different times during their study period
c) The students´ experiences of how the program had contributed to their employability and prepared them for their professional lives as graduate engineers.

The Y-program is *one* of several graduate engineering programs at LiU. The employment rate of engineering students who graduated in 2001/2002 were about 81% and about 70% among those who graduated in 2002/2003. The employment rate is, on an average, high at LiU, compared to other universities in Sweden (4).

What is the “ethos” of a program and how is that related to the concept of culture?

The concepts of “ethos” and “culture” are sometimes used synonymously. In this paper I will define he *culture* of a study program or an educational environment, as an all-pervasive system of beliefs and behaviours enacted in a specific educational context. It specifically consists of the set of values and norms or rules held by staff and students together with its material expressions (5). In management studies the concept of *corporate culture* is widely used to describe key factors that are assumed to enhance competitive performance through employee commitment and flexibility (6). In an educational context, only staff are employees, while students have more of a customer/client relationship with the department. Employees in “strong cultures” knows what is expected of them, identify with the culture and take pride to be part of it. Different kind of people experience different fit with a culture. For the same individual, one culture can promote his/her achievement, self-confidence and self-esteem but another culture can contribute to his/her feelings of failure and lost self-confidence and self-esteem and even stress and ill-health. If the culture is strong, people do not need orders or rules because there are social norms and values that are internalised and people are self-motivated (7). *Thus, “culture” is not something an organisation “has”, it is created in daily interactions in a specific context.* The mission of an engineering program is teaching and learning and this is performed in an academic, educational context, which students are dependent on for several years, in order to get their degree. Students learn both from formal curriculum and formal/informal interactions within a study context with explicit/implicit norms and values (culture). The organisational culture can impact the creativity and potential for change, or stability, in an organisation as well as for individuals (8), i.e. individual as well as organisational learning. Argyris & Schon (9) argue that organisational, collective, learning can be defined as single- and double-loop learning. Single-loop learning takes place *within* existing system of values and norms, which create an action frame, while double-loop learning *involves changes in values and frames* which calls for reflection and inquiry. Some researches argue that single- loop learning is merely a form of adaptation to existing values and that the concept of learning should be reserved for double-loop learning.

To summarise: The culture of an organisation impacts and directs peoples´ way of thinking and acting in a specific context. If the underlying values and norms are *not* changed curricular or pedagogical changes will usually be restricted to form, content and complied actions, and thus become more of performed rituals than changes and learning. Policies and artefacts change but in every-day actions business is as usual. Research on the Bologna process show an example of this, as policies and curricula are been reformulated, but teaching and assessment has not changed (10).

From wikipedia we can learn that ethos is a greek word meaning “accustomed place” and that the word forms the root of ethikos, meaning “moral, showing moral character”. The meaning of it is "the state of being", the inner source, the soul, the mind, the original essence, that shapes and forms a person, group or context.
From that definition the “ethos” of a university, a department or a study program can be described as the spirit or soul that people *believe is* imbuing a context, i.e. a place, an organisation or a relationship, or what they *want* it to be imbued with. Thus “ethos” can be defined as an idea, a representation or imagination of a context that will impact the world, in one way or another. The “ethos” can thus be imagined and narrated and sustained in artefacts, narratives and rumors by different actors, even those who not are directly engaged in, or involved in the physical interactions in the context, while the “culture” is created, sustained or changed in the way people and artefacts interact.

If the experiences of individual students and staff, in a study program are that their conceptions of the “ethos” are *aligned* with their experiences of the “culture”, they will contribute to strengthen this. A strong culture, based on a strong ethos can be a barrier for double-loop learning and change of values and norms. Attempts to change values and norms can be conceived of as attacks on the heart and soul of the “ethos” and even as a war where groups are turned against each other. If the experiences are *dissonant* with the expectations

of students and staff, they will exit, voice or stay and comply, maybe at a very high personal price (11)
To summarise: “Ethos” is an idea, a representation or imagination of a “state of being” that can be a spring-board for change but also a barrier, depending on the fit between the “ethos” and “culture” in a specific context.

Previous research about the meaning and impact of “ethos” in educational contexts

There are some studies done where researchers have investigated the relation between students/staff experiences of their study/work environment and their achievement, study/job satisfaction and health. In some of these studies the concept of “ethos” is used explicitly, while in other studies use the concept of “culture”, “climate” or “habitus” is used.

Astin (12) conducted a longitudinal study between 1985-1989 of about 200 universities/colleges and more than 25.000 students. The aim was to understand how college environment and college education affected students. The results showed that the following aspects impacted the outcome of students´ academic achievement and development (12)

- Student involvement was beneficial for different student development outcomes
- Hours spent studying was positively related to nearly all academic out-comes
- The amount of interaction among peers had far-reaching effects on nearly all areas of student learning and development
- Peer group and faculty represented the most significant aspect of the student's undergraduate development.
- A strong research orientation of academic staff had a substantial negative effect on student satisfaction with faculty.
- A strongly student learning-oriented faculty contributed to the affective and cognitive development of the undergraduate.

From these results Astin (12) reflected on the design and organising of academic work. As there were no inherent contradiction in a faculty member's being both research oriented and effective in teaching the problem seemed to reside in institutional policies; most institutions that hired large numbers of research-oriented faculty gave little priority to effective undergraduate teaching. Another reflection was that the form and content of the general education curriculum made little difference for student learning, instead it was *the manner in which curriculum was implemented* that seemed to be much more important therefore the traditional institutional approach to curriculum development must be changed. Curricular planning efforts resulted in greater payoffs in student outcomes if there were less focus on formal structure and content and more emphasis on pedagogy and other features of the delivery system. His conclusions were that what really matterd was if faculty were willing to consider the possibility that the student's "general education" consisted of something more than the content of what was taught and the particular form in which that content was packaged. Although the HE context has changed since the 1980ies, it is worth reflecting on the conclusions that it is underlying values and norms in the organisation, enacted in an emerging culture that directs peoples ways of thinking and practicing.

Based on results from an other longitudinal project, DEEP (Documenting Effective Educaitonal Practices) Kuh (13) argue that a key factor that must be considered in fostering student learning is an institution's ethos which he defines as ” a *belief system* widely shared by faculty, students, administrators, and others. It is shaped by *a core of educational values* manifested in the institution's mission and philosophy”. With reference to Geertz (14) he means that ethos creates "a sense of intrinsic obligation: it not only encourages devotion, it demands it; it not only induces intellectual assent, it enforces emotional commitment”. The results indicate that colleges with a salient ethos imprint on their students a distinctive pattern of attitudes and values. By talking with students some of these distinctive imprints were identified (15). At institutions marked by an ethos of learning, the tension between cohesion

and accuracy must be recognised because that tension indicates that the organisation has successfully resisted the press for conformity. How an organisation responds to conflicts between individualism and conformity is a key indicator of whether an ethos of learning exists (16). A salient ethos can be a double-edged sword, according to Kuh (13). Such an ethos creates a psychological culture where the majority of students see things in much the same way; they sense the importance of succeeding--to achieve, persist, and graduate. On the other hand, students with motivations and aspirations that differ from those of the dominant group may have trouble adjusting. The ethos can have debilitating effects when some group members are silenced or alienated by the values of the ethos. That these select group members feel uncomfortable is, partly, a historical artifact and product of where, by whom, and for whom the program was established.

In the 1980ies researchers reflected on the relation between the ethos of an institution and its´ propensity for change which can be of interest in 2009 when ranking and competition contribute to a discourse about quality and change.

” The changing nature of college students and an increasingly pluralistic world demand that colleges change to accommodate and welcome students for whom the institution was not originally designed. But can a college develop and maintain a salient, coherent ethos while attracting and affirming students from diverse backgrounds? It is beyond the scope of this article to answer that. But the implications for institutional renewal are significant, beginning with asking faculty to examine their assumptions about who belongs at their college and which students can learn what. At colleges marked by an ethos of learning, faculty communicate to all students that they are full members of the campus community and are expected to succeed. Unless faculty agree that all students can learn what they teach, then they will transmit signals of belonging to some groups and rejection to others” (13).

Conclusions from the project were that institutional ethos contributed to desirable changes in students when it permeated every aspect of campus life, including students' experiences outside the classroom. The institution's ethos also could explain why certain groups of students had affirming experiences while others felt alienated in “the same” context.

In a study of a primary school in Northern Ireland Donnelly (17) showed that school ethos, defined as observed practices and interactions of school members, departed considerably from the school ethos defined as those values and beliefs the school officially supported. Her study focussed on how staff perceived the ethos. Donnelly (17) argue that both culture and ethos are abstract concepts related to the actions of people within a specific context, but she argues that ethos is subsumed within the broader concept of culture, which is contrary to the position taken in this paper, where culture is assumed to be subsumed in an ethos. One conclusion drawn from the study was that what was understood as “ethos” was both superficial and contradictory. Ethos can not be defined either as an objective phenomenon or a social process, but as a process characterised by contradictions and inconsistencies. What directions a change process takes, depends on the key actors involved, their values and attitudes as well as the dominating social and political culture. School ethos can constrain people to adapt to the prevailing regime, but also enhance resistance and opposition. Ethos can be defined as a negotiated process whereby actors come to some agreement about proper actions.

Smith (18), a researcher in the sociology of education, argues that ethos can be defined as the habitus (19) of an organisation and that habituses external to an educational context provide dispositions that continuously construct and re-construct its´ ethos, which provides the context for situated learning (20). He uses the concept of “ethos” instead of “culture”, arguing that the concept of culture mainly is associated with, an used in non-educational organisations, while “ethos” is “reserved” for schools and kindered organisations. From a

neo-institutional perspective Scott (21) sees Bordieu´s concept of habitus as a matrix of perceptions and actions that allows individuals to structure their behaviour within situations. Smith (18) proposes an ecological perspective where an organisation can be understood as "the impact of cultural groups or classes on an individual´s behaviour as it is mediated through an organisation". According to Smith (18) ethos can be thought of as the aspects of the culture, climate and philosophy that impinge directly upon students affective and cognitive learning and are perceived by all stake holders. It is constructed through interaction between actors and the official value system and is mediated through organisational structures and processes as well as by staff culture and competence. The durability of the ethos is evidenced by the difficulty by which it is transformed. Where there is a high degree of congruence between the ethos of a program and the class/social habitus of the majority, students of significantly different habitus may be deterred from seeking entry or they might drop out. Ethos is seen as resulting from a) the mix of values, attitudes and behaviours that students and staff bring to the context, and b) policies as expressed through curriculum and formal rules and regulations. This is enacted in social interaction and mediated by staff culture and competence in the way they construct their ideal students.

Conclusions: The results referred to above indicate that although "ethos" is an abstract concept, difficult to define and measure, it can be useful as a tool to better describe and understand student learning and other aspects of institutional functioning. To study the "ethos" of a study program can contribute to an understanding of why programs, departments or universities act and react in different ways to policy initiatives, i.e. to the Bologna process. Attracting, enrolling and graduating more female students in mathematics, science and technology, and to adequately prepare *all* students for the next century, requires a change of values and norms and double-loop learning about how the "ethos" encourages or discourages student learning and personal development. When an *ethos of learning* prevails, people perceive a pressure to think and behave *inclusively* and the goal that drives policy and practice is *unity*. However, unity as an institutional value should be distinguished from conformity and compliance, which can indicate a failure to appreciate, encourage and make use of a diverse community. If unity and diversity are to be values impinging the "ethos" of a study program, their mission and history has to be reinterpreted and they must organise their work so that a wide range of voices and a wide spectrum of diverse views and interests are acknowledged.

Was there an "ethos" of the Y-program and how was it enacted and sustained?

The results of our longitudinal study of the Y-program have contributed to an insight of how complex the phenomena of learning, motivation, employability and change in higher education are. The intention with the CDIO-project was to implement a curricular reform in order to meet the requirements from students and potential employers. The realisation of this, from policy to practice, proved to be challenging in a program that had a deeply rooted reputation of being tough and demanding, and where quality aspects were associated with this reputation. The first cohort, 1998, studied within a curriculum where these values were predominant and defended by the students, even those who failed and dropped out. These students motivation, their approaches to learning and their way of thinking about their future were aligned with an idea of a "hard-working, enduring student, sacrificing some freedom today for the dream of an interesting job and a good life in the future". The introduction of a new curriculum, with more focus on generic and social skills and team-work, as well as more applied knowledge was met by some ambivalence by the students. A "softer" approach indicated a lowering of the quality of the program and they anticipated an impaired reputation. The implementation coincided with the entrance of students (2000 and 2002) with a "new" attitude to studying and learning. These students expected to get good quality teaching and support in their learning process on their way to an academic grade, as this was considered to be a basic requirement for an entrance into the job market. They focussed on being and

living as students, they were not prepared to make sacrifices and had vague ideas about what a career as a Grade Engineer would mean.

Summary of results from the longitudinal study of four cohorts engineering students in Linkoping

The Y-program was marketed as tough and difficult and managing this was the main motivation for some of the students interviewed to enrol, for others the motivation was an interest in relevant subjects or getting a grade as an entrance to a graduate labour market. Between 150-200 students were enrolled annually in 1998, 1999, 2000 and 2002 but despite the curricular changes made we estimate that on an average (across all cohorts) 32% dropped out after the first year, and in the fifth year 48% had dropped or stopped out.

Experiences from Upper Secondary School were that all students had been successful, some of them at the price of hard work, others without to much efforts, which indicates a great variation in perceived work-load. The cohorts of 2000 and 2002 described an accelerating rush and competition for the highest grades. About 30-40% had experienced some kind of study-related stress (sleeping problems, stomach problems, feelings of self doubt and insufficiency; problems of concentrating and depressions). These experiences were gender related. The increase in students´ experiences of study related stress was considered in an overall cultural context as studies of psychological well-being in the Swedish population showed that the increase of psychological ill-health was accelerating in the age group of 19-29 (young adults) (Hallsten et.al, 2002; Wenemark et.al. 2003).

The students´ motives for having the Y-program as their first choice changed between 1998-2002. *In 1998 and 1999* a the motive was the students´ special interest in mathematics and physics and their anticipations of a promising job market as Graduate Engineers. By the end of the 1990ies the IT-boom was declining and *in 2000 and 2002* the students´ were more ambivalent to their future. The job market was more insecure and the motive was the breadth of the program as it enabled the students to postpone their career choices. The choice of study program was informed by life style and an image of the study context more than of a future job market.

There was a difference in the approaches to studying adopted, between the first and the latter cohorts. In 1998 and 1999 the students wanted to “test” their capacity to live up to the standards of the program, while it for the latter cohorts it was “a test” if the program could live up to their expectations. In all four cohorts the students expected long working hours (about 50h/week) and a challenging and stimulating co-operation with faculty and peers.

In 1998 and 1999 the students´ described their first impressions of the academic study context as “chocking”, “chaotic” and “overwhelming”. Managing a high tempo and tough classes in mathematics evoke much agony and self doubt. A perceived harsh attitude among faculty contributed to their feelings of panic. In 2000 and 2002 the students reported different experiences. They praised the activities related to the reception of the students and they felt “taken care of and lavished”. The attitudes among faculty were perceived as “helpful”. The students commented that the high proportion of teacher-led lectures and lessons was unexpected but very positive. Most interviewed students commented that they were aware that the image of “The Y-student” was that of a bore and a nerd with no social interest or competence, but although this was true for *some* of their peers, that it did not correspond to their own self-image. Some students solved this dilemma by not telling people outside the class that they were a “Y-student”. They believed that when you got to know these “other” people they were much the same as them selves, ambitious and clever students who also liked to party and participate in student activities.

In all interviews the students commented on their overall study satisfaction. Although they belonged to a cohort of about 180 students, on a Campus with about 26.000 students, their study life was very much limited to the life of their class or their campus corridor (Edvardsson Stiwne, 2004). During the first weeks they participated in a lot of Y-program activities. During these first weeks people grouped together in smaller units as peer groups, study groups, commuting groups, student union groups etc. When the Y-students compared themselves to other students they characterised themselves as more ambitious, more self-demanding, smarter and more hard working than other students. When they compared themselves to non-students of the same age they described themselves as living a good and comfortable life, in spite of hard study work, and they could not think of "an ordinary job" as an alternative.
The students´ experiences of their teachers´ competencies were unified. They were considered to be highly competent and professional within their specific fields of knowledge, but lacking in pedagogical competence. In the first cohorts many students were upset by the lecturers attitudes towards them as students, exemplified by comments that *some* lecturers seemed to be fed up with students and seemed to enjoy tormenting them. Another comment was that some lecturers did not bother to explain issues that they considered too simple and too evident. The students´ developed different strategies to cope with this, such as attending all lectures, selecting lecturers, working in tight peer-groups or work on their own. The students in 2002 were most positive towards their lecturers, who were considered helpful and considerate but still lacking pedagogical competence.
In all cohorts the average working hours/week were 40-50. Lectures, classes and laboratory work were highly attended to. New forms of assessment and project-work were considered interesting, but time-consuming and disturbing the "real" studies. What was creating stress and ambivalence was a conflict between tough working conditions and the status of the program. "It is supposed to be a tough education, you are becoming a graduate engineer, and then it has to be demanding an tough". Problem-based learning, projects and training generic skills like communication, management etc, were activities that might impact the reputation and image of the program in a negative way.
The students in the latter cohorts did not see any alternative to studying, a concept that also included activities like leaving home, fixing accommodation, economy, household duties and creating new social networks. These activities were considered very stressful during the first semester and in conflict with a tough and demanding study situation. About 40% of the students had considered taking study leaves (stop-out) during the first year, or to drop out. The reason for that was not primarily the work-load or failing tests but the experience of a lack of meaning and relevance. and of not fitting in. The students hoped that the first year was the worse and that it would be more interesting later.
In interviews after graduation the students commented that the reputation of the Y-program, to be tough and demanding, was a core value of the program, something that made the Y-program stand out from other programs and that being a Y-program graduate was a quality indicator in itself, ensuring an employer that it was an enduring, smart and hard-working employer they would get.

From the definitions previously made in this paper, I would argue that there was an "ethos" related to the Y-program, ideas relating to a moral essence, some core values of the program, that were shared and communicated *within* as well as *outside* the program. The ethos can be described as an idea of a context that will foster tough, loyal, hard-working persons who do not give up too easily. This was announced in the marketing of "The toughest" program, and by referring to alumni students who had become CEOs in prestigious, international

companies. The ethos was communicated to new students in the narratives of tough examinations where few students pass. This was also what interviewed Y-students mentioned as "key skills", appreciated by their employers. The students commented that the reputation of the Y-program as to be tough and demanding, was a core value of the program, something that made the Y-program stand out from other programs and that being a Y-program graduate was a quality indicator in itself, ensuring an employer that it was an enduring, smart and hard-working employer they would get.

If this "ethos" is shared and communicated I would argue that the question if it will be a springboard, or a barrier, to change of curriculum and pedagogy, or what direction a change may take, will depend on the *culture* of the program. The culture of a program is defined as an all-pervasive system of beliefs and behaviours *enacted in a specific educational context.* The culture is created in social interaction, and in our study we can see that there were changes in the culture of the program between 1998-2007.
The study context for the 1998 and 1999 students was a traditional study program and the students wanted to "test" their capacity to live up to the standards of that program. They described their first impressions of the academic study context as "chocking", "chaotic" and "overwhelming" and trying to manage a high tempo and tough classes in mathematics evoke much agony and self doubt. A perceived harsh attitude among faculty contributed to their feelings of panic. Some students were upset by the lecturers attitudes towards them as students, exemplified by comments that *some* lecturers seemed to be fed up with students and seemed to enjoy tormenting them. Another comment was that some lecturers did not bother to explain issues that they considered too simple and too evident. The experience of a conflict between tough working conditions and the status of the program created some stress and ambivalence among the students. "It is supposed to be a tough education, you are becoming a graduate engineer, and then it has to be demanding an tough". These students came to the program with a wish to be part of, and manage, a tough program, and they were prepared to sacrifice and work hard to achieve their goal to graduate from the Y-program. They were frustrated and stressed by the demands and attitudes of faculty, and some dropped out (exit), some stayed, managed well and engaged in student union activities and some stayed but to a high price, personally and socially. For these students, a strategy to survive was to distance themselves from the campus culture and maintain a feeling of "authenticity" among family and friends, or to take a study leave and study at an other faculty, travel or work. The culture they created was an "achievement culture", where compliance to authorities (faculty) and where social activities and "life-matters" were seen as interfering with the common goal to uphold the reputation of the Y-program. When these students heard about the planned changes in the curriculum, implying projects, group-work, learning of social skills and new forms of assessment, i.e. home assignments and group assignments, they were hesitant and sceptical. They argued that the quality of the program would be jeopardized and open up for "inferior" students. This was in line with their image of themselves, as Y-student, in comparison to other students. They characterised themselves as more ambitious, more self-demanding, smarter and more hard working than other students, at the price of being labelled as bores and nerds, lacking social skills.
The context for the 2000 and 2002 had changed. These students also shared the ethos, but expected "the program" to maintain that and faculty to facilitate the students´ efforts to manage their studies. The curriculum had changed, but the students´ experiences were that new ingredients had been crammed into the traditional curriculum. Although they appreciated project work, group-work and new forms of assignments, they had a feeling that what really counted was the cramming of content and passing traditional assessment procedures. These students experienced a welcoming atmosphere, a helpful attitude from staff. The students were not prepared to make great personal or social sacrifices as quality of life was as important to them as passing exams. They searched for support among peer- groups and younger faculty. They were encouraged by project work and group discussions, but were anxious that the quality and reputation of the program, and thus their grade, would be

jeopardized. Their image as Y-students was much the same as before, but they adopted a more distanced approach towards it.
The ethos of the Y-program was identified as some core, moral values, characterizing not only the study program but also the students graduating from that program. The culture was changed, and this change was associated with a curricular change, from a traditional curriculum to a CDIO curriculum. The students attitudes and approaches to studying had changed, between 1998-2002, but so had the attitudes and approaches to teaching adopted by faculty. Despite that it can be argued that the changes made possible were those who did not challenge the ethos of the Y-program as a study context fostering and producing tough, loyal, hard-working persons who do not give up too easily.

Conclusions

From previous research and from the results of our longitudinal study, I have come to the conclusion that a strong culture, based on a strong ethos *can* be a barrier for double-loop learning requiring change of values and norms. Attempts to change values and norms can be conceived of as attacks on the heart and soul of the "ethos" and even as a war where groups are turned against each other. A strong culture, a strong ethos, can promote the achievement, self-confidence and self-esteem for some persons, but also contribute to feelings of failure and lost self-confidence and self-esteem and even stress and ill-health for other persons. For future recruitment, enrolment and graduation of students in engineering this should create questions like "What kind of students do we want to recruit"? and "What kind of engineers do we want to educate"? "How is the ethos of the program enacted in the content and form of the program and in the out-of class activities, in the interactions between students and between staff and students"?

As previous studies indicate, if the experiences of students and staff are *dissonant* with the expectations they have, they will exit, voice or stay and comply, maybe at a very high personal price and a high institutional price.

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THE FOUR FORCES THAT INFLUENCES THE QUALITY OF KNOWLEDGE PROVISION SERVICES

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ABSTRACT

In this article, we present an engineering knowledge management methodology that aims to improve the quality of services of educational institutions. We first define educational institutions as agencies in a service industry that provide knowledge accumulation and dissemination services to their surrounding society. We then leverage the conceptual framework originally proposed by a Constitutional Law Professor, Lawrence Lessig, in the book "Code and Other Laws of Cyberspace", to control the quality of services on knowledge management. We found his conceptual model of the four forces particularly suitable for understanding the complex interactions between technical content knowledge and the motivational forces in human societies. Based on this four-force model, we will use the design and implementation of a series of engineering courses at Tsinghua University to illustrate the concept.

KEYWORDS

Service Agency, Quality of Service, Architecture, Law.

INTRODUCTION

Engineering education is not only about improving the general human qualities of its target students, but also about offering knowledge provisioning services to the society. For instance, an engineering school should act as an agency that disseminates technical knowledge and inspires both current and future engineers' ability to Conceive, Design, Implement, and Operate (CDIO, see http://www.cdio.org) modern technical artifacts. The objectives of an engineering curriculum should not only focus on individual performance, but also the collective service qualities of the entire institution. A good curriculum design must take into account the various socio-technical factors that are similar to designing a miniature society. Intellectually speaking, designing a curriculum for an engineering department or an engineering school, is analogous to writing a constitution. However, most engineering

curriculums are designed by professors or administrators that were primarily educated as engineering specialists. Engineering curriculum has usually been focused on students' individual understanding of certain technical subjects, with less emphasis on students' ability to systematically utilize the technical resources in their surrounding environment. Inspired by the four-forces model presented in Lessig's book on "Code and Other Laws in Cyberspace", we found that the law professor's mental model could enhance our understanding in the process of forming and executing an engineering curriculum.

What are the four forces?

Lessig defines the four-force model as the intrinsic motivating forces of social behaviours. His model provides a vocabulary to describe the behaviour of a school as an agency that provides services in its surrounding social and economic context. In a way, it provides a social scientist's framework to study the first CDIO standard, "Context". It could help curriculum designers to see the motivating forces and inherent constraints through a strategic lens. Lessig's four forces are: architecture, law, market and norm. The following definitions are the authors' interpretation of Lessig's forces, in the context of engineering education.

Architecture

Architecture is the kind of constraint that impacts a system before any activities take place. For example, a password protected information system would require its users to first obtain certain authorization, or expense a certain amount of intellectual effort to hack the security system, before one may tap into the protected information resources. In short, architecture is a kind of pre-emptive force that guides the behaviour of agents. This force is particularly relevant to engineering education, because engineering disciplines are naturally associated with technical artifacts. The workspace of an engineering school, the technical instruments available for teaching and research, and the organizational architecture of the school, can all be considered as the "architectural" force. Due to its pre-emptive nature, "Architecture" is a strategic item that should be planned to last a significant period of time. It is the stable element in a system [Koo 2005]. In contrast to "Architecture", the other forces, such as "Law", "Market", and "Norm", might be applied to constrain the collective behaviour based on case-by-case scenarios.

Law

Law is a set of explicit regulatory rules that could be executed after certain behaviour takes place. For example, a school may set up a "law" or "policy", that punishes students who frequently skip class. However, the effect of the "law" must be tested at two time points after it is established. First, it must wait until certain students actually miss enough number of classes, then, the other students must observe whether the punishment is properly executed with sufficient strength. In other words, the persuasive power of "Law" can be demonstrated only after certain activities takes place. If the award or punishment is too weak, it will not sufficiently affect the behaviour on a societal level. Moreover, its power primarily lies in the ability to execute the law in a consistent fashion. If the cost of law enforcement is too high, or it misses too many offensive acts, the law would have very little value. Its regulatory effect could only be as good as the agencies' (in our case, the engineering department or schools') ability to execute their "laws". Clearly, regulations or policies of a school should be planned along with the architectural elements of the curriculum. However, from a temporal viewpoint, "Law" is complementary to "Architecture", because its successful enforcement of the constraints happens after certain specified activities take place.

Market

Market is the force that pulls, or attracts the agents to participate in or react to certain self-interested opportunities. For example, media coverage about certain students' or teachers' achievements could be counted as a kind of market force. Similarly, students who might be given an award, or a ranking, or a higher mark for their learning effort could also be categorized as a force in the "Market". According to Lessig, the force of "Market" pulls agents to follow a certain direction. Clearly, if the market awards are not attractive enough, students or teachers could sneer at them. In short, Market is just an invitation; it relies on the agents' willingness to engage with the force.

Norm

Norm is a force that pushes, or actively encourages the agents to participate in certain activities. One may think of it as the force of culture, or peer pressure. When everyone in a school uses a network-based version control system to manage shared files, it would be a strong force to change the habit for people who only use email to send files. Clearly, there will always be people who run against the norms, but the forces in the culture would actively push, or more politely, encourage these people to act more "normally". Norm is a force that is much stronger than an invitation, it will try to push the "abnormal" agents into the mainstream, it doesn't rely on agent's self-willingness to engage with the movement.

A high level process for curriculum design

When applying the four forces to the design of curricula, we argue that the sequence of curriculum design activities should roughly follow the four stages. Architectures provide a stable framework in systems; therefore, they should be selected in the beginning. If the architectural choices are good, they should be leveraged for a long time, otherwise, they should be replaced as early as possible, because all the remaining forces will act in the context framed by chosen architectures. Law follows and complements architectural decisions, because it needs adequate administrative organization structures and the supporting technical infrastructure to execute the law. Market forces supplement what laws cannot cover, they should draw people, resources, and new ideas into the learning environment. Norms are shaped over time by slowly aggregating the effects of the previous three forces. Once a norm is established, it would serve as a filter to identify or reject micro-level behaviours that are not compatible with the collective whole.

First, we need to be cognizant of the consequences of architectural choices. For example, do we want to choose an organizational architecture that is flat, where students can freely interact with each other without an explicit team structure? Would this organizational architecture best support our learning objectives? From an operational viewpoint, architectural decisions like this would have profound impact on the learning outcome, and they must be determined before classes start.

Second, one need to conceive and implement certain regulatory mechanisms to enforce the architectural intent. This might include grading policies, attendance policies, policies on class participation and policies against plagiarism. All these rules must be explicitly stated and effectively executed in ways that would improve student learning while not stifling the freedom and creative energies in the student community.

Third, students must be motivated by sufficiently attractive incentive systems. This is called the force of market in Lessig’s term. Normally, grades and ranking can be treated as effective currencies in school. There are also other kinds of intellectual currencies. For instance, certain marketable skill sets are attractive to students. In courses related to computing science, skills in popular programming languages and modelling tools are considered to be valuable, because students think that these skills could help them find jobs or solve problems in less time. These kind of knowledge assets can be utilized as market incentives.

Fourth, all human organizations have some cultural norms. It could be leveraged to promote effective learning. Ideally, one would create a positive cultural norm, so that students and teachers will automatically encourage each other to raise their quality of work, be more creative, or just encourage each other emotionally when something didn't work as expected.

A CASE STUDY AT TSINGHUA UNIVERSITY

For illustrative purposes, we use a series of required courses in the Industrial Engineering Department of Tsinghua University, to show how we designed a CDIO curriculum based on the four-force model. Specifically, we want to show that by treating a class of students as a miniature society, four forces could naturally fit into the planning and execution of learning activities.

The two courses, "Data Structures and Algorithms", and "Database Systems", are chosen for detailed explanation in this study, partially due to their close relationships. One is the theoretical foundation of the other, and our department conducts these two required courses in two consecutive semesters. Administratively, this matches CDIO standard 3, "Integrative Curriculum". In terms of supporting infrastructures, both courses could leverage massive amounts of digitized content and tools that are freely available on the Internet. Over time, this makes it particularly easy to compare student performance given different technologies.

Architectures and functional goals

Architectural decisions include three aspects: technical, organizational, and workflow. Baldwin et al.'s book on Design Rules [Baldwin 2000] inspired us to divide curriculum planning in this fashion. In this paper, technical architectures refer to the technical content of a course. Should one focus on describing relational databases as the main theme, or start the course with a detailed discussion of declarative programming language to establish the foundational concept of a course? These two drastically different approaches determine the "technical" architecture of the course, and the differences could impact how students learn ongoing courses differently. Organization architecture refers to how students and teachers are administratively organized. For example, students can be organized into groups, and teachers organized into departments and research centers. Workflow architecture specifies the interactive patterns among human activities, physical instruments, and information flows. Specifically, weekly classroom lectures, bi-weekly lab sessions, and team-based final reports are typical workflow patterns. These simple terms actually involve sophisticated human and material interactions.

The technical content architecture, the organizational architecture, and the workflow architectures, must be aligned with a set of flexible, yet instructive functional goals. Before we make any architectural decisions, we decided to invite students to work with teachers to design a collective learning system. To guide the thought process of this design challenge, we came up with a set of functional goals expressed in the following words:

1. Knowledge Aggregation
    a. Aggregate people and resources to better retain existing knowledge
    b. Aggregate experience and traditions as a technology conservatory
    c. Aggregate momentum to develop future technical opportunities
2. Knowledge Dissemination
    a. Disseminate knowledge to students
    b. Disseminate knowledge across different departments and schools
    c. Disseminate knowledge to surrounding societal participants
3. Knowledge Creation

a. Create knowledge based on incremental aggregation
b. Create knowledge based on cross-pollination of disciplines
c. Create knowledge based on innovation

First and foremost, this set of functional goals is not a set of compliance metrics. For example, administrators might use numerical measurements as the “goals” of certain educational program. Similarly, many students believe that their goals in school are getting a degree, and getting top scores in certain tests. To inform the students and teachers that learning is about acquiring knowledge, not about fulfilling some abstract metrics, we decided to write down these goals and use them as guidelines to help them design their own learning activities.

These functional goals spell-out the operational purpose of a generic learning organization, which we call “Knowledge City” or KC in short. Initially, KC is just a code name that refers to a project that integrates all other teams’ work in the database course. Later, we realized that its goals are aligned with the goals of our whole department. Overtime, these goal statements become a central part of our course material, because they provide hints to run group-based learning operations. They also serve as a source of inspiration to help students explain why their self-chosen projects in both data structures and database courses are valuable. Invariably, all interesting projects must leverage some knowledge and support from people outside of their group, even outside of the campus.

These goal statements are also helpful in making architectural decisions during curriculum design. When presenting technical content of a course, the overarching themes of the lectures should reflect these purposes. When organizing student teams, the motivating factor is not about beating the other teams, but about serving these collaborative goals. When designing learning workflows, the activities and interactions are checked against these goal statements. These functional goals are used in the beginning of the class, to help all stakeholders of the course to choose the appropriate technical, organizational, and workflow architectures of the courses.

The three architectural concerns

Learning activities in our courses must contribute to the goals of knowledge aggregation, dissemination, and creation. These activities are also pre-emptively constrained by certain pre-established structures, or "Architectures". In this paper, we present three architectural concerns, namely technical architectures, organizational architectures, and workflow architecture. The following sections explain their roles in the design of our two courses.

Technical Architecture

The main technical goal of data structures and database courses is to aggregate, disseminate, and create knowledge about how to manipulate, store, and present data, using computing devices. Following ideas presented in the famous textbook, “Structure and Interpretation of Computer Programs” [Abelson 1996], we found that the technical content about data structures and computer programs can be established on a rather simple principle: *how to use mathematical abstraction to approximate concrete phenomenon using computing devices*. To ensure students could immediately realize the concrete implication of these abstract mathematical concepts, the textbook uses Lisp, an interpretive programming language, to engage students with the concrete world of computation. The design of this textbook provides a technical architecture of similar courses. From a pedagogical viewpoint, one may conclude: learning activities should be designed to illustrate, challenge, and demonstrate the connections between the abstract mathematical concepts and the concrete applications of computing technologies. Lectures should be organized to sequentially introduce the conceptually inter-dependent techniques of mathematical abstraction, and

more specifically about various abstract data types (ADT), such as set, list, tree, and graph. Then ADTs become the officially sanctioned vocabulary to describe concepts and examples in class. A technical architecture for knowledge aggregation, dissemination, and creation is established on top of the elements of a scientific language. As students advance in class, they acquire more vocabulary in class, which expands their ability to express their technical ideas. For example, when they learn about sorting and searching, they will not only acquire the "verb" phrases in their technical language, they will also learn bout the measurement metrics, such as the computational time complexity, and memory-space consumption. When they learn about various programming languages or database technologies, their vocabulary also increases, so that they can relate their abstract mathematical terms with increasingly richer and more concrete technology applications. We summarize these ideas into one sentence:

The vocabulary, grammar, and the application context of a scientific language, determines the technical architecture of engineering courses.

Courses related to data structures, algorithms, and databases naturally involve programming assignments. To students of introductory data structure classes, this course might be their first exposure to the reality of software engineering. Often times, students consider programming assignments as tasks, not software engineering projects. In our courses, we want to use programming assignments as an opportunity to practice software engineering. To conduct software engineering projects, we deployed an SVN-based version control service [SVN website] on our campus network. This service provides the ability to synchronize different authors' documents, source code trees, and other digitized information assets on a central repository. This technology provides a mechanism to compare and record the changes between versions of documents and therefore emulates the engineering environment of an Internet-based software development community. There are various open source tools that can automate the process of analysing changes between versions of source code. This includes the authorship, frequencies of changes, amount of changes, and the correctness of changes. Version control technologies provide a technical platform can be used to inform grading decisions, and detect plagiarism. According to our functional goals, we primarily use it to help students witness each other's learning progress. Without these open source technologies and an existing network infrastructure, conducting engineering courses that require frequent interactions and collaborations would be much more challenging.

We use Moodle [see http://moodle.org], an Open Source course management websites, to provide students with blogs, calendaring, and file sharing services. Instructors also communicate with these students by posting homework assignments, and lecture notes on the website. We choose Moodle primarily because it is a mature Open Source product, and has a large community developing modules that support a wide range of esoteric functions. This technical infrastructure also helps us better observe students' learning activities on a fine-grained level. We can see who are most vocal on their blogs, and who constantly share information with others. For people who are less active, we may also schedule private meetings to learn about their progress. The adoption of these tools improves the community's awareness level of media literacy [see http://newmedialiteracies.org/].

Higher levels of technical literacy came from students' direct experience with the new technical infrastructures. Version control software gives them automatically generated "version numbers" and customizable "branch names" to manage the evolutionary history of their digital media. Moodle gives them online "team-based discussion boards" to post questions and share knowledge across different teams. These technical infrastructures expand the vocabulary in students' daily conversation. The expansion of their vocabulary doesn't only make them speak like (software) professionals; it also improves their efficacy and efficiency in communicating discipline-specific ideas.

Organizational Architecture

Organizational architecture is a constraining force that regulates how people interact with each other. Given the above-mentioned technical architecture, students perceive themselves as the citizens of Knowledge City, and a people that understand a common language. They can attain this social identity partially because the technical infrastructure and architectures can be used beyond just one course. In Knowledge City, instructors of each class are politicians, or Mayors, who always delegate tasks to Vice Mayors, or teaching assistants. Teaching assistants are inspectors, who observe students' group and individual learning habits. Their jobs are not just about answering technical questions, they use above-mentioned tools to judge students' habitual behaviour. They observe whether individuals and teams post messages and read frequently asked questions (FAQs) on Moodle. They examine whether students adequately upload and modify source code on the source-code repository. Students are organized into teams. Each team plays the role of a service agency or a product manufacturer. In the beginning of a semester, each team comes up with a name and a logo. Within the first two weeks of a semester, they need to submit and present a proposal on how their firm could serve their potential customers in Knowledge City. In most cases, their customers are other teams in the same class. Then, each team will self-organize their local administrative structures based on their respective proposals.

In project-based learning, teams are organized to develop products together. Products in our two courses include: team-based student lectures, progress reports, individual homework assignments, in-class quizzes, and team-based projects. Based on our experience, many students simply don't have the knowledge or experience that it requires iterative negotiation cycles to integrate individual work. Normally, student teams just come up with a list of tasks, and assume that once individual tasks are done; they can be easily assembled into a complete and functional product without expecting additional work. Based on this mindset, students would usually work alone, and then be stunned by the often-disastrous outcomes when things need to be put together.

To address this naive project-development mindset, the organizational architecture must make teams be cognizant of their surrounding context; all products and technical content delivery must answer the needs of some living and breathing customers. Students must repeatedly negotiate with the instructor and the TAs to refine their team projects. Under the organizational context of Knowledge City, each team must defend their technical merits and technical contribution to the city's infrastructure. All their oral and written technical reports must include sections that explain the social value of their projects in the City. They are also encouraged to integrate technologies contributed by other teams. The notion of a city helps students articulate various business and social interactions between teams. The projects are not about making one outstanding team, but about creating a harmonious society consist of inter-dependent chains of product development teams.

Size matters. In a class of 60 to 80 people, there are usually 10~12 teams. Each team is allowed to have 5~9 student members. In our department, most students stay in the same dormitory and take the same set of courses. This organizational background makes it easier to coordinate team schedules. Occasionally, there are students coming from other engineering departments. They are usually the minority group, so that they can often accommodate the majority's scheduling needs. Due to the intensive amount of workload in these two courses, instructors who conduct courses in the same semesters often are from our department, and they are very understanding of students' overall workload. With the political support from the department, these organizational features strengthen students' willingness to work on projects related to Knowledge City.

Workflow Architecture

Technical architecture determines what is to be learned. Organizational architecture determines who will be responsible for different types of learning activities. Workflow architecture determines how to learn. Using Knowledge City as a context, learning naturally takes place before and after classroom-based lecture hours. Overtime, students compiled a set of workflow patterns. They are listed as follows:

1. In-Classroom Workflow (Roughly 3 hours a week)
    a. Instructor Lecture
    b. Student review on content presented in the previous week
        i. Show a 3 minute video from the previous week
    c. Student lecture (a lecture using their team project as an application context)
    d. Randomly selected student team progress report
    e. In class quiz
2. Content-Preparation Workflow (Weekly cycle)
    a. Lecture Topic Definition (derived from the Syllabus)
        i. Intra-team discussion with support from previous team.
    b. Create the alpha version of Lecture Notes (story boarding)
    c. Rehearsal with instructors and teaching assistants
    d. Create the beta version of Lecture Notes (detailed content)
    e. Rehearse with instructors and teaching assistants
    f. Prepare a quiz based on student-created Lecture Notes
    g. Upload all digitized content onto KC's source code repository
3. Content-Refinement Workflow
    a. Review with instructors immediately after lecture hours
    b. Create a list of errata
    c. Create a review presentation, this includes
        i. Key concepts in this past lecture
        ii. Information that was missing or incorrect in the lecture
        iii. Additional references
        iv. A 3 minute video, highlighting inspiring moments in lecture hours
    d. Rehearse the review presentation in team
    e. Upload all digitized content onto KC's source code repository
4. Weekly Team-Project Report Workflow
    a. Compile a list of relevant content knowledge gained from weekly lectures
    b. Continue development of team-based products
    c. Prepare a progress report with technical demonstrations (5~9 slides)
    d. Upload progress reports and demos onto KC's source code repository

This list of workflows is not intended to be comprehensive. They provide constraining guidelines to regulate learning activities in different timescales. The list of workflows is documented to provide an architectural guideline to orchestrate learning activities. All courses in Knowledge City are run as multi-threaded programs. When one team is creating a presentation, the other teams could have been developing technologies that might serve as an example in the presentation. If the presentation didn't have a chance to include it in an earlier week, they are encouraged to include them in later weeks. Students are also encouraged to include content derived from other courses. Classroom-based lecture hours are considered to be weekly synchronization points. Like townhall meetings, they can only highlight learning opportunities, but opportunities must be captured after meetings.

To evenly distribute the workload, each team is responsible for organizing at least one week's worth of learning activities. If a team fails to meet the minimum standards, they are required to do it again. Each week's improvements are used as the minimum standard for the next week. To deliver accumulative quality improvements, teams must work with previous

teams to transfer experience. These requirements naturally trigger intensive learning activities after lecture hours. The increasingly challenging standards make following teams want to start their preparation work early. Based on student feedback, some students started preparing for the course a year ahead of time. This workflow architecture emphasizes incremental improvements and iterations. The synchronization points in workflows help students better manage their time. This workflow architecture also de-emphasizes test scores and student ranking. In this workflow, tests and scores are employed as tools to diagnose and improve learning, not as the goals of learning.

Laws that complement architectural elements

Architectural elements only establish pre-emptive constraints, laws specify the consequences of constraint violation. For instance, Internet-based source code control systems provide a technical infrastructure to monitor by whom and when assignments are submitted. Students must obtain user accounts and passwords before they can participate in this networked community. However, this technical architecture provides no mechanisms to ensure that students would actually commit their assignment on time. The motivation of submitting assignments on time; comes from “laws”, such as grading policies in the courses. The effectiveness of laws is directly associated with the community’s ability to enforce the execution of these laws.

Law execution consumes energy, time, and labour. Ideally, good architectural elements would not only reduce violation of laws, but also make it easy to execute the laws. Higher levels of technical infrastructure support provide the means to execute relevant laws. For example, version control software has features to automate the process of detecting late submission. It can also perform source code differencing to identify plagiarism. Laws, or grading policies, should be designed after the established architectural elements, and executed under the support of good technical, organizational, and workflow architectures.

The power of law should be derived from the power of reasoning. People need to be consciously aware of their own crime when they violate laws. Otherwise, when people unconsciously violate the laws, they tend to consider whatever legal consequences to be surprisingly harsh. When legal consequences induce emotional reaction, they will diminish the power of law to constrain human behaviour. In the case of plagiarism, many students simply don’t know how to properly cite the sources. Under innocence and ignorance, they might frequently commit “intellectual crimes” without knowing it. To address this problem in Knowledge City, we spell-out the differences between knowledge aggregation, dissemination and creation. Through the differentiations between different kinds of knowledge provisioning services, students learn to become aware of legal versus illegal intellectual practices.

In the process of knowledge aggregation, students gain intellectual credits by demonstrating their scholarship in the historical origins of certain content knowledge. In both data structure and database courses, students need to know the inventors of certain algorithms, when they are invented, and what tools use these algorithms for what purposes. Laws play a role here by judging the precision of their scholarship.

In the process of knowledge dissemination, teams are judged by their ability and compliance in making content accessible to others in various formats. First, they need to organize the technical content of interests in a presentable format, so that the recipients of this content knowledge can follow the messages being disseminated. Oftentimes, badly organized content prevents the audience from finding references to cited content, therefore compromising the integrity of the disseminated message. Moreover, students need to be aware of whether the act of knowledge dissemination is suitable. For example, in the database course, we discuss what kind of data is easily attainable and why? What kind of privacy concerns of demographic data stops us from sharing certain information? Are there

copyright laws that limit the distribution of certain data content? In this process, our goal is to improve the literacy of intellectual ownership and copyright laws to reduce unnecessary violations.

In the process of knowledge creation, students must go through a rigorous reasoning exercise to validate the claim of knowledge creation. Students need to present an argument that establishes the intellectual basis of knowledge creation. This exercise usually takes place when students start formulating their thesis in research papers. Many also quickly realize that it could be very convenient to work with others to systematically examine claims of knowledge creation. Knowledge creation requires teamwork, even if the discoverer is a single person. Claiming a creation is very similar to applying for a patent or going through procedures in court. To validate a creative idea involves many witnesses. It needs to have accumulated a relevant set of facts, and the facts must be presented to witnesses in a well-organized manner. Without a social context and the preparation in the two previously mentioned processes, creativity would appear lawless. As stated earlier, the power of law comes from the power of reasoning. Students need to learn to defend themselves and argue for their claims. These debate sessions usually take place in the instructor's office, because it is difficult to anticipate the time required to defend a creative idea. These learning activities help students to develop their litigation skills on engineering subjects. Students' awareness on how to claim intellectual contributions could systematically reduce the chance of unintentionally violating the code of conduct in Knowledge City. To prevent people from intentionally breaking the code of conduct, such as cheating or just being lazy, we need to analyze market incentives and cultural norms in the City.

Markets and the currencies of knowledge

In a university environment, students often want to obtain higher grades to improve their grade point average. Instructors often care about publications and student feedback to support their tenure cases. Teaching assistants are usually working on research projects, therefore, they often need new ideas and volunteers to help them conduct experiments. In Knowledge City, we consider grades, student feedback (students grade the instructors), and time commitment as different kinds of currencies. Under different contexts, these currencies have different exchange rates between each other. This section explains how currencies are measured and used in the two courses.

Grade Assessment

For most students at Tsinghua, grades matter. They need high grade point averages to apply for graduate studies. They also need to be ranked in the top fifty percent to be considered for certain paid public service positions at school. Grades are a very concrete form of currency. It directly motivates students to follow grading policies as prescribed by instructors. In this sense, instructors and teaching assistants own the power to distribute this currency. Normally, instructors would prescribe the weighting factors for different kinds of assignments in the syllabus. Students often have little input to the syllabus.

In Knowledge City, a syllabus is like a business contract between teachers and the students. We engage former and future students to edit the syllabus and ask for feedback in the beginning of the semester. We want both teachers and students to think about whether the grading policies are acceptable to them. The process of involving students to refine the syllabus sends an important message to students. Grading policy is just a somewhat arbitrary mechanism; there is not a lot of science to it. They have the power to determine their own grades, including the mechanism to calculate their final grade. This process makes them think about the objectives of learning. It is not the grade that we are after, it is the knowledge acquired in the learning activities that has more value. We instruct the students to come up with grading policies that support the functional goals of Knowledge City. They soon

realized that it is not that relevant, because a grade is a form of conservative resource, like oil or gold. It can be freely distributed without exhaustion. If they work toward the goals, they can get a passing grade. To distinguish between their level of success, higher grades go to people who contribute more to the City. People should compete on how much they collaborate with others. The process of establishing this grading policy motivates students to focus on learning outcomes, not gaming the system to get a higher grade.

Student Feedback

In many schools, students fill out teacher evaluation forms at the end of a semester. At Tsinghua University, these evaluation forms may directly affect their cases for promotion. To please students and get high marks in return, teachers might soften their academic standards and give bloated high marks to students. This exchange mechanism doesn't necessarily motivate teachers to become better teachers. Contrary, it has the potential to compromise teachers' authority.

To improve Tsinghua's educational practice, the leaders of Industrial Engineering Department, specifically Gavriel Salvendy and Li Zheng (郑力), convinced the university level administration of Tsinghua, to conduct an experimental program for innovative teaching in the Spring semester of 2008 in the department. They chose three courses, and conducted a few experiments to test whether different lecturing styles have different effects on students' creativity. During this experimental period, the administration agreed to remove student feedback as a component in the corresponding teachers' promotion cases. This special policy applies to the Data Structures and Algorithm course, and two other related courses in the same semester. To compensate for the extra work caused by the experiment, all participating lecturers and teaching assistants received a reasonably attractive financial reward.

In Knowledge City, we consider student feedback a critical element to help us improve the learning experience. However, we don't want to turn students and teachers into bean counters. Badly designed reward systems often distort the original administrative intent. A school is a human society. It is willing and capable of change. When presented with reasonable arguments, the political system in the larger context may act favourable to support innovation. It is up to all members in the community to propose incremental changes to the larger context. Overtime, we believe that concepts originally experimented with in the Knowledge City will be able to help better design the linkage between student feedback and lecturers' incentive systems. For example, in Knowledge City, students are invited to help design their own grading scheme. Similarly, there are many other experiments we can conduct in the City to identify better currency exchanges between different stakeholders in the community.

Time Commitment

Time is a precious resource for most people. When it is expensed, it cannot be replenished. Learning is a time-consuming process; it takes even more time to think about, and to refine a system that would improve the effectiveness of learning. When Knowledge City was first conceived, processes, services, and infrastructures to improve learning must be designed, implemented, and operated from a blank slate. These resources and services require students, teaching assistants, and lecturers to devote their personal time to build something out of nothing. As most engineering projects, initial attempts may encounter setbacks, and it was never clear what would have been the material benefits of trying to do something innovative on the subject matter of "learning". We often joke that university administrative structures are the slowest changing components in human society. Based on this observation, it is not administratively obvious for an engineering department to expend its

resources in the highly abstract domain of helping people to learn. Conventionally, engineering professors and their students should focus on concrete applications of scientific disciplines, so that it may pragmatically and technically demonstrate values of the time expensed.

In different marketplaces, value judgements are different. The academic discipline of Industrial Engineering is to identify improvement opportunities on a system level. When you want to build one rocket, you turn to rocket engineers. When you want to build one thousand rockets, you need to apply the principles of industrial engineering. Similarly, to teach one student, one needs to find a good teacher. To teach one hundred students, many principles of industrial engineering could help. At the Industrial Engineering Department of Tsinghua, and the Engineering Systems Division at MIT, it is our technical interest to study the complex interactions between humans and technologies. In other words, spending time on the design of learning organizations can be easily justified within engineering departments that study systems. In our biased view, we believe that all other engineering department should also be interested in the complex interactions between human and technologies. However, each department will likely bring in a different angle to enrich the marketplace of useful solutions.

In Knowledge City, all students and teaching assistants are explicitly informed that their goal is to improve the performance of the learning community as a whole. We invite students to come up with mathematical abstractions to measure their contribution toward the effectiveness of learning. We require students participate in team-based presentations and team-based projects, so that they can share their experience on learning new concepts and learning new tools. When sharing becomes a common practice, supported by reliable technical infrastructures, people start to benefit from their own contributions toward the community. Students who contribute more to the learning community gain respect from others. Their contributions are recorded in the database, so they improve their chance of receiving higher grades. Teaching assistants gain from sharing by knowing who are the most talented students in class. These students could complement teaching assistants in answering questions from other students. Lecturers gain from sharing by focusing in-class lectures on more advanced intellectual ideas. More fundamental ideas that could be explained by students and teaching assistants should be covered by students' team-based lectures, or in recitations conducted by teaching assistants or team-based study groups. In short, in the marketplace of Knowledge City, one spends time to gain more time. In many cases, the more you spend, the more you get out of it.

Norms and the effects of peer pressure

Conformity in a community has the power to push its citizens to establish certain habitual tendencies. Norm or conformity establishes social binding, and it can be leveraged to promote effective learning. In Knowledge City, conformity is utilized in a format similar to fashion shows. The town-hall meetings, or in-class lectures, are their opportunities to demonstrate their latest fashionable products. Each student lecture must be at least as stylish and as innovative as the previous team. Otherwise, members will receive pressure within a team, partially because their performance will be reflected on the team-based grade. If a team or an individual performed poorly, they will feel embarrassed in their respective community. The degree of embarrassment is related to the social norms. What is the normal amount of innovation one must exhibit to be considered normal?

The right to be different

We are not interested in indoctrinating students into a normalized regiment to tackle problems. Engineers must solve problems by recombining seemingly incompatible concepts and techniques into some working solution. Ideally, we want students to exert peer pressure in ways that keep other students interested and committed to their teamwork. We don't want

to instil a culture that blindly considers some tools or some approaches are strictly better than the others. For example, students are allowed and sometimes encouraged to mix and match Java, Mathematica, C and C# to create solutions in their team projects. We suggest they learn and use one programming language, namely Java, partially due to the ease of deployment and its popularity. For novice programmers, they can leverage a wide range of tutorials, documentation, and source code samples to help them learn. This doesn't mean that they should only use Java to solve all their problems. When students work with a language like Java, or C++, they tend to treat problem solving as a software engineering problem. They need to construct many class diagrams and collect many source code libraries before typing a line of source code. This also forced them to spend a lot of time to learn the syntax and existing libraries of the programming languages. Once they spent too much time on source code, they forgot the purpose of engineering is to solve an applied problem, not about demonstrating their programming skills. Certain tools tend to bring along a culture or norm to solve problems that may not be adequate to all problems.

To counter this Java-centric culture, we also introduced Mathematica as a programming and presentation environment, which shows them how to rapidly construct computational experiments and solve problems in an interactive manner. Mathematica is an interpretive language, it comes with a large functional library and visual programming components. For quick and dirty tasks, it bypasses many stages of software engineering practices. We want students to learn this different style of programming, so that they can see the norms in this type of work. Norms can be useful, when they are applied in the adequate context.

A shared value across Knowledge City

According to Richard Stallman, the founder of the Free Software Foundation [5]: "free software is a matter of freedom, people should be able to use software in all the ways that are socially useful." This philosophy ignited a software engineering revolution that created GNU, more popularly known as Linux, the first "free" operating system. It established a social norm that made a significant amount of well-engineered technologies available for free use.

We believe that this value must be deeply embedded in Knowledge City. The social value: "sharing is good", is different from "attaining competitive edge" as often mentioned in popular MBA courses. We establish the norm in our courses by demonstrating that engineering methods and technical resources usually create more value by having a larger community share the same standard. From an operational viewpoint, the world has already benefited from the philosophy and social norms created by the Free Software Foundation. It made many technologies freely available to the masses, created many egalitarian technical communities, and most importantly, this simple philosophy generated many high quality but low cost products. Without the technical achievements and social norms initiated by Richard Stallman, the two courses, data structures and databases, would be supported by a much smaller set of tools, therefore diminishing the forces that we could utilize the support learning activities outlined in this paper.

DISCUSSION AND CONCLUSION

We now go backwards from the force of norm, toward the force of architecture. In the 21st century, we have witnessed that the social norm of sharing engineering knowledge has generated many innovative products in various markets. The markets that endorse the exchange of open-sourced products and services also changed the practice of law, because it created new ways to interpret intellectual ownership. The lowered cost of engineering products also changed the architectural elements that support the functions of knowledge aggregation, dissemination, and creation. We argue that community-based learning activities

are driven by these forces, and curriculum planners should not only focus on the discipline-specific technical content, but they should see a class of students, or an engineering department as a miniature society. Then, it is possible to create an emergent learning society that is much more effective than treating individual students as the knowledge container.

Based on Lessig's four forces, this article presented a sequence of strategic considerations for designing a system-based engineering curriculum. We argue that curriculum planning must start with a set of architectural intent statements, or functional goals. Then, curriculum planners can proceed to select the technical, organizational, and workflow architectures for the subject matter of interest. Once the architectures are decided, we can leverage these architectural features to execute laws. Only through effective execution of "laws" or "school policies for learning", can the force of laws enhance the learning experience of the whole community. Otherwise, "laws" are just slogans and words that have no constraining powers.

Architecture and Law are the two forces for regulating activities before and after they take place. Market and Norm are the two forces that pull and push the entire learning community to learn more, or to learn with more effective methods and tools. These four forces complement each other, and they provide a new framework to think about curriculum planning and execution. In the past, engineering professors with deep domain expertise often designed curricula in ways that provide content knowledge to self-motivated individuals, so that they may eventually qualify for their future engineering tasks. In our proposed curriculum, students enrolled in a series of courses should be organized as a miniature society. This miniature society serves as a realistic context to practice collaboration, negotiation, and other survival skills that students must have before their graduation. To ensure the miniature society will productively deliver useful engineering experience to students, we described how the four forces model is used in Knowledge City to ensure delivery. Although our experience is limited to just one engineering department in one university, we believe that there are many elements of our work can be shared with other departments and universities to reduce their learning curve.

Balance and Symmetry

We need to first recognize that two courses in a series do not yet constitute a complete curriculum. However, we believe that the principles and techniques described in this paper are "symmetrical" across many types and scales of human organizations. In other words, the effect of these forces will not change when it is applied to situations that are much more complex these what we described here. We need to give credits to Lessig again, by mentioning that these forces were originally conceived in the context of the entire Internet-aware society. Therefore, we have the confidence that these forces can be used to balance many human activities independent of scale and type.

The administrative structures of organizations are often designed to include checks and balances. When we think of mobilizing a community of people to provide learning opportunities to each other, we need a set of symmetrical constraints that will cover all possible directions of movements. Architecture and Law complement each other on the time axis. Market and Norm are mirror reflections, because market pulls and norm pushes. These forces drive the quality of knowledge provision services in a learning community. We need a succinct mental framework that covers all bases; so that we can rely on constraining devices or pre-conceived correction actions to instil order. Without utilizing the vocabulary provided by social scientists, engineering knowledge provision will remain as a form of art.

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THE LEVEL-2 PROJECTS FOR COURSE CLUSTERS

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ABSTRACT

CDIO educational framework helps students to construct their expandable knowledge, personal, interpersonal and system competencies. We have put in practice the 3 level projects CDIO approach in the College of Engineering, Shantou University. The projects are divided to three Levels: Level-1 projects would be designed to cover the most of the knowledge and competencies of a bachelor program; Level-2 projects are designed to cover the knowledge of a group of the related core courses; Level-3 projects, which are similar to a course designing, are designed to cover a core course. We describe the designation, implementation and evaluation of the Level-2 projects in Computer Science program. The students answer our inquiry to the approach. The inquiry indicates that the level-2 projects are benefit to training students understanding of the project design, team spirit and mode of thinking..

KEYWORDS

EIP-CDIO, Three Level Project, Computer Science Program, Course Cluster.

INTRODUCTION

The CDIO is an innovative educational framework for producing the next generation of engineers. It provides students with an education stressing engineering fundamentals set in the context of Conceiving — Designing — Implementing — Operating real-world systems and products. It emphasizes the personal engineering abilities, not only the academic knowledge and skills, but also the hands-on learning of product and system building, disciplinary knowledge, and social learning. Combining the situation of China context, Prof. Gu developed EIP-CDIO (Ethics, Integrity and Professionalism) Engineering education framework. Focus on fostering high lever engineer, EIP-CDIO enhances the amalgamation of the personal character of Ethics, Integrity and Professionalism to the skills of Conceiving, Designing, Implementing and Operating.

EIP-CDIO is an education framework directed by the project design. The goal is training student's ability of engineering. It is the description and brief presentation of "Learning by doing" and "Project based learning." "Learning by doing", "learning by action" or "Experiential learning" is an education principle developed by John Dewey. He pointed out that the Learning by doing is advance than Learning by hearing. "Learning by doing" embodies the combination between learning and doing. It spans the knowledge from the classroom and real word actives. "Project based learning" lets students learning engineering through active and experiential methods. It constructs the relevance between courses. EIP-CDIO tries to

integrate whole course system through project designing process. In the framework, all the knowledge and skills needed learning are set surrounding the project design as a core.

THREE LEVELS PROJECT STRUCTURE

We categorize EIP-CDIO projects into three levels, as illustrated in Figure-1, depended on the size and the range of knowledge covered. Level-1 projects would be designed to cover the most of the knowledge and competencies of a bachelor program; Level-2 projects are designed to cover the knowledge of a group of the related core courses; Level-3 projects, which are similar to a course designing, are designed to cover a core course.

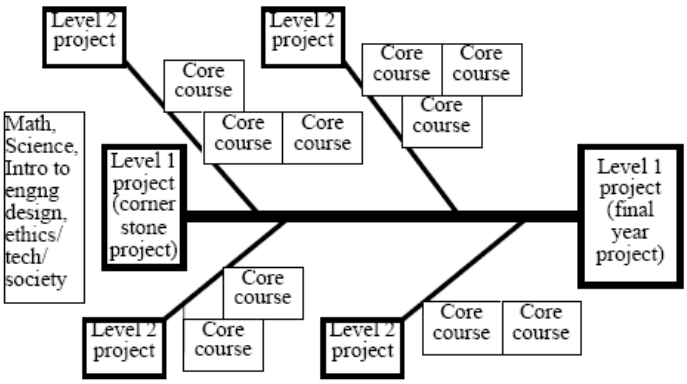

Figure-1. The three levels project structure

Level-1 project spans whole undergraduate program. It trains students in Conceiving, Designing, Implementing and Operating. A student, at least, involves in two Level-1 projects. The first one is the introductory project. Usually, it starts at 2nd or 3rd semester and ends at 6th or 7th semester. Students selected, supervised by teacher, one product as an instance, which covers the basic knowledge and application, to dismantle and analyses for learning its structure and designing thought. So that, students can understands the relation between the core knowledge of the area and real-work products early. Through the project designation, students learn the role of core courses in the area, improve the interesting in studying and create the knowledge structure in the area. The final year project is the second Level-1 project. Two projects connect each other. Through the training of the first project and courses studying, students have mastered the basic knowledge, gained the experience of project design and laid a well foundation for the final project (the second Level-1 project). The goal of the second Level-1 project is to design a real-word product. By Conceiving, Designing, Implementing and Operating the real-world systems and products, students learn how to resolve an engineering problem and know well thinking methods in Engineering.

Level-2 project link individual courses and echo to the issues rising from Level-1 project(s). In general, 3-6 Level-2 projects are involved in the undergraduate program. A project covers the knowledge related to a cluster of core courses in a certain area. As the support to Level-1 project(s), Level-2 project integrate the key knowledge points within related course cluster. In these projects students conceive, design and implement a middle size real-word background project using the knowledge related to the courses cluster. Its aim is training the ability of knowledge integration and application. Additional, as the complement to the classroom teaching, it plays an important role in cultivating the innovation ability and lifelong learning ability. While Level-2 project is the first time to complete a whole project, it is important to train the ability of teamwork, engineering understanding and rising the interesting.

Level-3 project is a project within a core courses. Based on the knowledge of Mathematics, professional background and scientific training, Level-3 project is set in a small size practical

project in a core course, in order to enhance the understanding and application of the content taught in class.

On overview of the 3 levels projects, the Level-1 projects play the role of the backbone in the EIP-CDIO education framework, the Level-1 projects look like the rib bone who supporting the back bone, and the Level-3 projects, which are similar to a course designing, are designed to cover a core course.

THE DESIGNATION OF THE LEVEL-2 PROJECTS IN COMPUTER SCIENCE PROGRAM

We have started to implement EIP-EDIO framework in Computer Science Program at Shantou University from 2007. The first Level-1 project is to develop a Card system used in campus. The system includes the hardware system, which reads and writes the information from (to) card reader; the software system, which processes the data saved in the database that stores the information of students, for example, the score of each course and the personal information; the transformation system, which transfers the information between the above two systems and keeps the information safety. The second Level-1 project (final design) is determined by director teacher. Next, we describe the Level-2 projects in our program.

We design four Level-2 projects are designed in the computer science program. The first one is designed for a group courses related to the basic theory of computer science: Introduce of Computer, Discrete Mathematics, Programming and Data Structure. It covers the knowledge of the physical structure of computer, the programming, the file system, the theory of relation, the mathematical logic, algebra, linear list, the tree structure and algorithm, graph structure and algorithm, search algorithm, sorting algorithm. Considering the support to the Level-1 project, we select the project---“The teaching management system in university”. In the system, the knowledge of the group of courses would be used. For the reason, we command the system:

1. The data is stored in documents (not existing database). This let students understand the document system well, specially, the management and operation of binary document, text document and data stream. Developing sorting, ordering programs training the ability of programming.
2. Creating the data structure based on relation system. The relation theory is the basement of modern database system. This work let students understand the importance of “Discrete Mathematics” in computer science program and enhance the connection between courses.
3. Developing data input and output system to connect with public software. Modern software often is a multi-platform. This work let students familiar in transform information with public software.

The second project involves in the courses related to the hardware: Electronic Circuits, Digital Logic, Assembly Language, Computer Organization and Architecture, Microcomputer Principle and Interface Technology. It coves the knowledge of the combination of timing and logic circuits, design of small-scale digital system, the basic methods of hardware description language (VHDL), the usage of the simulation and electronic design automation software (Quartus Ⅱ), the usage of the PLD develop version (DE2), the input and output instructions of Assembly Language, programming of cycle, the delay and keyboard control. For these tasks, in this term, we give four projects to select.

1. Designing a Digital Clock. The Digital Clock has the function of timing, correcting and ringing.
2. Designing a Scare answering devise for four persons. The digital scare answering devise with the function of scare answering, counting down and buzz warning.

3. Traffic light controller. The project needs designing a traffic light model, which simulates the working of a traffic light in a crossroads, with the function both of automatic and manual controlled.
4. Digital Frequency meter. The project needs designing a simple frequency meter with the function of multi-grade measurement, automatic measure grade adaptability and supporting multiple wave inputting.

The third Level-2 project includes a group courses related to advanced software: Principles of Database, Object-Oriented Analysis and Design, and Software Engineering. It covers the knowledge of software developing models, programming, algorithm designation and database designation and management. The project focuses on the large-scale software system designation, application of database and Object-Oriented system analysis and programming. We give the project is “the manage system of student game”.

The fourth Level-2 project contains the core courses related operate system and network: Network and Communication, Operate System and Multimedia Technology and Application etc. For these reason, our project is “Real-time communication network platform”. Through the project, we propose that the students use the knowledge of network to a real-world and practice the whole procedure of Conceiving, Designing, Implementing and Operating.

THE IMPLEMENTATION AND EVALUATION OF THE LEVEL-2 PROJECT

We have implemented the first 2 Level-2 projects in Shantou University. The students are assigned to teams. Each team contains 5-6 students and a teacher as the couch. Students through concrete projects will be able to learn the professional knowledge and skills, the spirit of teamwork and cooperation, communicate with each other and work together. During the design process, they can take advantage of technology and scientific knowledge, to have innovative thinking and creativity.

When the students finish the project, the instructor team carries out the inspection reports. The inspection follows the steps: 1) the team leader introduces the entire project designation and implementation; 2) group members shows their specific tasks, as well as the development and solution method to the key problems; 3) demonstration their system; 4) the teachers and students ask questions for the project and the group members answer; 5) The instructor team summarize the project and assesses the grade, and pointed out existing problems and give suggestion to improve the project.

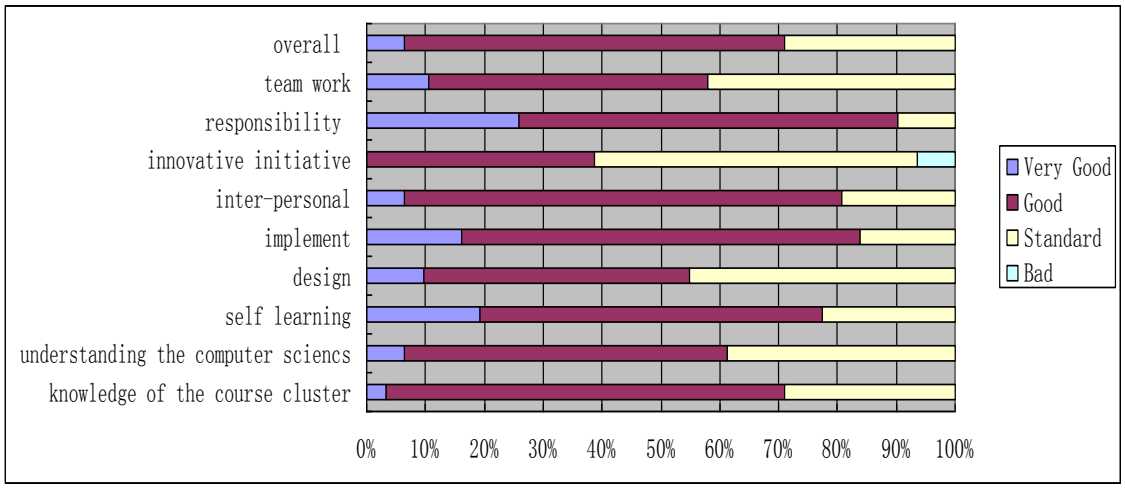

Figure-2. The evaluation of the Level-2 projects

For evaluating the availability of the approach, we inquiry the students (about 60% students attended) with a questionnaire. There are 10 questions in the table and each question has 4

options: Very good, Good, Standard and Bad. There are 6.5% and 64.5% students with Very good and Good to the approach; 25.6% and 64.5% students feel Very good and Good to improve the responsibility; and most questions have got the Very good and Good answers. The Figure-2 indicates the results of the approach.

CONCLUSION

The Level-2 projects are designed to cover the knowledge of a group of the related core courses, as well as cultivate the relevant competency. As the support to Level-1 project, it is an integration of the knowledge points in the related course cluster involved in. This requires students to use the knowledge conceiving, designing, implementing and operating an actual background of the project. Each project is the supplementary to the classroom teaching system, in order to cultivate innovative thinking ability and lifelong learning ability. From the time point, the first Level-2 projects is the first time to complete a full project. Training of his understanding of the project design, team spirit and mode of thinking as an engineer is the main purpose. At the same time, it plays an important role for the interesting to their major learning.

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The problem of scale in design-implement experiences in civil engineering

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ABSTRACT

Engineering knowledge has been subject to software development for decades. Software opens the door for new kinds of multi-disciplinary collaboration between architects and structural engineers. Software gives architects access to specialist knowledge and engineers can test and compare many more solutions faster because of the software. But simulations of e.g. structural behaviour must be based on real-life experience of the effect of forces and of various structural concepts or they will lead to errors or processes and designs that are too costly. Design-implement experience for students of civil engineering poses a special challenge because of the large scale involved in civil engineering. The dilemma is defined by cost on the one side and on the other by the need for the design implement experience to grasp issues of real civil engineering.
The paper describes how the testing of scale models and fragments of structures is problematic, and how a chain of design implement experiences can be arranged to lead up to a reflective use of digital simulation as a professional tool.

KEYWORDS

Design-implement experiences, civil engineering, architectural engineering, structural engineering, scale, digital simulation, Finite Element Analysis, models, structural concepts.

A NECESSARY CONTEXT FOR DIGITAL SIMULATION

Digital simulation of structural behaviour is an integral part of the working methods of civil engineers. Digital simulation tools were developed through the last generation's focus on numerical methods. Finite Element Analysis is used at many different levels in the design and construction process. Over the last decade, the speed and precision of these digital simulation tools has increased. This opens the door for new ways for structural engineers to work. Numerical information on design proposals can now be generated along with the very first and blurry sketches from the project start-up phase, and this information can be continuously updated as the design process proceeds. It was quite different 20 years ago, when the calculation of exact dimensions was done at the end of a design process as a kind of final documentation because it consumed so much time and money. The modern design engineer is a new professional character in civil engineering and depends heavily on the technological revolution that has taken place in digital simulation tools. The potential gain in

terms of aesthetics and finance in this new kind of design process seems to be enormous. Ideally, solutions with serious drawbacks should get exposed clearly early in the design process and there should be new opportunities for collaboration between engineers and architects.

But has Finite Element Analysis led to refined and optimized structures through better understanding of structural behaviour? [1] When dimensions (thickness) of concrete shells and plates from 1930-1960 are compared with those of recent projects, a regression is observed. [2] Either industry lacks real confidence in the results of the simulations or the simulations are being made wrongly or based on inadequate understanding of structural principles. As a consequence, the dimensions of structures exceed what is necessary. Closely related to this observation is the phenomenon that in many projects senior or even retired engineers with great experience are engaged to give input at a conceptual level and late in the process to check that common sense has been observed in the interpretation of the results from Finite Element Analysis. One example is Professor Niels-Jørgen Gimsing's role in the present project for a new bridge over Firth of Forth by a large British engineering firm.

There is apparently a missing link between digital simulation and real-life civil engineering. To take full advantage of digital simulation of structural behaviour, a real-life context needs to be taught and experienced already at university. What should this context consist of? First of all, it is important to have an overview at a conceptual level – of structural concepts. Second, but closely related, the student needs a good sense of the effect of the structural forces at work.

Using digital tools requires "old-school" knowledge of structural concepts

Understanding structural concepts
Galileo Galilei showed in the 17th century that you cannot simply enlarge a structure – at a certain point a change in structural concept is demanded. [3]
The very notion of structural concepts is too often absent in the education of civil engineers; it seems to have been pushed into the background, to make room for numerical methods (Finite Element Analysis).

Figure 1. Students work with cardboard and plaster scale models

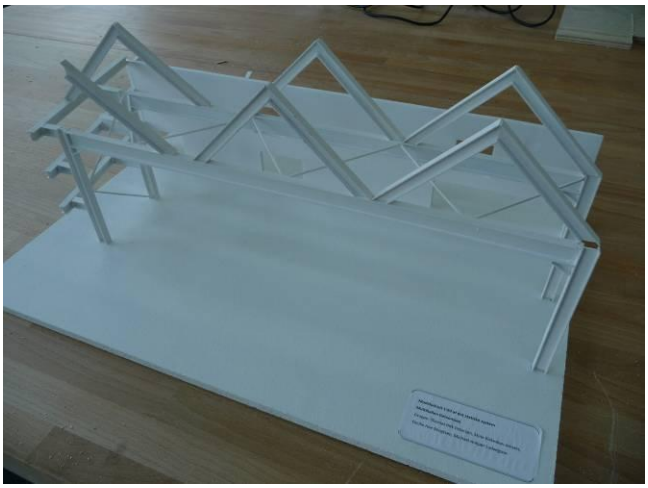

Figure 2. Cardboard models of structural concepts of existing buildings in the vicinity of the university campus

What civil engineers actually do when they design a structure is use their knowledge of how forces work in the structure. But as one of the grand old men in Danish civil engineering, Jørgen Nielsen, put it, “No one has ever seen a force”. He still works (in his 90s), as always, by designing structures in accordance with how the force lines run through the structure. [4]
In his generation, the analytical tool called ‘grapho-statics’ helped develop this visual understanding of forces in structures. [5] Today, the colourful graphics of the new digital simulation tools do a similar job. But there is still a mental transformation to make from the digital graphics to the structural behaviour of real-scale civil engineering structures. In spite of the digital graphics, it is clear that there is still a missing link in terms of the notion of structural concepts. Analysing structures at a conceptual level demands a kind of mental ‘X-ray’ view, with which the engineer looks through the many layers of information and sees the core, the skeleton of the building, and has a clear vision of whole sets of related concepts. When a scaled-down cardboard model of a structure is built, it becomes a concept and ceases to be numbers and equations, blue and red graphs running up and down the computer screen. Scale-models in cardboard work in a straightforward manner and give an instant impression of how forces run. If you press down one corner of the model you can observe how it deforms and feel how it pushes back. And you may realise where the balancing tension will appear. In fact, you can sense the forces in the structure in this way with the body. [6] Once you have this experience and an overview of categories of structural concepts, the digital tools have an adjusting and error-finding role.

Getting an idea of the forces at work by experimental testing of scaled-down models

In the education of civil engineers, the large dimensions of structures have always been a challenge. As a student of civil engineering, it is difficult to get a hands-on experience of the real forces we work with. Scale models give a chance to experience with all senses and look at structures in a holistic manner. Much more complicated is the use of scale models for experimental and accurate testing in order to understand the effect of forces and as a professional tool for giving exact dimensions.

In Germany, Switzerland and Spain, there is a long tradition of working with scale models in designing real-life civil engineering structures. Engineers Frei Otto and Heinz Isler set up advanced workshops with test facilities in order to develop structures solely through scale-model testing of structures. The famous structures of the 1972 Munich Olympic Games were conceived and constructed by means of scale models.

But it is not possible to ‘translate’ directly between scale models and real life. Transforming results from the testing of scale models into real-life structures is a scientific speciality in itself. The complex layer of theory acts as a barrier to students’ understanding of the forces at work in a structure. The complexity is such that, unfortunately, it is not for bachelor-level students to work with. And there are a number of problems in the practical set-up of scale-model testing. In general, the geometrical requirements for tolerances are high. Some materials are difficult to scale up and down (e.g. wood and concrete), fittings need to be custom-made, etc. All this ‘translation’ moves the student away from the goal: to have a better sense of the effect forces in real life. So long as exact dimensions are aimed at, the potential in scaled-down testing as an option for design-implement experiences is limited.

If the aim is a conceptual understanding of structures, scaled-down testing is useful as described previously, but in that case quick and cheap mock-ups in card work better.

Testing real-scale (1:1) fragments of structures (timber joints)

One solution to the problems of the large dimensions of real-scale civil engineering structures and the problems of scale models aimed at giving the exact dimensions of structures is to create a design-implement experience with a fragment of a 1:1 structure. The idea was to calculate, build and test various joints in a wooden frame structure. First of all, the second-semester students designed a small summer cottage in an architectural studio course using the structural concept of wooden frames. Then some of the various kinds of joints were chosen by the teacher of statics. The students then calculated on a theoretical basis the maximum load capacity of the joints. Then they went to a workshop, made the wooden joints, and finally tested these timber joints. Comparisons between the calculations and the test results were recorded in a report.

Figure 3. Testing 1:1 timber joint

Unfortunately, students did not give this design-implement experience a positive evaluation (table 1). There were several lessons to learn. The most important was that joints or fragments of structures are difficult to calculate from a theoretical point of view. Understanding how forces meet and distribute in a fragment requires a lot of experience and knowledge. It is actually too demanding and complex for second-semester students. Apart from this important obstacle, there were also other minor problems with the design-implement experience. The workshop facilities were not adequate and perhaps this is why, the students assembled the joints in a crude and inadequate manner. The large tolerances

involved resulted in completely different test results than they had expected from calculations. But it also drew attention to another important outcome of design-implement experiences: good craftsmanship and the issue of tolerances are not just about looks and finish. Students observe the consequences of a poor construction process in term of structural collapse. Due to inadequate communication between the three courses involved, the assessment of the process had not been agreed and students were quick to notice that no separate mark would be given for this design-implement experience. Communication with the students at the planning level was also poor. However, it was a true eye-opening experience to see a structure tested to destruction. The impressive power involved and the outburst of energy and sound at the point of destruction gave students a new perspective on theoretical statics.

Table 1
Assessment of the first version of second-semester design-implement experience
18 students out of 42 replied (N=18)

Q: The learning outcome of the CDIO design-implement experience was:

Very good	Good	Medium	Poor	Very poor
0%	0%	5.6%	27.8%	66.7%

Q: Having collaborative projects between several courses in the curriculum creates a better overall study:

I fully agree	I agree	I agree to some extent	I do not agree	I do not agree at all
22.2%	27.8%	38.9%	11.1%	0%

Q: If we are to build models we need better workshop facilities:

I fully agree	I agree	I agree to some extent	I do not agree	I do not agree at all
50%	38.9%	11.1%	0%	0%

The evaluation was carried out by DTULearningLab, Assessment and Evaluation Specialist Peter Hussmann, November 2008.

A CHAIN OF DESIGN-IMPLEMENT EXPERIENCES IN THE FIRST 3 SEMESTERS

Based on the above experience and evaluation, a chain of design-implement experiences for first to third-semester students was organized to provide an understanding of the forces and structural concepts before introducing digital simulation.

In the first three semesters, the basic theory of statics is taught with lectures, literature and exercises. But in a process parallel in time, the students are gradually prepared for using the digital simulation tools.

First semester – cardboard models & structural concepts

Their preparation starts during their first semester, where they do case studies of buildings in the surroundings of the university. Three different courses work together in a teacher team to create an eye-opening experience: structural concepts are all around us! The students develop their notion of structural concepts by building cardboard models of structures in the

neighbourhood. After some weeks, the students are then asked to take their specific case-study structural concept and transform it into a small tower. This demands a high level of skill in relation to Bloom's taxonomy. If the student does not understand the notion of structural concept it will show in the tower design. The tower design is presented in a 3D digital model.

Second-semester – real-scale testing

To include the lessons of the first version of the design-implement experience, students were involved in the planning from the beginning. The following alterations were made: instead of a fragment (joint) of a real scale 1:1 structure, a complete structural member is built and tested. This, of course, is far more time and money-consuming, but it had proved too difficult for second-semester students to calculate joints, and the way forces work in a structure becomes much more apparent when a whole structural unit is built and tested. Students calculate dimensions and make their own accurate construction drawings. A better workshop was organized with a professional air to it. Students were told to pay attention to the precision of execution and that their craftsmanship skills would be a large part of their grade for the design-implement project. Actually there was an unexpected bonus in having the focus on tolerances in execution, because this is one of the rare occasions where ethics can be directly discussed in connection with engineering. Furthermore, of course, there are consequences in terms of the behaviour of the structural member.
New assessments of the revised CDIO design-implement experience (now running) will be presented at the Conference in June 2009 to be compared with previous results (presented above).

Figure 4. Building 1:1 timber frames in the new workshop

Third-semester – using professional digital simulation

The design-implement experience for third-semester students finally involves professional simulation tools **(**STAAD.*Pro* software). Although valued low in the CDIO hierarchy of design-implement features [7], it can be argued that we build up thoroughly for this first experience of using professional simulation tools with other more 'hands-on' experience. To be part of a design team with architects at an early stage in a project, it is important to know how to use fast simulation tools that give feed-back as you go.

In the first week, students develop structural concepts for a small footbridge using STAAD.*Pro*. Each group has in fact outlined a specific group of structural concepts to work in

(cable stays, beam, arch and trusses) and an effective height and width, but no specific location. The concepts are therefore easy to calculate because they are ideal and abstract. Students present their work in sketches and graphical results from STAAD.*Pro* software.

After the first week, students are asked to redesign their ideal structural concept to meet the demands of a complex urban context. After two weeks of simulation and design they present their footbridge proposal in Indesign posters together with 3D Studio MAX animations and a static reports with both simulation results from STAAD.*Pro* and hand-calculated 'safety checks'.

CDIO design-implement experiences in civil engineering form a necessary context for software-based engineering. They can be combined in a series with good results, where only one of them implies real-scale structures. The design-implement experiences create a better understanding among students for the reality behind the simulations.

Figure 5. Students presenting results from STAAD.*Pro* simulations of structural behaviour

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Biographical information

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Henrik Almegaard is an associate professor at the Department of Civil Engineering at the Technical University of Denmark (DTU). His current research focuses on ways of supporting and qualifying the conceptual structural design process as well as the dialogue between the structural engineer and the architect.

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THE ROLE OF MATHEMATICS AND THE CONCEPT OF MODELS IN A CDIO - APPROACH

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ABSTRACT

Since the mid eighties educational concepts based on students' work as organized in groups and based on project work with assignments from the real world have dominated Danish engineering programmes as well as many others and proved valuable in terms of preparing the students for complex working situations. The Qualification Frame terminology with emphasis on competencies pushes in the same direction. In the definition of didactical methods it is suggested that theory to a large extent be substantiated by examples from the professional field in question, and that the project work comprises a range of disciplines to appear realistic.
With changing and more varying job profiles it may be a threat that students are pushed to achieve results at the expense of the supporting theory or performing sensitivity analyses.
This first inspired me to look more closely into the students approach to and qualifications in theoretical subjects. Subsequently it appeared rewarding to set up a tool describing a systematic approach to the application of theory and performing sensitivity analyses, as a supplement to achieving results in a project, or building/ constructing something as the "I" and "O" in the CDIO terminology suggest.
Engineers are very familiar with working with models, be it physical or theoretical. Proper application of the traditional modelling concept leads the students through the same stages as physically making a product, and hence enlarging the concepts of implementing and operating.

KEYWORDS

Theory in projects, Acquiring Mathematical knowledge and skills, the European Qualification Framework (EQF), Applying a Model approach to the C-D-I-O´s

ENGINEERING PROFILES

Various engineering profiles and the implications to the span of curricula

Numerous papers and reports on the required qualifications and competencies of future engineers point out that development in technology, society and profession demand more complex and varying competencies than only few years ago [1],[2]. It is typical, however, though for the same reports that the knowledge and skills within classical topics are implied, for instance in [2]. Hence classical engineering disciplines experience a pressure, and institutions are compelled to define rigorously the profile(s) of the candidates and the didactical methods applied.

Short on definitions in Qualification Frame terminology, and learning taxonomy

Incidentally, before continuing to describe profiles, it could be useful to quote some definitions in qualification frameworks, as these reflect the present level of ambitions throughout many institutions.
In the European Qualification Framework [3] the terms knowledge-skills-competencies are adopted. A short definition is as follows:

- The term *Qualification* is used to describe professional *knowledge and skills* typically, but not necessarily solely, acquired through studies. It may be theoretical and/or practical, and will often be documented by diplomas.
- The term C*ompetence* is used to describe, whether the sum of qualifications, personal qualities, experience and attitudes enables the person to solve a given assignment.

The tripartition knowledge-skills-competencies is used to characterize the various levels within the educational system, although it is obvious that competency should be regarded a super conception to the others. Competencies are characterized as:

- *Making judgements*
- *Communication skills and cooperation*
- *Learning skills*

It should be noticed, that although there are similarities, the Qualification Frame is not equivalent to a traditional learning taxonomy, which to different degrees assumes a progression between levels.

The training at engineering educations should then be organized with the aim of preparing the student to acquire competencies by solving complex, maybe vaguely defined but realistic tasks. The engineer should be trained to delimit problems, to identify solutions, and to take into consideration many constraining aspects like sustainability, economics, social conditions, and others. Project work with a proper defined assignment is a good tool to achieve this, but may suffer from each of many contributing disciplines being suppressed.

Relating the project work to the conception of a model could be a useful tool to ensure that theory supports the solutions. At the same time the conception of a model nicely follows the main ideas in the CDIO-concept as described in [4].

Engineering profiles, continued

In [5] five profiles of an engineer are suggested:

- *The Consultant* needs to be confident with standardized methods of technical solutions and their implications to a wide range of applications.
- *The Designer* needs to comprehend the final consumer's demands to the product and any technical aspects without necessarily making the detailed design.
- *The System Builder* needs to be an expert in a narrow field yet at the same time understand the context.
- *The Organizer* needs to combine the knowledge of others into a system or a product.
- *The Model Developer* needs to be confident with both practical applications as well as theory behind models.

More traditional profiles could be added such as:

- *The Communicator:* needs to communicate the rationale behind technical solutions to a broad audience.

- *The Salesman:* needs to know strengths and weaknesses of a product, but not necessarily the theory behind it.
- *The Producer/Entrepreneur:* needs to be familiar with many adjoining fields.

The profiles above are quoted very briefly – the qualifications required and the degree of expertise vary, but common to the profiles is the ability to adopt a systematic approach. Two tendencies for more of these profiles in relation to the application of theory are [5]:

a) It is being easier to apply computer programs, while demands to those creating them increase.
b) New technology implies improved possibilities for advanced and repeated computations, but seldom less demands to the ability by the user to judge results and methods. The challenge is to educate engineers with a proper mixture of knowledge, skills and competencies.

In continuation of this the background for the investigation as referred to in the following was partly the straightforward to design effective mathematical teaching, and partly to focus on the coherence between theory and application.

STUDENTS APPROACH TO MATHEMATICS, AND REASONS FOR FAILURE

In order to investigate the prejudice that Mathematics is difficult to comprehend for Bachelor engineering students and also to find out possible impediments to the acquisition of routines in the application of basic mathematical tools, a quantitative survey was initiated. So far results from 260 students in 5 programmes have been included. For time series of parameters (marks in Maths), a succession of 5 terms of admissions have been included. For certain parameters comparisons are made to a similar investigation for first year students in the scientific programmes at Aarhus University. A huge amount of qualitative data in the form of course evaluations are available as well, but is not taken into consideration in this context. The following parameters have been investigated:

a. Rates of passing first examination in mathematics
b. Background in terms of marks from high school
c. Correlation between marks in mathematics in high school and at university
d. Particularly failing students as representative for the total population
e. The effect of participation in optional introductory courses
f. Time elapsed since qualifying examination
g. Type of qualifying examination
h. Gender
i. Possible change over time
j. Comparison between various methods of examination (projects, oral, written)
k. Students' efforts

Only selected results that lead to conclusions will be quoted. They are presented as a mixture between results and interpretations:

a. Rates of passing vary between 73% and 83%. This figure is computed solely for students actually taking part in the examination, and it is still to settle, what influences a drop-out rate of 15 -20 % at this stage. A passing rate as quoted is not considered critical, but still result later in the studies indicate lack of ability to apply the knowledge (j)
b. This parameter is included in order to compare to populations at other comparable programmes, but so far no results are available.

c. Results are shown below (figure 1) as a typical scatter diagram, and correlation is vague. Results from the Aarhus University confirm this pattern. It is obvious that the qualifications required at university level are different from those at high school: a high mark in high school does not guarantee similar good results at university, and vice versa. It must be mentioned that other investigations, e.g. [6] arrive at opposite conclusions, which could be due to more similarity between examination methods and curricula.

d. To further investigate this, marks from high school for failing students are compared to the full population. It shows that these students on average have marks that are ½ mark lower than all students. (the Danish marking scale has 7 marks, equivalent to that of the European scale)

e. Recently an optional brush-up course was offered prior to start of studies. Results are promising, but so far blurred by mainly well motivated students taking part.

f. It was assumed that students with high school qualification fresh in mind would do better at university – however the opposite proved to be true, and the difference is almost one full mark between students starting straight from high school, and students with 2 years of experience. This emphasizes the conclusion that university studies are different, and it also suggest that maturity and attitude to studies matter.

g. As this refers specifically to the Danish educational system it is omitted here.

h. There is no significant correlation to gender.

i. It is assessed that too many parameters influence this result to make any conclusions

j. Marks obtained in written examinations are significantly lower than those in oral or in project examinations (approximately ½ mark). Results from [7] show not surprisingly that marks in written test are rather sensitive to the way papers are designed. This is to be addressed, as well as the students' training in coping with written assignments in contrast to project work.

k. Students' efforts obviously play a great role. This is recorded through evaluations, but has not been possible to measure directly.

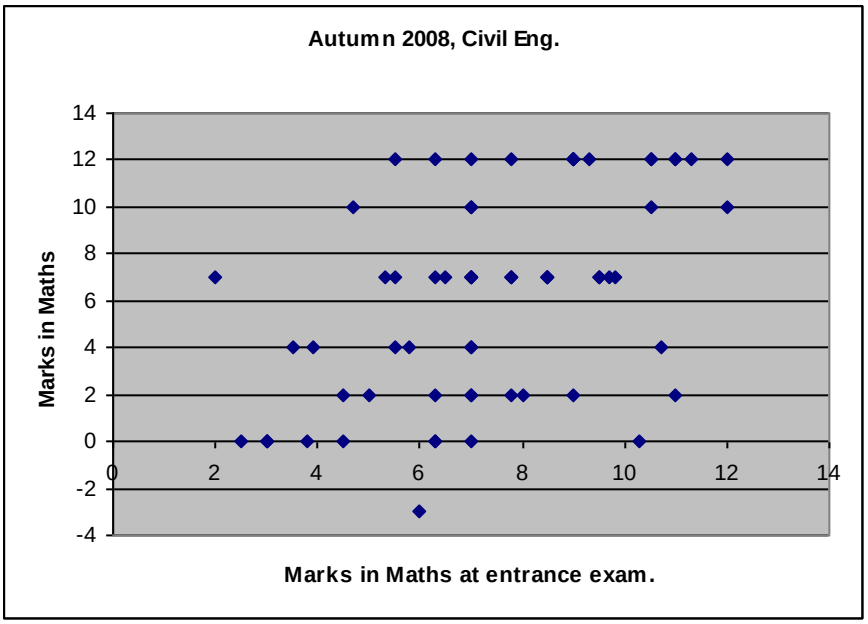

Figure 1. Scatter diagram showing the influence of marks at entrance examination

Experience shows that the interest among engineering students is directed towards application, which has lead to intense integration of application in mathematical teaching. In

later subjects the importance of theory is often blurred by the use of programs or table values. Summing this up the conclusion and actions relevant in the present context were:

It should be clear when mathematical skills are trained as abstractions, and when the application is in focus. In order to motivate students, application to engineering problems is important, but only after the basic skills have been acquired. The model concept as described in [8] and [9] is considered a useful tool for this.

In project based programmes the higher levels in a learning taxonomy (application, assessment, synthesis) are often more important than skills are. As the curricula in Danish high schools recently changed to emphasize the same qualifications ("preparing for methods of studying, rather than training skills") it is important for university educations to be aware of the basic skills. This can conveniently be handled in the "Model-model"

THE MODEL CONCEPT AS FRAME FOR COMBINING APPLICATION AND THEORY

The concept of a model can conveniently be used as the framework for projects and ensuring both the application part and the theoretical part.
The principles of the model are traditional and shown in many versions. The present is inspired by [8] and is extended by the C-D-I-O stages as explained below. It is crucial that the work is circular, which means that by returning to assumptions and tools through recalculation and verification, an experience is gradually built up. In a learning environment this means building up understanding and experience of theory.

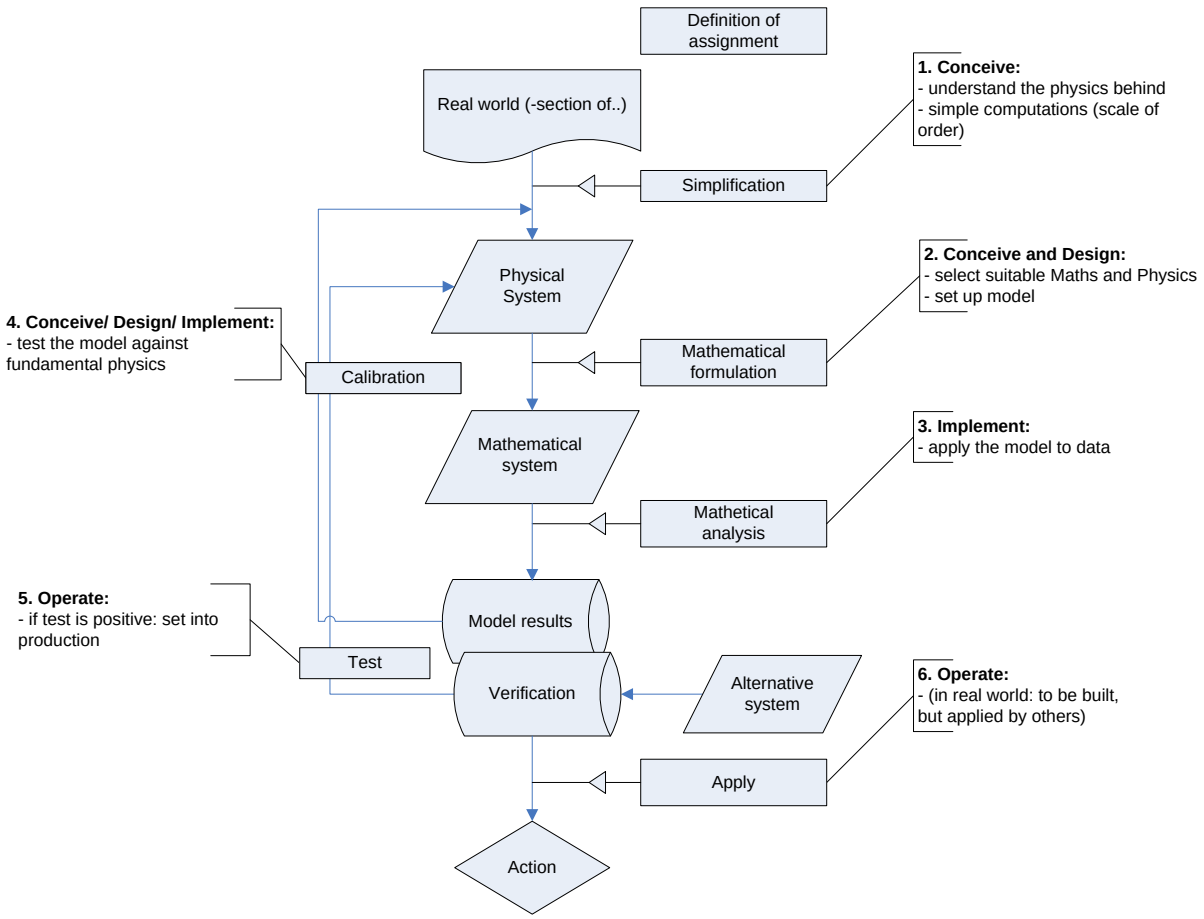

Figure 2. Stages of a model related to a CDIO-approach

The *"Conceive-stage"* (marked as "1" and "2" in Figure 2) is evident; depending on the complexity of the assignment given, it may include simplification of the real world (1), or the simplified physical system may be provided. At this stage the user needs to understand the strengths and weaknesses of Mathematics and Physics as tools in the context.
The *"Design-stage"(2)* is the process of setting up the proper formulations, be it a simple differential equation with proper boundary conditions, or be it a computer program.
The first step in the *"Implement-stage" (3)* is the work of producing results and performing sensitivity analysis. At this stage it is necessary to return to basic assumptions.
In a simplified version the concluding *"Operate-stage"(6)* would be actually constructing the physical item that was modelled. This may be beyond possible range in a university context, but advantage should be taken in the model being circular, and is suited to recalculations:
In a second and combined "Conceive-design- implement-stage"(4) test data are applied to the model – also called the a calibration. If results are valid, a final test may be performed against different data.
In model terms the model is now ready for production or the "*Operate-stage"(5)* – even though no physical items are produced.

The same sequence is illustrated by a very simple example, namely designing a beam:

Conceive:	appreciate the physics of support, loads, differential equations etc.
Design:	apply the tools to compute a beam from a real-world building
Implement:	analyze with respect to boundary conditions, price etc; re-compute as required
Operate:	compare to test results and to beams in structures; perform scale tests

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Biographical Information

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THE ROLE OF PEERS IN THE ASSESMENT OF STUDENTS' CDIO SKILLS

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ABSTRACT

At the University College Ghent, staff has gained expertise in peer assessment strategies for formative and summative assessment. Recently also online facilities have become available within the electronic learning platform, enabling flexible schemes in the use of peer assessment such as use of qualitative or quantitative scales, variable group size, variable assessment criteria, …. In the Faculty of Applied Engineering Sciences as well as in the Faculty of Technology peer assessment has mainly been practiced in the framework of design-implement projects. As reflected in the pilot survey, staff and students perceive peer assessment as a valuable manner to evaluate group dynamics, personal and interpersonal skills and to extend the evaluation process from "product" to "process". Some kinds of peer assessment appear to be an effective way in the acquirement of CDIO skills. The paper concludes with some guidelines for practitioners preparing to make use of peer assessment.

KEYWORDS

Online peer assessment, design-implement, student perceptions, coaches,

INTRODUCTION

In order to comply with the CDIO concepts and standards, the Faculty of Applied Engineering Sciences as well as in the Faculty of Technology redesigned their curricula, introducing design-implement projects from the first year onwards and introducing gradually all of the 12 CDIO-standard.

Together with the introduction of these new learning experiences, new assessment techniques needed to be implemented in alignment with these educational practice. It was opted to enrich the more traditional assessment methods with peer assessment. As found in many studies [1], peer assessment can be a valuable assessment practice in higher education although also problems occur, which can be prevented by combining peer assessment with self- assessment or co-assessment. Furthermore the CDIO vision includes the practice of a whole range of assessment methods that should be aligned with the specific teaching and learning outcomes [2].

Gaining expertise with peer assessment enabled the teaching staff to fine-tune their practice and to develop an appropriate online tool for peer assessment compatible with the Dokeos open source electronic learning environment.

IMPLEMENTATION OF PEER ASSESSMENT

The peer assessment experiences discussed in this paper include the practice linked to design-implement projects as implemented in the Faculty of Applied Engineering Sciences and the Faculty of Technology. In all the concerned curricula, peer assessment is conducted with the same online tool which has been integrated into the electronic learning platform. Although the assessment criteria may vary, the practice is based on the challenge to individualize group marks obtained for group work performances such as design-implement project and to include group process issues into the marking.

CDIO Students' Skills

The peer assessment mainly involves personal and interpersonal skills. This is related to standard 5, 7 and 11 of the CDIO syllabus [2], [3]. Standard 5 (design-implement experiences) offers a framework for acquiring these kind of skills. Standard 7 (integrated learning experiences) focuses on the integration of a range of skills including personal and interpersonal skills such as ability to work in team, communication skills, leadership, etc., while standard 11 (learning assessment) deals with assessment methods matched appropriately to all learning outcomes. The criteria assessed by the students in our peer assessment method include participation, collaboration, communication and problem-solving issues. The assessment criteria are shown more in detail in Table 1.

Table 1: Criteria used for peer assessment

Is alert , participates in the reasoning process, follows the train of thoughts, is task oriented
Takes initiative, is willing to engage in tasks
Is well prepared for meetings, contributes with useful information
Structures his/her information and gives a neatly arranged summary
Adds new ideas to the discussion
Has a critical attitude
Shows constructive engagement in problem solving, proposes appropriate solutions, is willing to accept compromises
Gives own views
Listens to the others and makes efforts to understand them
Contributes to a positive group climate

These criteria are all linked to one or more of the fore-mentioned CDIO standards and have been proved useful in testing competencies related to functioning in a team.

Online tool

The online tool for peer assessment was first introduced at the University College Ghent in 2007. Until then, peer assessment had been done by letting the students fill in a test form and manually processing these data. The work involved and the rigidness of the paper form made it virtually impossible to continue with this form of assessment. The present online tool has been build-in into the electronic learning platform Dokeos and allows flexible use in terms of group size, number of groups, assessment criteria, etc. and guaranties anonymity. It also allows for imposing a time span in which filling in the electronic evaluation form is allowed. Figure 1 shows a screenshot of the peer assessment tool when it is used for the first time.

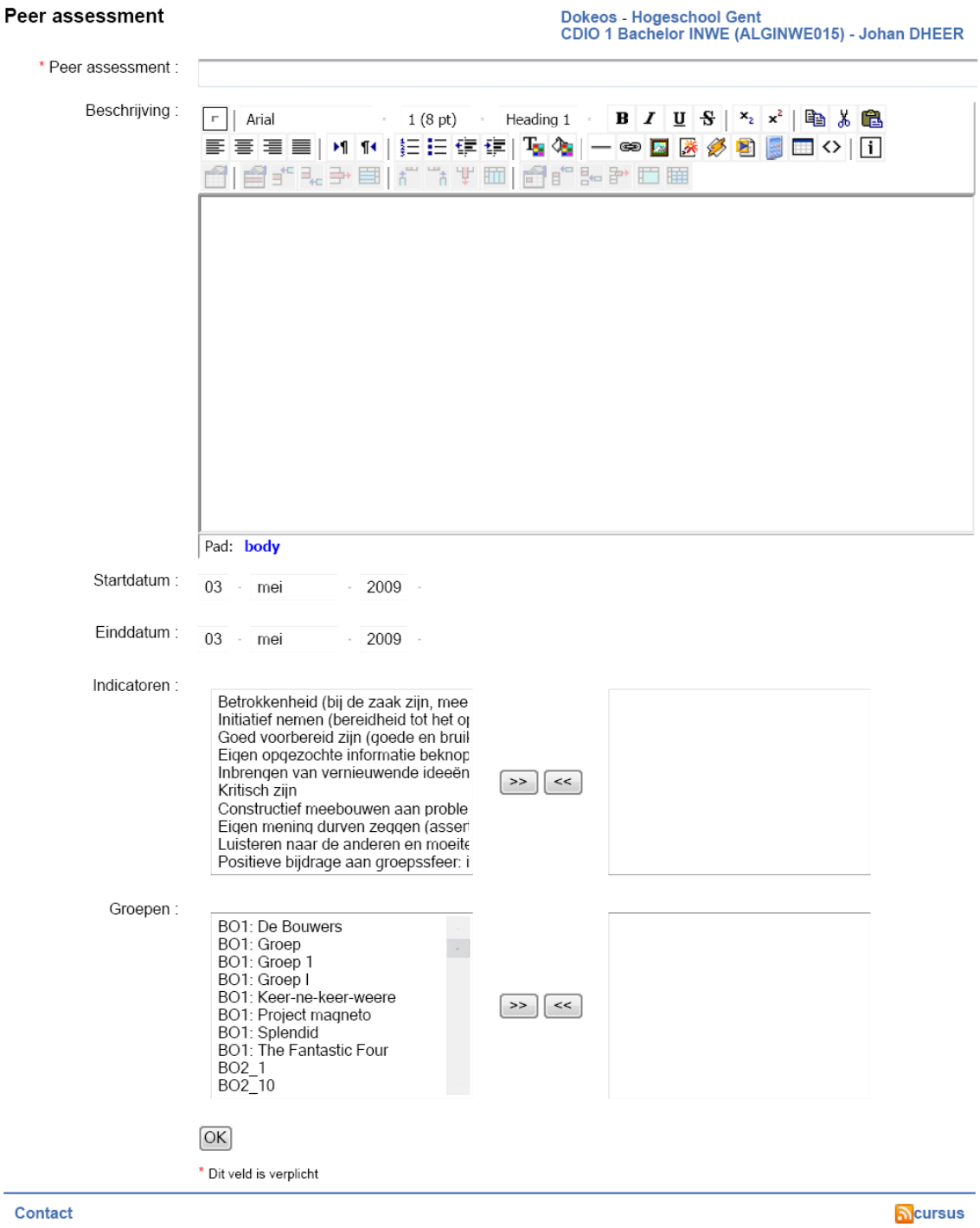

Figure 1. Preparing of a new peer assessment

The screenshot has been taken from the Dutch version of the online tool and illustrates the various options such as the possibility of creating multiple peer assessments with a short description (Peer assessment, Beschrijving), varying the start and end date (Startdatum, Einddatum) between which filling in the peer assessment is possible, the assessment criteria one can use (Indicatoren), the groups that can participate in the assessment (Groepen). The online tool allows also for the possibility of creating new assessment criteria and offers complete freedom in the composition of the various groups. The 5-point scale used for the criteria ranges from –1 (counterproductive) to +3 (better than rest of group), but is not fixed. Other scales can be easily introduced.

This tool has triggered the institutional wide use of peer assessment as it also substantially reduces the administrative workload compared to paper-based systems. This advantage of online peer assessment systems has also been reported in other research [4].

Case study

Students complete the online peer assessment form from their own computer any time between the fixed start and end date. Figure 2 shows a screenshot of the online form students have to complete when they start the assessment (student names are fictitious).

Peer assessment

Indicator	Bracke Frederik	De Backer Andy	De Cock Jorg	De Keulenaere Jelle
1. Enthousiasme en participatie	2	2	3	2
2. Ideeën aanbrengen	1	1	1	2
3. Begrip van wat verwacht wordt	1	1	2	1
4. Inhouden correct en duidelijk kunnen uitleggen	3	3	3	2
5. Bijdrage aan het functioneren als team	2	2	2	1
6. Groep organiseren en sturen	3	3	-1	1
7. Planmatig en doelgericht werken	1	1	2	2
8. Precisie en nauwkeurigheid	0	0	0	0
9. Respecteren van afspraken	2	2	3	3
10. Doorzettingsvermogen	2	2	2	2

Opslaan

Overzicht van de scores

- 3 : beter dan de rest van de groep
- 2 : gemiddeld van de groep
- 1 : niet zo goed als de rest van de groep
- 0 : geen hulp voor de groep
- -1 : hinder voor de groep

Figure 2. Start screen peer assessment (student view)

Column 1 (Indicator) shows the various criteria. Column 2 shows the self assessment marks, while in the following columns the marks given to the other team members.. The bottom of the screen shows the 5-point scale and its meaning. Multiple occurrences of the same score for a criterion are possible, but attributing the highest score to every team member results in a warning given by the online tool. Scores out of range of the scale are not accepted.

Once the assessment is completed, students can consult their scores via the same online tool. Figure 3 offers a typical screenshot of the scores of an arbitrary student. The second column shows the scores for the various criteria (column Indicator), while column 3 (Gemiddelde) shows the mean of the group. To diminish the effect of favour or dislike between students, a correction factor is applied to this mean, giving the corrected mean as shown in column 4 (Gemiddelde na correctie). The student also sees the comments (Commentaar) from his/her coach. The online tool guarantees anonymity and never shows scores of team members.

Peer assessment

Indicator	Bracke Frederik	Gemiddelde	Gemiddelde na correctie
1. Enthousiasme en participatie	2	2.33	2
2. Ideeën aanbrengen	1	1.33	1
3. Begrip van wat verwacht wordt	1	1.33	1
4. Inhouden correct en duidelijk kunnen uitleggen	3	2.67	3
5. Bijdrage aan het functioneren als team	2	1.67	2
6. Groep organiseren en sturen	3	1	0
7. Planmatig en doelgericht werken	1	1.67	2
8. Precisie en nauwkeurigheid	0	0	0
9. Respecteren van afspraken	2	2.67	3
10. Doorzettingsvermogen	2	2	2

Commentaar :

Je hebt jezelf goed ingeschat.

Je pluspunten : organisatie en sturing, respecteren van afspraken.

Verbeterpunt : precisie en nauwkeurigheid.

Overzicht van de scores

- 3 : beter dan de rest van de groep
- 2 : gemiddeld van de groep
- 1 : niet zo goed als de rest van de groep
- 0 : geen hulp voor de groep
- -1 : hinder voor de groep

Figure 3. Scores peer assessment (student view)

Coaches have access to all results, including individual scores given by all team members, allowing them to intervene if necessary and providing feedback to the team. Figure 4 offers a screenshot of the coaches' view of the scores for a particular student and his team members. Column (a) shows the scores of the student, column (b) shows the mean of the team, column (c) shows the individual scores of the other team members, column (d) shows the corrected mean, while column (e) shows the final scores of his fellow team members. The weight of the contribution of the student to the team result is measured by a peer assessment factor for the uncorrected scores (f) and for the corrected scores (g). The mark each particular student will get for his work is given by the product of his corrected peer assessment factor (g) and the corrected mean (column (d)) (here: 0.85 x 16.00 = 13.6).

Peer assessment

Student : Bracke Frederik

Peer assessment : Peerassessment1

Indicator	Bracke Frederik	Gemiddelde	De Backer Andy	De Cock Jorg	De Keulenaere Jelle	Gemiddelde na correctie	De Backer Andy	De Cock Jorg	De Keulenaere Jelle
1. Enthousiasme en participatie	2	2.33	2	3	2	2.00	2	-	2
2. Ideeën aanbrengen	1	1.33	1	1	2	1.00	1	1	-
3. Begrip van wat verwacht wordt	1	1.33	1	2	1	1.00	1	-	1
4. Inhouden correct en duidelijk kunnen uitleggen	3	2.67	3	3	2	3.00	3	3	-
5. Bijdrage aan het functioneren als team	2	1.67	2	2	1	2.00	2	2	-
6. Groep organiseren en sturen	3	1.00	3	-1	1	0.00	-	-	-
7. Planmatig en doelgericht werken	1	1.67	1	2	2	2.00	-	2	2
8. Precisie en nauwkeurigheid	0	0.00	0	0	0	0.00	0	0	0
9. Respecteren van afspraken	2	2.67	2	3	3	3.00	-	3	3
10. Doorzettingsvermogen	2	2.00	2	2	2	2.00	2	2	2
Totaal	17	16.67	17	17	16	16.00	11	13	10
	(a)	(b)	(c)			(d)	(e)		

Peer asessment factor : 0.83	(f)
Peer assessment factor na correctie : 0.85	(g)

Figure 4. Scores peer assessment (coach view)

STUDENTS' AND TEACHERS' PERCEPTION OF PEER ASSESSMENT.

Students as well as teachers may be more motivated to involve themselves in peer assessment when they have positive opinions on the advantages it can bring to the learning and/or assessment process [5].

Questionnaire

In order to get an idea on how students and teachers perceive peer assessment, a questionnaire adapted from a previous recent research [6] with 12 questions (Likert type 5 point scale) on advantages and disadvantages of peer assessment was administered to first year engineering students (n= 211) and their coaches (n= 9). The response was coded from 1 (strongly disagree) to 5 (strongly agree).

Findings

From our pilot study, we can draw the following conclusions:

- Students and coaches perceive peer assessment as an authentic evaluation method that closely parallels a possible career situation.
- Students and coaches agree that peer assessment encourages students to critically analyse work done by others.
- Students as well as coaches are worried friendships might influence the markings in peer assessment.
- Students find peer assessment helpful for clarifying assessment criteria, while coaches don't express a clear outspoken opinion about this.
- Coaches do think students have the necessary skills to evaluate each other. Students however are less convinced about their ability to do this.
- Coaches and students think peer assessment offers a wider range of feedback, i.e. more people and more criteria are involved in the marking compared to more traditional evaluation methods.
- Coaches feel strongly peer assessment is a way for students to learn from each other. Students agree but are less outspoken about this.

From these findings and from previous experiences with our form of peer assessment, we can formulate some guidelines for practitioners. These guidelines confirm those found in the literature [1] [7].

SOME GUIDELINES FOR PRACTITIONERS

- From our initial use of peer assessment in 2005 we find it should be combined with self-assessment and co-assessment. The results of self assessment disclose the functioning or malfunctioning of an individual in the group. It can also disclose the self perception from an individual group member about his functioning in the team. In this respect, the use of radar charts can be very illuminating. The outcomes of this self assessment should be in line with observations from the coaches and, if necessary, adjusted by them. This justifies the need for combining peer assessment with co-assessment.
- Some form of peer assessment training could be helpful. Determining the criteria jointly by staff and students could increase students' confidence in assessing their peers and themselves appropriately.
- The initial paper based peer assessment tool, introduced in 2005, used a 5-point "absolute" scale, without the possibility of giving negative scores. After examining the results of the peer assessment, coaches felt the need for the possibility of giving negative scores. From 2006 onwards, a 5-point "relative" scale, ranging from –1 to +3, was

introduced. In a relative scale, criteria are evaluated against the mean of the group. This scale is still in use, much to the satisfaction of coaches and students.

- When using peer assessment as part of the overall evaluation of design-implement experiences, it is important to find a balance between the score for the peer assessment and the scores obtained for other aspects such as finished product, oral presentations and written reports. When we started with design-implement experiences, the score for the peer assessment contributed for 40% of the total grade. Coaches felt to much weight was given to the peer assessment. Now this weight has been reduced to 20%. This enables us to make peer assessment more acceptable to sceptical coaches and still evaluate the functioning of students in a team.
- To reduce peer pressure it is strongly advised to ensure anonymity. This will help students to give honest markings to other members of their team.
- Explicitly inform students about the reasons for and the benefits of peer assessment. This helps to override the initial reluctance against this evaluation method.
- Avoid using paper based forms of peer assessment! Electronic forms reduce considerably the workload for coaches.

CONCLUSION

From our pilot study, we can conclude that coaches and students have a positive attitude towards peer assessment. This evaluation method adds a new dimension to the overall evaluation process by allowing for "process" evaluation through marking personal and interpersonal skills.

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The Tremorlator - Responsibilities of Civil Engineering Technologists to Society

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ABSTRACT

This paper describes how some technical aspects of structural engineering can be redesigned, modified and transferred for operation by civil engineering students for emergency preparedness training by the community. The Singapore Civil Defence Force (SCDF) officers and SP faculty members from the Civil Engineering Division of its School of Architecture & the Built Environment (ABE) collaborated and conceived the Mobile Tremorlator. The Tremorlator is a room fitted with home appliances and is mounted on an Earthquake Simulator to simulate earthquake ground motion accelerations. This simulator is in turn mounted on a truck to bring the Tremorlator to the community. The Tremorlator has been deployed on weekends at various grass-root communities to help them learn emergency preparedness and other civil defence skills.

KEYWORDS

Technologists, societal context, civil defence, tremorlator.

INTRODUCTION

Graduates in civil engineering have made contributions to the quality of life for communities by providing efficient transportation system, safe homes, proper sanitation and clean water utilities. These civil engineering infrastructures are taken for granted until natural disasters disrupt them. Earthquakes and earthquake-induced secondary disasters can cause great distress to the affected communities. In such situations, civil defence teams will have to come in to rescue people who are trapped in collapsed buildings. Civil engineers will eventually be involved in restoring the damaged public buildings and infrastructure. However before such disasters occur, the community needs to be prepared for emergencies. This is where civil engineers and technologists can chip in to help the civil defence equip the community with basic skills to respond to possible disastrous events.

The four phases of the product or system cycle are Concept, Design, Implement, and Operate (CDIO) [1]. Civil engineering infrastructures are conceived, designed, built and maintained so as to meet the design specifications and occupiers requirements. In earthquake prone areas engineers have to consider seismic loads from earthquakes. These phases of work flow are primary responsibilities of civil engineers and civil engineering technologists.

TREMORS IN SINGAPORE

Geologically, Singapore is located on the stable Indo-Chinese Plate. Some 600 kilometres to the southwest of Singapore is the active Alpide Belt along the Indo-Australian tectonic plate [2]. The so-called "Pacific Ring of Fire" and the "Alpide Belt" are the first and second most active seismic regions in the world respectively. The earthquake that triggered the December 2004 tsunami in Aceh was due to movements in the Alpide Belt. Earthquakes that

hit parts of west of Sumatra can send weak tremors to certain parts of Singapore. Some people living on the higher floors of tall buildings in these areas can feel these tremors.
The Meteorological Services Division (MSD) has set up a network of seismic sensors around the island to monitor the effects of these earthquakes. The data can be accessed by engineers to help them evaluate the tremor effects on civil infrastructures. The network of stations automatically and continuously monitor seismic activities around that area [3].
Historically, Singapore is not known to have experienced any earthquakes. However it remains relevant to civil engineering students in Singapore Polytechnic to appreciate the effects of earthquakes on structures that are built in regions which have earthquakes. Although structural dynamics is outside of the scope of the technologists' structural design modules, the experience of building a structural model to withstand simulated seismic loads have given them deeper and experiential knowledge of structural fundamentals. The design, implementation and testing of their models on the earthquake shaking table is one of the students capstone projects.

SINGAPORE CIVIL DEFENCE FORCE AND ITS PUBLIC EDUCATION EFFORTS ON TREMOR ADVISORY

Tremors in Singapore in recent years have occurred on 26 Dec 2004, 29 Mar 2005, 18 Dec 2006, 12 , 13, 14 and 20 Sept 2007, 4 Jan 2008, 20 Feb 2008 and 24 Feb 2008. These tremors are due to earthquakes in neighbouring countries, measuring 6 to 8 magnitude on the Richter Scale [4].

The Singapore Civil Defence Force (SCDF) is a uniformed organisation under the purview of the Ministry of Home Affairs. In addition to providing fire fighting, rescue and emergency ambulance services, SCDF formulate, implement and enforce regulations on fire safety and emergency preparedness matters [5]. SCDF as the lead agency for emergency services has also adopted an active approach at developing capacities in communities to cope with disasters such as tremors. To invoke greater community ownership and self-help when dealing with crisis, SCDF has introduced a wide range of community involvement programmes such as Community Emergency Preparedness Programme (CEPP) and Emergency Preparedness (EP) Day. These activities are initiated to introduce systematic yet convenient platforms for public to pick up knowledge and skills to prepare for emergencies [6].

To prepare the community to respond to unknown fears caused by tremors, SCDF has come up with the Tremor Emergency Plan (TEP). The Tremor Emergency Plan (TEP) was activated in November 2007 and a PDF version of the TEP has been made available on the SCDF internet website. Additional public education materials on Tremor Advisory are distributed to educate the public on the procedures to adopt when a tremor occurs at their premises. However, it is imperative that SCDF should also focus on an experiential learning approach through the involvement of residents as active participants rather than passive audiences. Therefore, SCDF collaborated with the Singapore Polytechnic to design a simulated setting which will facilitate a realistic training environment whereby participants will be adequately trained in the precautionary measures to adopt in the aftermath of an earthquake when a tremor is felt.

RESPONSIBILITIES OF CIVIL ENGINEERING TECHNOLOGISTS

Civil engineering technologists in Singapore support civil engineers, operation managers and government agencies in a wide array of duties. Under each of the four phases of product life-cycle, the technologists are responsible for accurate collection of field data necessary for

preliminary and detailed design by engineers. Diligent data collection, processing and translation of engineering design into detailed working drawings constitute some of their professional responsibilities. As ground personnel in the day-to-day implementation and operation of the infrastructure system, they have the duty of care to ensure that the infrastructure system is successfully implemented. The system has to be structurally sound and safe for the occupiers and users. The students learn content of structural engineering in the polytechnic. Besides technical knowledge, they need to be aware of how the system fits in the external and societal context. Students need to engage with the community so as to prepare to themselves to work in the real world. The civil engineering faculty members scanned the environment to look for an external context that is also sustainable for the students' civil engineering education.

FROM AN EARTHQUAKE SHAKING TABLE TO A MOBILE TREMORLATOR

Civil engineering students studying structural engineering have been making models that are resistant to vibration loads. The making of models is a capstone project for their module "Structural Steel Design and CAD." The project-based approach gives them the opportunity to work as a team and benefit from the experiential learning [7]. However this still lacks the external and societal context which will help the students see the direct impact of the application of engineering knowledge on the community.

Figure 1. Students in their capstone projects

Figure 2. Models ready for testing

The civil engineering faculty contacted the Singapore Civil Defence Force (SCDF) and learned that SCDF was looking for a system that can give the community hands-on experience in emergency preparedness when there is a tremor. This mutual need led to collaboration between SCDF and SP.

As pace setters, SCDF officers and SP's civil engineering faculty embarked on the CDIO phases of the product cycle. The Concept: A room that can respond under simulated earthquake tremors and be mobilized to different constituencies in Singapore. SCDF has the truck and SP has the shaking table. The Design: Meet SCDF's specifications for tremors and for emergency preparedness training. The Implementation: Detailed design and drawings, and fabrication in the workshop at SP. The Operation: SCDF plans the contacts with the community in their emergency preparedness routines, and mobilizes the mobile Tremorlator accordingly. SP staff and civil engineering students operate the tremorlator when members of the public enter the room in the tremorlator. This gives the external and societal context for the community involvement by civil engineering students that is both relevant to their learning and sustainable.

OPERATION OF THE MOBILE TREMORLATOR IN THE SOCIETAL CONTEXT

The "Mobile Tremorlator" is deployed at Emergency Preparedness (EP) Days and other community outreach programmes organized by SCDF. About ten civil engineering students are rostered to operate the Tremorlator on some weekends. The participation in the community outreach programmes to educate the public regarding earthquake tremors will certainly benefit civil engineering students. By participating actively in these outreach programmes, these students have gained invaluable knowledge and skills on emergency preparedness. Hence, they serve as a useful change agent by leading others in tremor procedures and imparting useful emergency preparedness knowledge and skills to their school community.

In addition, they will be able to appreciate why sound structural engineering design and construction, and regular structural appraisals of buildings are important. As the tremorlator is deployed regularly in the community by SCDF, most civil engineering students will have the opportunity to educate the public on how to prepare for tremors. This would give all of them the opportunity to meet people outside the campus and develop other personal, professional skills and attributes that are difficult to impart within the campus environment. Since the Mobile Tremorlator can simulate earthquake tremors that originate from neighbouring countries, the experience in the Tremorlator room is realistic.

Figure 3 The Mobile Tremorlator

MUTUAL BENEFITS OF OPERATING THE TREMORLATOR

A few anecdotes and speeches will illustrate this.

On Saturday, 6 September 2008, SCDF officially launched the 6th edition of the CD Emergency Handbook. The launch took place at Chong Pang Community Club at 11:00am. Mr K Shanmugam, Minister for Law and 2nd Minister for Home Affairs officiated the event. A highlight of the event was the SCDF's latest Public Education simulator known as the "Mobile Tremorlator" [8]. The Tremorlator simulates tremors within a residential setting.

Here is part of a speech by Mr Shanmugan:

"For example, even though Singapore is far away from earthquake zones, we do experience tremors occasionally. So the SCDF, together with Singapore Polytechnic developed a "Mobile Tremorlator" to simulate earthquake tremors. This innovative project involves simulating tremors in a home setting complete with dining table, chairs, stoves and fittings such as hanging lamps and cupboards. The "Mobile Tremorlator" is a useful tool as it

replicates the experience of tremors. It allows residents to learn the correct measures to adopt when a tremor is felt. We will launch this innovative creation today. I am also pleased to note that students from the Civil Engineering and Management course of the Singapore Polytechnic will also partner SCDF as "Singapore Polytechnic-Civil Defence or SP-CD Ambassadors" to help educate residents in the tremor response procedure. I commend this partnership between the two organisations as it not only helps to raise the EP awareness of the community, it also helps us to anchor our Community Engagement Programme" [9].

The Principal of Singapore Polytechnic, Mr Tan Hang Cheong, explained the origins of the Tremorlator:

"We've always been working very closely with the Singapore Civil Defence Force. And I think through all our interactions we then conceived this idea, that perhaps it's need now for us to educate Singaporeans about all the tremors that we've been feeling so frequently nowadays. To get them to feel that at this particular level of the Richter Scale, what is it like at home and what you should do should a tremor like that occur" [10].

For a start civil engineering students from SP are partnering with SCDF as ambassadors to conduct demonstrations and help the public respond to tremors. Gary Wong, a year one civil engineering student has gone through several rounds of public education. He said, "The buildings in Singapore are built to withstand quite strong tremors. And by running out while the building is still moving, you have a higher chance of injuring yourself in that process, as opposed to hiding under a table and waiting till the tremors stop."

Figure 4 The Prime Minister and Grassroot Organisation Leaders At the Tremorlator

Figure 4 shows the Prime Minister and grassroot organisation leaders being briefed by SCDF officers. The mobile tremorlator was moved by SCDF to Ang Mo Kio Avenue 3 as part of the Teck Ghee Constituency's Emergency Preparedness Day on 18 October 2008. Scott Wong, a year 3 civil engineering student, prepares to give a demonstration on how to respond in a room when tremors occur. Residents were able to experience hands-on how to respond before and after the tremors hit the room.

CONCLUSION

Singapore Polytechnic is one of the early partners in the adoption of the CDIO approach in engineering education. The collaboration by its School of Architecture & the Built Environment with the SCDF to jointly develop the Mobile Tremorlator using the Conceive-Design-Implement-Operate approach benefits both the civil engineering students and the community at large through the community events organised by the SCDF. Students are able to learn actively, experientially and at the same time make direct contribution to the welfare and education of the community. A students' club has been formed to include students from other courses to partner SCDF as "Singapore Polytechnic-Civil Defence or SP-CD Ambassadors." This new initiative has helped other polytechnic students to connect meaningfully with the community. The mobile tremorlator has become an important vehicle to prepare civil engineering technologists connect their peers to SCDF, a strategic partner and exercise responsibilities to the society.

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5th International CDIO Conference
Reframing Engineering Education: Impact and Future Direction
6-8 June 2009 Singapore Polytechnic

The Use of Project Based Learning As a First Year Integrated Teaching and Learning Medium

Mushtak Al-Atabi

TAYLOR'S UNIVERSITY COLLEGE
Wisdom • Integrity • Excellence

Agenda

- Introduction
- The Approach
- Sample Project
- Results
- Other Projects
- Conclusions
- Questions & Answers

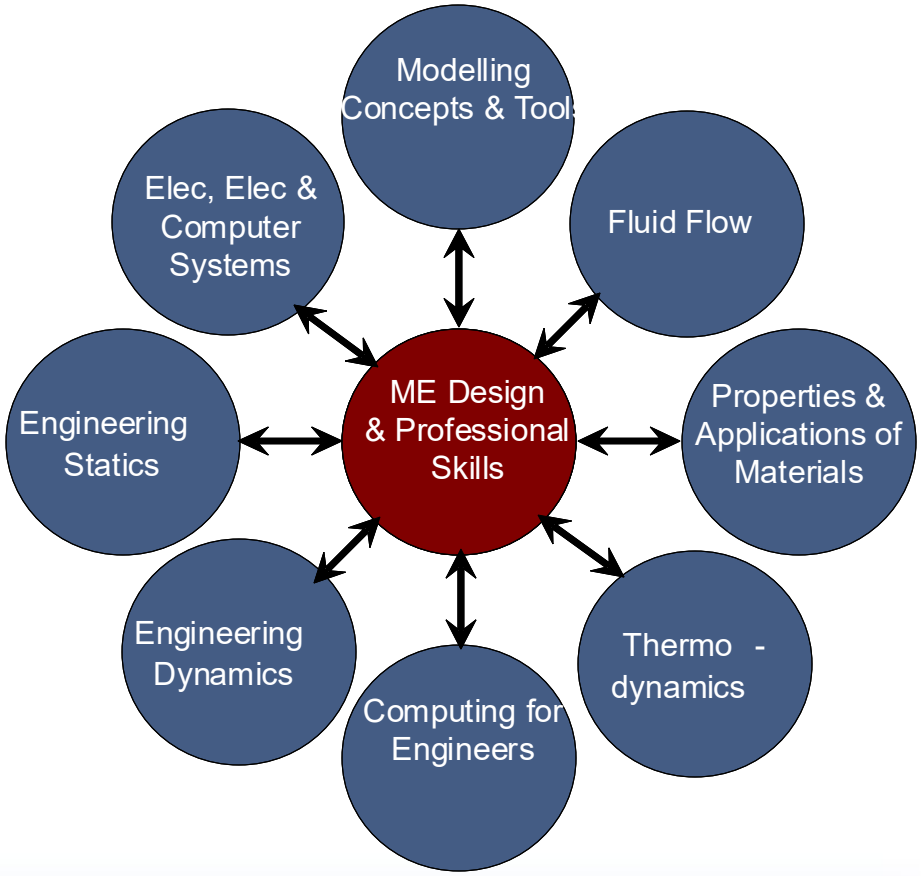
Introduction

- Adopting the PBL across the curricula is desirable.
- Obstacles
  - lack of time and resources.
  - Not suitable (?) for theory based subjects
- Design subject can be central platform to enhance the achievement of the learning outcomes of other modules.
- This is achieved without alterations to the modules at hand and is done with careful choice of a design project.
- The work is based on the syllabus of the first year mechanical engineering course offered at Taylor's University College- Malaysia.

Approach

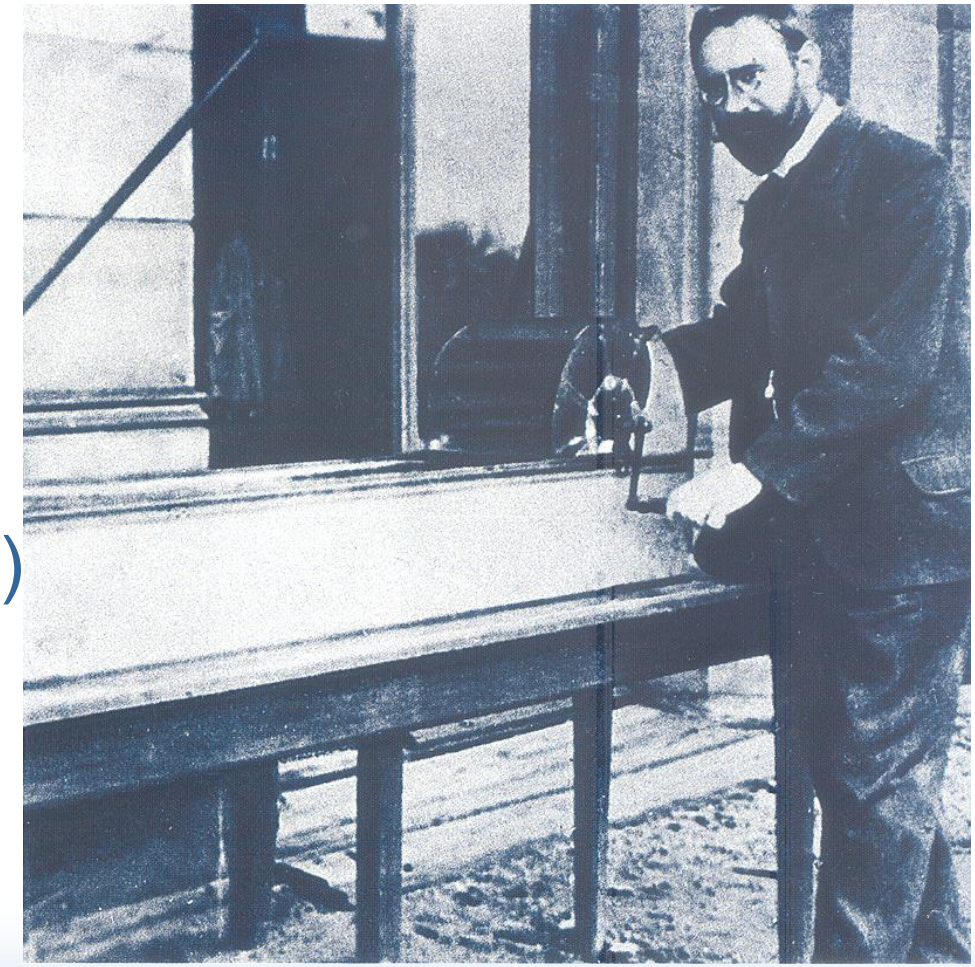
- "Mechanical Engineering Design & Professional Skills" module
- Students work in groups on "projects"
- Carefully selected project(s) can help support other modules such as Fluid Mechanics, Materials, etc..

Approach

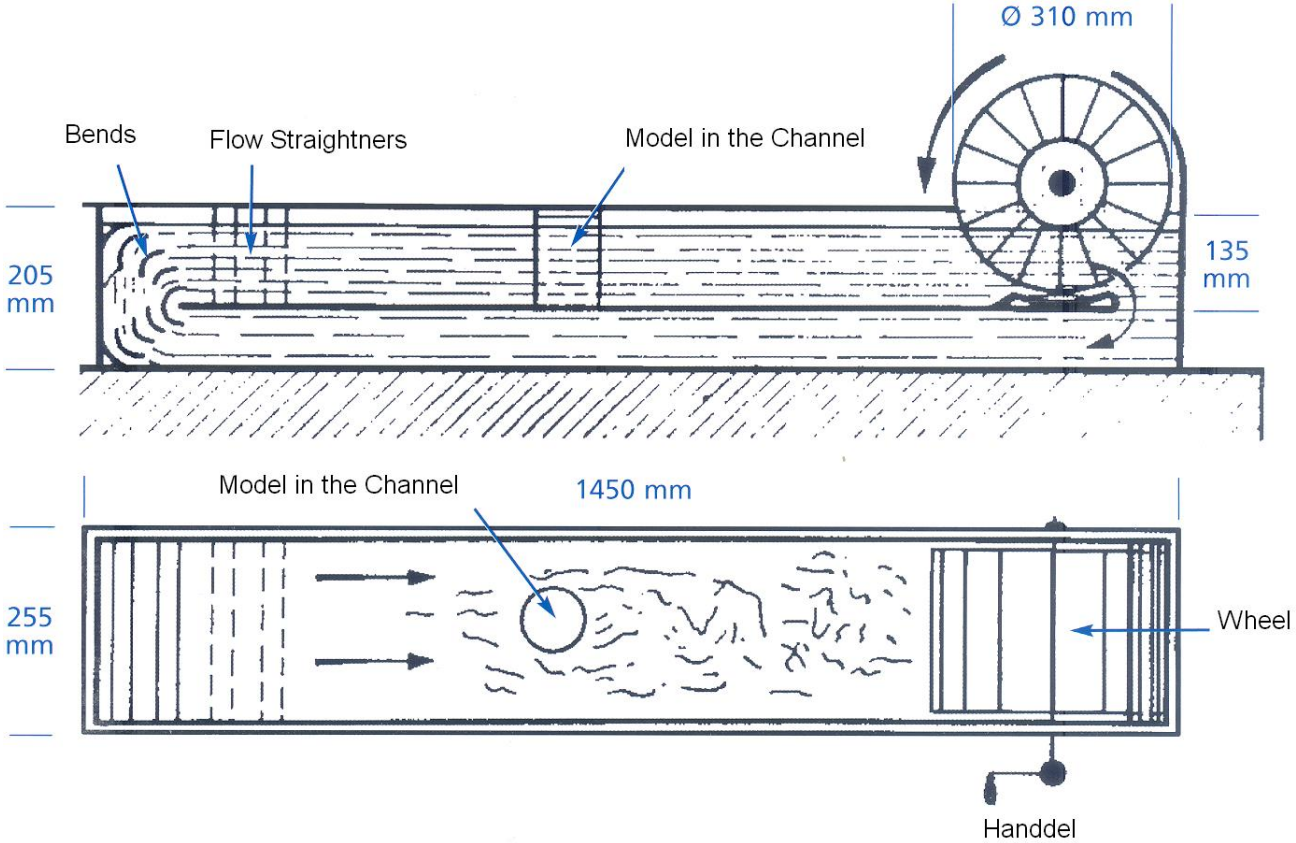

Modelling Concepts & Tools
Elec, Elec & Computer Systems
Fluid Flow
Engineering Statics
ME Design & Professional Skills
Properties & Applications of Materials
Engineering Dynamics
Computing for Engineers
Thermo - dynamics

Sample Project

- Prandtl circulating water channel
- Material provided
  - Handouts
  - Brochure (in German)



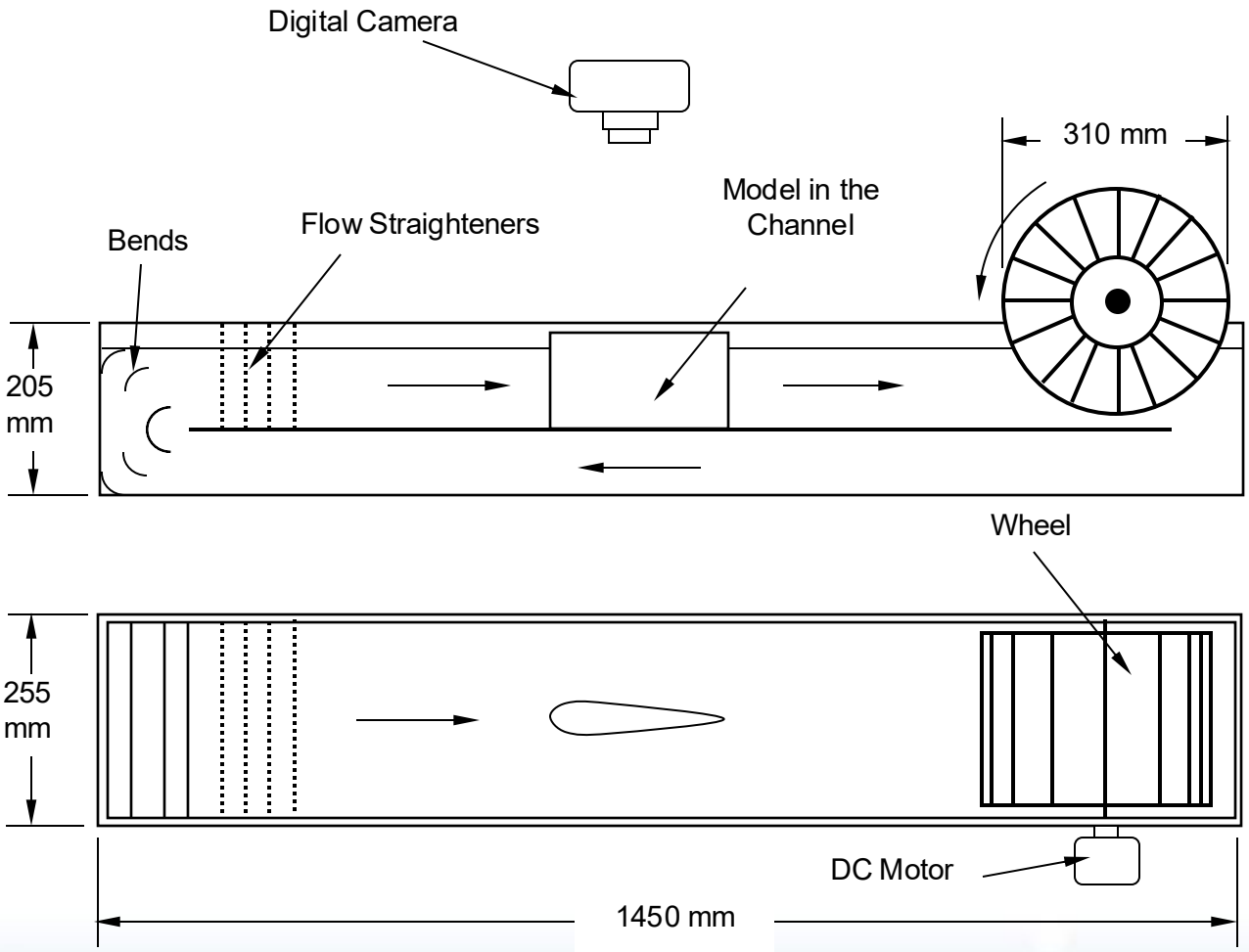
Sample Project



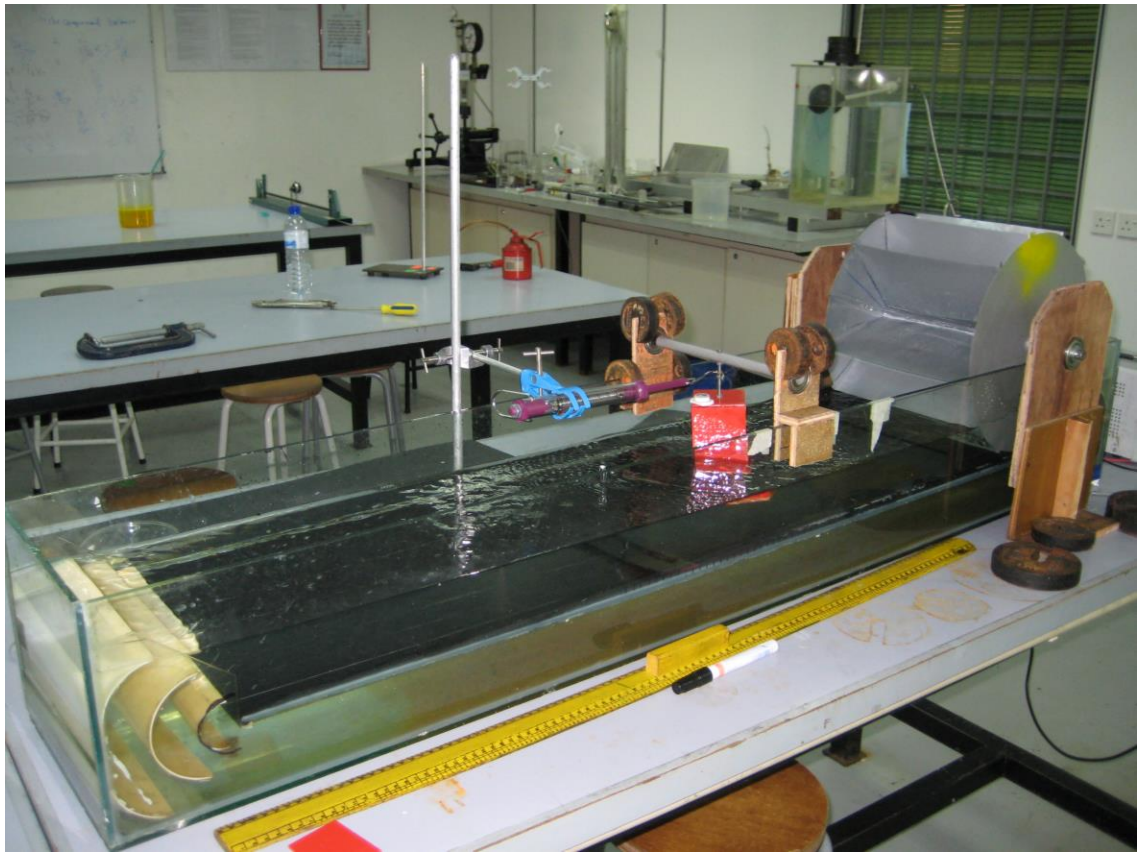
Project Delivery

- Students work in groups of 5
  - Analyse the existing channel
  - Make an (improved) replica of the water channel
  - Make models to be tested in the channel (flow visualisation)
  - Use the channel to explain a phenomenon in fluid mechanics

Results

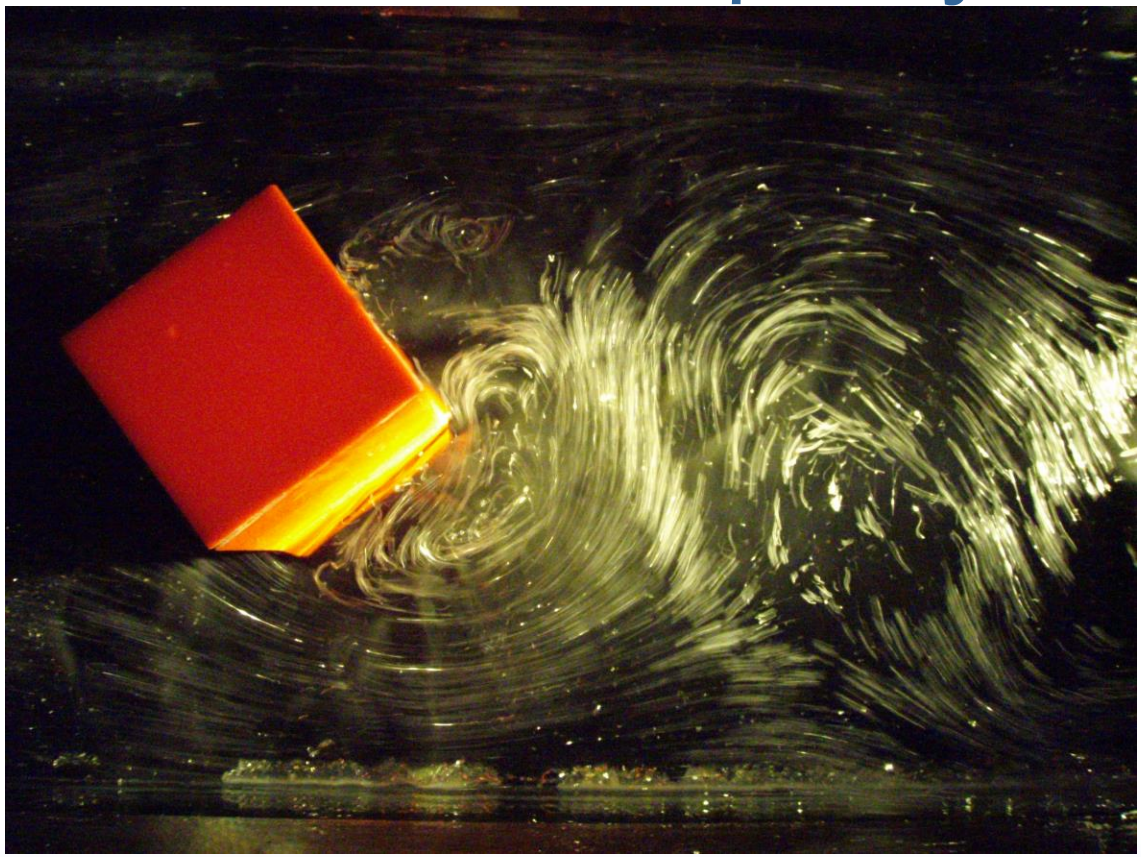

Digital Camera
310 mm
Model in the Channel
Flow Straighteners
Bends
205 mm
Wheel
255 mm
DC Motor
1450 mm

Results

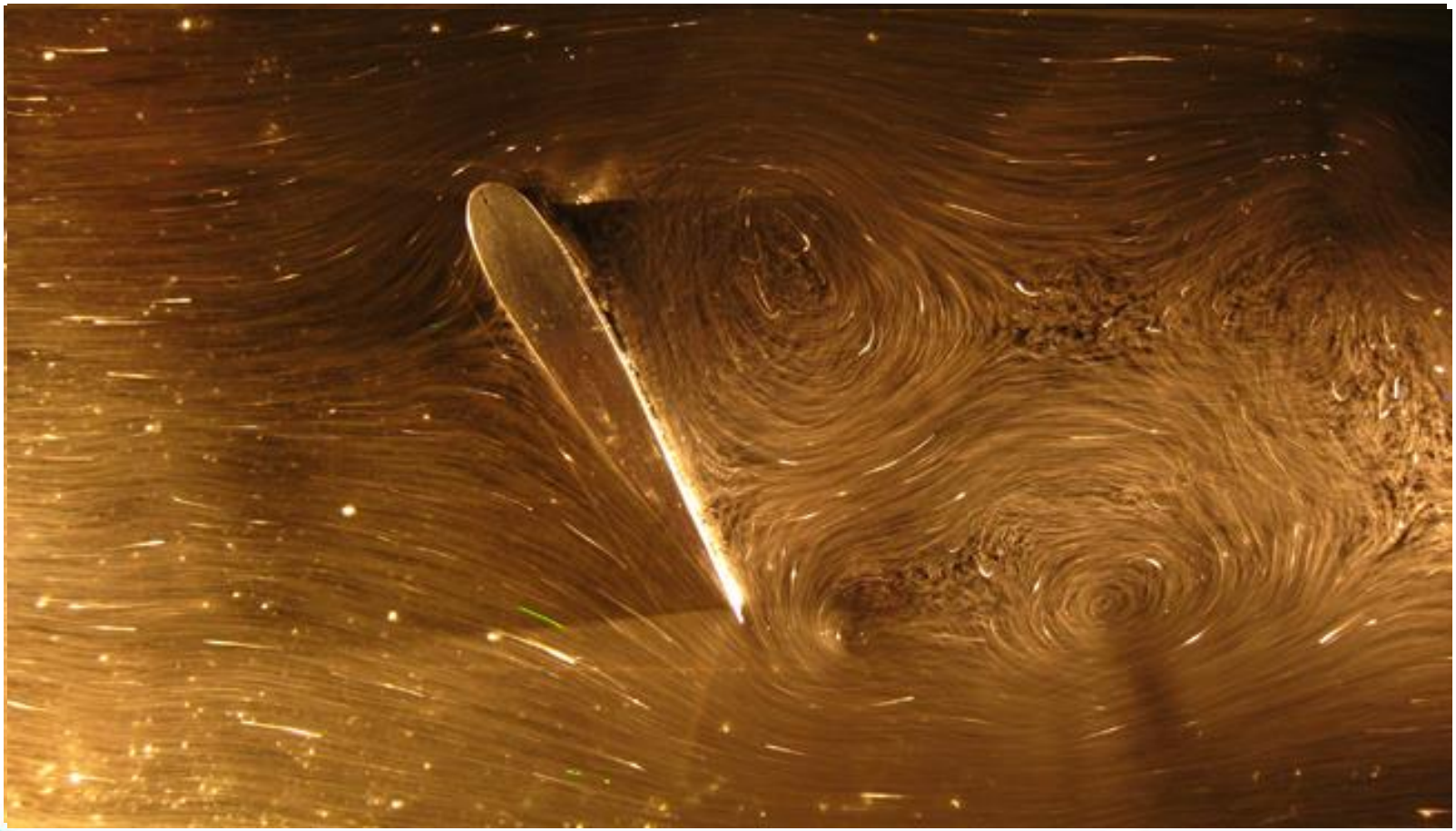


Results

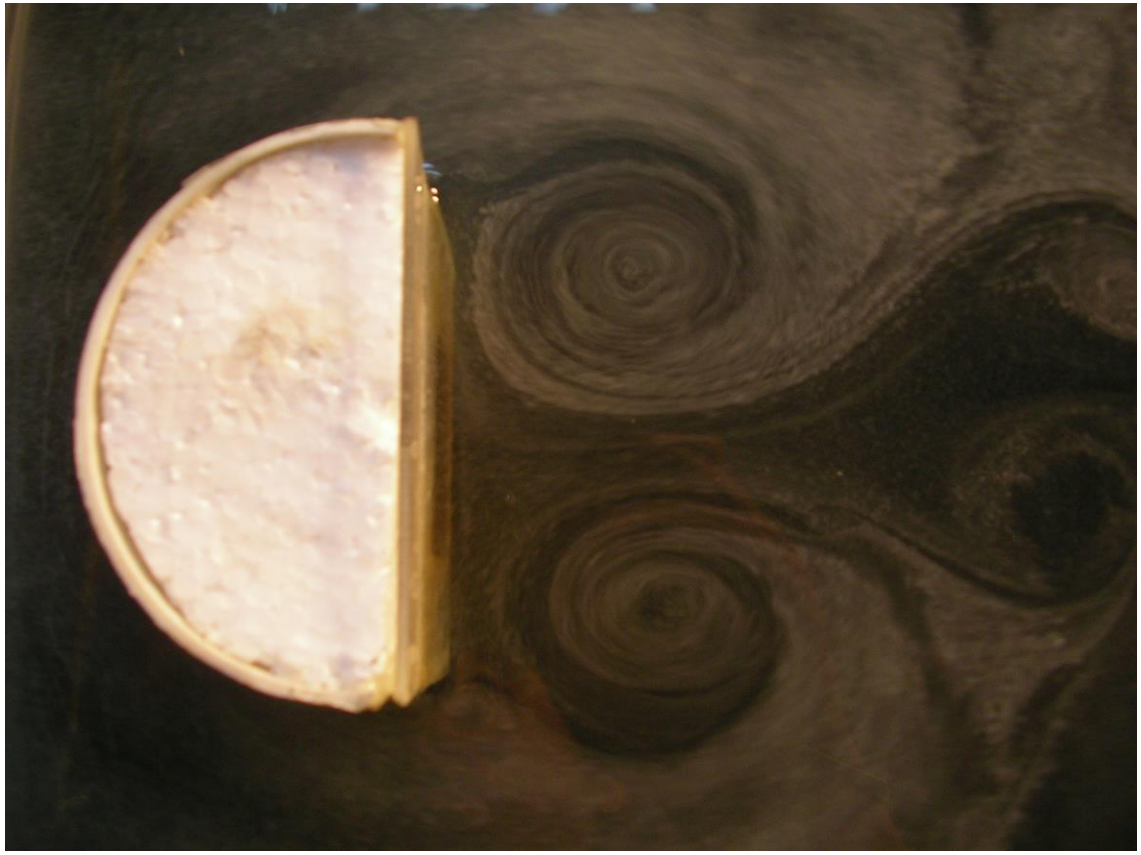
Flow downstream of square cylinder



Results- Flow around airfoil



Results- H_2 Bubble Flow Vis



Results- No Slip Condition

Results- Newton's Law of Viscosity

Other Projects- Wind Turbine

- Year 2 Integrated Design, FFDL, Manufacturing
  - Wind Turbine

Other Projects- Wind Tunnel

Conclusions

- It can be done
- It can make the course cost effective
- Will never run out of projects
  - Wind tunnel instrumentation

Thanks a lot for your attention.

Transformation of Traditional Engineering Education to CDIO Programs

– Shantou University's Experience

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Shantou University

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Shantou University

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Shantou University and University of Calgary

ABSTRACT

This article summarizes the experiences of implementing the CDIO initiative in the College of Engineering, Shantou University. With a reflection on our practice in the past three years, we have summarized ten important points leading to a successful implementation of the CDIO initiative: 1. Commitments and support from university and faculty leaderships; 2. Comprehensive planning before implementation; 3. Integrated solutions for multi-tasks; 4. Identifying champions and form core team; 5. Involve most faculty; 6. Innovative implementation of the CDIO initiative; 7. Piloting before full implementation; 8. Awareness of the resources constrains; 9. Supports for teaching, learning and leaning assessment and 10. Form coalitions.

Our experience may be more relevant to Chinese universities. However, a comparison with the eight steps of the "number one leadership guru" John Kotter reveals that our ten points largely correlate well with the eight steps. This manifests that the general rules for a successful change may be more general than what we initially thought. Consequently, Shantou University's experience is of value to the CDIO reform of other institutions inside and outside China.

KEYWORDS

Shantou University experiences, CDIO implementation, change management, engineering education

INTRODUCTION

CDIO Initiative has documented an Adoption Process for implementing CDIO in a program or an institution [1]. Chapter 9 of the CDIO book [2] also outlines the ways to adapt the CDIO approach. However, making a change in an organization is so difficult that, according to a Harvard Business Review study, 70 percent of change initiatives were not successful because organizations failed to manage the human reaction to change [3]. It is therefore, important to share and accumulate experiences of managing the changes during implementing the CDIO initiative. The College of Engineering, Shantou University (STU) has started the CDIO educational reform since later 2005. Drastic changes have been introduced into all the five programs offered in the College. The traditional engineering education in China has been profoundly influenced by planned economy, a successful transformation from such an educational model to CDIO demands comprehensive planning and careful implementation. As many universities are adopting CDIO in their engineering educational reform, we believe that it is useful to document the transformation process of the CDIO reform at STU. It would be helpful both in disseminating the CDIO initiative in China and in managing changes in educational institutions in general.

We have summarized ten points that are important for a successful implementation of the CDIO initiative according to our experience. Below, we summarize the ten points roughly according to chronic order of consideration.

THE TEN POINTS FOR SUCCESSFUL IMPLEMENTATION OF THE CDIO REFORM

Commitments and Support from University and Faculty Leaderships

The CDIO reform should be carried out at program level and above. It covers almost every aspects of education, including the goals, objectives, stakeholders, curriculum, course syllabi, teaching philosophy, teaching and learning, workspace and facilities, faculty development and so on. It is nice for individual faculty to implement a few CDIO elements in his or her teaching activities. However, this kind of changes would not bring full benefits of CDIO educational reform. Individual faculty members cannot provide the necessary resources needed for the reform. Thus, it would be crucial to have full commitments and support from the university and faculty level management in terms of carrying out the changes and the essential resources required for the entire reform process.

The College of Engineering of STU has been very fortunate that we do have strong support from both university and faculty levels. The CDIO reform in the college has been headed by Provost and Vice President of the university, Dean of Engineering and Director of Educational Affairs. Though we have not been specially allocated more resources than other colleges within the university, a clear direction and firm commitments for the changes from the top had helped to remove many obstacles otherwise we be encounter. We have observed other successful and not so successful cases. Without exception, all successful implementations have been led or have got strong support from the top leaders.

Comprehensive Planning before Implementation

The CDIO reform needs a systematic approach. One must realize the complications of the educational reform. The first thing needs to be considered is to motivate the faculty and the students. The need for a change and the rational for embracing the CDIO initiative must be communicated with frankness and through thorough debates. External feedback from the industry and society in geneal would be helpful supports. The next is to establish confidence within the institution. Successful cases of other institutions can be collected and shared among the faculty and the students. The third would be right account of available resources, including facility and human resources. Workspaces and necessary facilities are deemed

necessary. A team of passionate faculty with relevant experiences is critically important, especially at the beginning of the reform. The forth and a very important point is to plan for continuous improvement right from the beginning. Many reform cases fail to proceed because short of new driving forces.

Integrated Solutions for Multi-tasks

We are in an era of fast and continuous changing. We daily face many tasks and changing requirements. It must be realized that quality education would always be the core business of an educational institution. The CDIO reform addresses the ultimate calling of engineering education. Thus, many of these tasks and requirements would be combined with the CDIO reform. By doing so we would encounter fewer resistances and make more effective uses of time and efforts of people involved.

By the time we started the CDIO reform, STU was preparing for the university wide accreditation of higher educational quality by Ministry of Education. This was the first ever exercise of such kind in the country. Given the importance and consequence of the accreditation results, everybody in STU was activated and was ready to contribute to teaching affairs. Therefore, it was much easier to organize seminars and carry out effective debates and discussions. Therefore, much of the work that we did, indeed produced dual effects: changing people's mindset and adding headline features into the accreditation reports. In addition, the CDIO reform has helped us to successfully apply for a list of national and provincial educational projects and awards.

Identifying Champions and Forming Core Team

Whenever a change is needed, some people are more willing than others to test and lead the change as champions. It is important to identify these people and have them form a team. With the help of these champions the change efforts would be multiplied and fast spread. It distributes the leadership among the champions and creates senses of achievement and ownership.

Unlike the situation in many universities in North America and Europe, the university administration is relatively powerful and has the tools and resources to initiate and making changes. This, in a way, can speed up a change process. However, it would, even if the direction is correct, create a team of passive followers. Once the leadership runs out of energy or has other priorities, the whole reform could stall. Hence, it is important that from the very beginning of the reform, the administration should identify the potential leaders emerging from the organization members.

Involve Most Faculty

Change from traditional education style to CDIO would need great changes in people's mindsets. Our experience shows that many basic concepts and practices required in the CDIO standards cannot be properly understood by simply reading the texts and the translations. This is especially true for people having less exposure to contemporary industrial and educational practices. Therefore, engaging everybody in the learning, discussing and implementing processes is a crucial measure to ensure that the reform reaches its goals.

We arranged a list of discussions, seminars and debates of all scale ranging from course level, program level, department level to college level. Results showed that discussions and seminars alone were not enough for in depth understanding.

All faculty members were asked to look into the courses they were teaching and to suggest modifications to the course structures of their respective programs. By doing so, the faculty

were provided with an opportunity to rethink on what they might take as granted. At the same time they could try to apply what they have learnt from the CDIO initiative. The result of the exercise revealed that faculty members have very different understandings. It highlighted a misconception in the course of discussions and seminars, during which it seemed that a unanimous understanding of the CDIO initiative had been reached.

Though the resulted syllabi might not be fully used, the exercise itself had been very useful. Firstly, it helped both the administration and the faculty to realize that to change the mindset of staff would need more efforts. Secondly, the exercise exposed some unreasonable aspects in the old program curricula. Lastly and the most importantly, an exercise like this involves everyone into the mindset-shifting process. Everybody actively reflects on the current situation and looks into solutions. It is therefore much easier for people to communicate on the "what" and "why" problems in the CDIO initiative. Consequently, the "how" problem would be understood and accepted correctly.

Innovative Implementation of the CDIO Initiative

The CDIO initiative answers "why" and "what" quite clearly. In term of "how" it gives guidelines stipulated by the 12 standards. The vast spaces have been left for innovation in implementing the CDIO initiative. Though a few implementation examples can be found in the CDIO resource center, it is important to find ways best satisfying our own requirements. Our approach has been learning and sharing among faculty and staffs. The process involves all relevant parties. It helps to establish consensus and ownership.

In the College of Engineering, STU, a "design directed" approach was taken as integration theme [4]. Here, the word "design" possesses a broader meaning than the "D" in CDIO. It covers conceiving, designing, prototyping, and testing. That is, it spans a large part of the CDIO life cycle. We believe that engineering design is the essence of engineering. Most technical knowledge and engineering skills and attitudes would be reflected in the engineering design processes. In addition, reflecting the need of the Chinese engineering education, we put special emphasis on professional ethics, integrity and professionalism in our education. Thus, we adopted the "designed directed EIP-CDIO" reform.

Piloting before Full Implementation

Though it has been discussed that the CDIO reform should be conducted at program level, it is still necessary to run a few pilot courses before full scale of implementation of the reformed curriculum and program structures. Indeed, the piloting the course could neither really prove nor disapprove the CDIO reform. However, the pilot courses are still meaningful and necessary. First, usually new curricula are only applied to newly enrolled students. Majority of faculty will not have the chance to teach the new courses in one or two year time. They would need to practice and accumulate experiences for the new ways of teaching before they have lost their interest, which might have been established through various kinds of activities. Second, there is a need to build up confidence needed among the faculty and the current batches of students, so that there can be a smooth transition from the old to the new curricula. Third, the process of piloting will cultivate more champion faculty in addition to accumulation of experiences.

Teaching pilot courses is different from conducting scientific experiments. The faculty members as well as the teaching environment change dynamically with the piloting process. Piloting will help establish the desired context for further reform. This has only been realized in our recent reflection.

Awareness of the Resources Constrains

Resources are crucial for the sustainability of reform efforts. Workspace, facilities and materials are the first list of items that must be considered. Students will need to carry out some design-build projects in the workspaces. The scales and the amount of work needed for the design-build items would need careful consideration. These will, to a large extent, determine or be constrained by the available resources.

Available technical staffs would be another constraint. Hands-on projects involve issues like safety and skills of operating machines. Many teaching faculty themselves are short of hands-on skills and/or engineering skills. Even if some faculty members have engineering and building skills, they may not be available all the time. In addition, many students only have time to do their projects outside normal working time. We have scheduled lab opening hours in the evening and in the weekends. But the availability of technical helpers is still a problem for us.

Support for Teaching, Learning and Leaning Assessment

For implementation of integrated learning, teaching, learning and assessment methods should be carefully chosen. Traditional approaches of teaching and learning would not be effective in this context. The CDIO resource center introduces some teaching methods. However, it would not be easily learned by reading only. Experiments and sharing experiences are excellent way of spreading new teaching and learning methods. It should also be realized that assessment schemes are also excellent guilds for both students and faculty in achieving dual learning effects.

In the College of Engineering of STU, each course or project aims to cultivate some the of CDIO skills. This is documented in the course syllabus. The faculty would need to find proper ways to fulfil the “I (Introduce)”, “T (Teach)”, “U (Utilize)” requirements stipulated in the course syllabi.

We have organised a list of workshops and seminars to share our ideas and experiences. This has helped us to enhance the teaching skills of our faculty.

Form Coalitions

The CDIO initiative is an open source, internationally collaborative effort. Collaboration among universities around the world makes the reform more effective and efficient. It also helps to coordinate efforts in establishing international trend of engineering education.

China has the largest number of engineering graduates each year in the world. Since the economic reform of the country, the industry and the society have been developed rapidly. There have been increasing needs for globally competitive talents. However, according to various reports, a large part of the graduate engineers do not meet these needs. It has become a challenge to find appropriate engineering employment for current graduating classes, especially during the current global economic crisis. To improve the competitiveness of Chinese industries, education of competent engineers and future industrial leaders is primary concern of the Chinese engineering educational institutions.

The CDIO initiative defines the goals and objectives that meet the global industrial needs. The principles of the initiative are based on well-established educational theories and best practices. Participating in the CDIO initiative has helped us in following the international trend, and narrowing the gap between the industrial needs and the engineering education. Thus we make every effort to disseminate the CDIO initiative to other universities in China. We have held a series of forums and seminars on engineering educational reform and introduction of CDIO.

With helps from the international CDIO leadership, under direction of Division of Science and Engineering, Department of Higher Education, Ministry of Education, two university coalitions have been formed in 2008. One of them is composed of over 30 universities. This group mainly works on the CDIO methods research and dissemination. The second coalition consists of 18 universities. This group of universities started pilot implementation of the CDIO initiative. Several participating universities have started fundamental reforms to their engineering education. By forming national coalitions, we have found partners and started building the momentum of the engineering education reform. This enhances our confidence in further engineering education reform based on CDIO, and helps us to carry on continuous improvements.

SUMMARY

The renowned leadership guru John Kotter [2] has listed eight steps for successful change management: 1. Establish a sense of urgency; 2. Form a Powerful Guiding Coalition; 3. Create a Vision; 4. Communicate that Vision; 5. Empower Others to Act on the Vision; 6. Plan for and Create Short-Term Wins; 7. Consolidate Improvements and Keep the Momentum for Change Moving; 8. Institutionalize the New Approaches.

A brief comparison between the eight steps and our ten key points would show that our reform management, though not deliberately following the eight steps, maps well with Kotter's guidelines. This demonstrates that both our experiences and Kotter's theory can be used for other insitutions to introduce the CDIO initiative in engineering education reform.

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UNFOLDING CERTAIN ENGINEERING PROCESSES IN A LECTURE-BASED ENGINEERING COURSE

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ABSTRACT

This paper presents the experiences of the introduction of some steps of “Conceive” and “Implementation” stage of the real-world engineering processes in a traditional lecture-based course, called Electromechanical Transmission Control, to develop the student competencies, such as system thinking, engineering reasoning and knowledge discovery. To intensify the understanding and perception of the technical fundamentals, a series of experiments are also scheduled in this course. In the lecture session, inquiring-based learning and design-directed learning are adopted to stress the design directive or requirement specification defining of “Conceive” stage. Meanwhile, in the series of laboratory work, the validation against the requirement of “Implementation” stage is unfolded in some sense with the different instruction in the before, during and after phase of the whole experiment process. Based on a set of validation experiments, a small-scale design-build-test project is arranged by the end of the course to enhance the students’ engineering experience and skill. The enthusiasm shown by most of the students and well presented reports are very positive to our reform attempt.

KEYWORDS

Design-directed learning, Inquiring-based learning, Experimental learning, Engineering processes

1. INTRODUTCTION

Nearly by the end of 2005, the CDIO initiative of engineering education [1] was introduced to the College of Engineering of Shantou University as the first one in China. Based on the CDIO concept, Shantou University developed the engineering education into a design-directed EIP-CDIO program with the competencies fostering as the main aim [2]. In response to the problem of the lack of the understanding and appreciation of the historical, social and environmental responsibilities in the conventional engineering education in China, EIP-CDIO program stresses Ethics, Integrity and Professionalism; furthermore these qualities should be reasonably integrated into the context of Conceiving – Designing – Implementing - Operating systems and products. The vision is to make graduates become qualified engineering talent not only with CDIO skills but also with high social responsibility, good professionalism and healthy personality.

With CDIO Syllabus 2004 and CDIO Standards 2004 as a reference, we preceded curriculum reform for all five majors of College of Engineering since the spring term of 2006. Before we formally started the four-year EIP - CDIO engineering program for 2006 freshman, several mandatory courses for year two and year three of every major are chosen as the CDIO pilot course. Among them, Electromechanical Transmission Control has been tested in fall term of 2006 and 2007 respectively. In some sense, it is interesting to share some experience of this reform test with the readers in the following sections. In section 2, we firstly introduce the main task of this course. Then, the teaching and learning characteristics during the lecture is presented in section 3, and followed by the corresponding experiment process description in section 4. After the introduction of the lecture teaching and experimental learning, how effectively assess the outcomes, e.g. student CDIO skill, is discussed in section 5. The feedback of the students is shown in section 6. Finally, section 7 contains the conclusions.

2. ELECTROMECHANICAL TRANSMISSION CONTROL PILOT COURSE

As a core mandatory course of the major of Mechanical design, manufacturing and its automation, Electromechanical Transmission Control provide students the basic electrical fundamental knowledge of mechatronic engineers. It is characteristic of the integration of mechanics and electrics while electrics serving for mechanics. Adapted to the technical development trend, kinds of power electronics technical knowledge relating to transmission is included spanning from the basic low-voltage electrical appliance, relay logic circuit to the most advanced variant frequency regulation system. On the other hand, this course stresses the value of the practice with 27% credit hours allocated to experiments, which can really strengthen the understanding of the corresponding knowledge [3].

For the student showing the low-level self-study ability and no interest to any courses duing to the high-school study mode mainly driven by the testing marks, the great challenge is how to stimulate their intrinsic curiosity, and how to provide the hands-on experience to foster lifelong self-learning habit.

Among the 12 CDIO Standards [4], the first one tells us the context of engineering education should be the product and system life-cycle development and deployment – Conceiving, Designing, Implementing and Operating. Thus in this CDIO pilot course, some steps of the Conceiving and Implementing stage are introduced into the lecture and experiment process, which is appropriate for the course's feature and student status. Compared with the CDIO Syllabus [5], the education goals of this pilot course are revised as shown in Table 1 [3].

Table 1
CDIO skills developed in Electromechanical Transmission Control*

		Contact	Train	Application
2. Personal and Professional Skills and Attributes	2.1 Engineering Reasoning and Problem Solving	A	B	C
	2.2 Experimentation and Knowledge Discovery	A	B	C
	2.3 System Thinking	A	B	B
	2.4 Personal Skills and Attitudes	A	B	B
	2.5 Professional Skills and Attitudes	B		
3. Interpersonal Skills: Teamwork and Communication	3.1 Teamwork	A	A	A
	3.2 Communications	A	B	B

4. CDIO process in the Enterprise and Societal Context	4.1 External and Societal Context	D		
	4.2 Enterprise and Business Context			
	4.3 Conceiving and Engineering Systems	A	C	D
	4.4 Designing	B	C	C
	4.5 Implementing	A	B	C
	4.6 Operating	D		

* Note: A, B, C, D are used in the goal column to show the different level, where A is the highest, and when there is no requirement, it is kept vacant.

By the close integration of the context of the lecture and experiments, students are expected to become more willing to participate the total experiment process, which will help them intensify the understanding of the fundamentals, enhance the skills of observation, analysis and expression, and moreover master the method of exploring the knowledge and develop lifelong learning ability.

3. CLASSROOM TEACHING PROCESS

During the classroom teaching, the Inquiring-based learning is adopted to experience the requirement analysis and specification definition of Conceiving stage. The key aim is to help students realize the relative position of the learned content in the subject discipline hierarchy system, and their connection with the relevant knowledge they have studied, then find out the orientation and the feasible way to enrich their own knowledge framework.

For inquiring-based learning, how to set the context to induce the various inquiries is the main point to guarantee the effect. Here, the clue is the core, which is used for steering students towards the main content that should be learned and facilitating the control of the inquiring process. Moreover, teacher should be aware of which kind of presentation of the clue is the fittest to inspire the student.

For example, when learning the Relay Logic Circuit and Programmable Logic Controller, based on the understanding of the basic principle and design procedure of the former, the students are induced to analyze with the lecturer its non-adaptivity exposed in the process of the production procedure change and the new one trial, and the cause of this situation. After being sure of the inherent defect of Relay Logic Circuit, the lecturer help students define which is the key problem needed to be solved combining the natural and regular patterns of the technology development. Furthermore, whether it is possible to find out the solution to it or not can also be analyzed with the aid of the fundamental knowledge of the related subject discipline, such as the micro-computer and micro-electronics. Finally, it is the lecturer that gives the description of the high efficiency and great economic value benefiting from the adoption of the new technology.

With the intrinsic technology development pattern as the clue of the Inquiring-based learning, student can get preliminary contact with the real-world engineering problem and actively experience the basic engineering reasoning process.

4. THREE STAGES OF EXPERIMENT PROCESS

The validation of Implementing stage is presented by the series of experiments scheduled to match with the lecture content. Taking advantage of the Experimental learning, different instruction is assigned in before, during and after phases respectively for every experiment. In the before phase, students are asked to do preparation according to the manual, to think

over why the operation is instructed as this step by step, and to anticipate what will happen in the key step. In this way, not only will the experiment process become more effective, it will also become very helpful to enhance the logical thinking skill of the student.

In the during phase, students are promoted to more actively engage in the trial and error. Through this process, students are expected to experience the value of the teamwork cooperation and the trust and support among members. On the other hand, for unforeseen problems will almost certainly arise, when they failed to observe the expected phenomena and data, they are encouraged to survey carefully the operation steps and the surrounding circumstance, and find the main factor of the failure for themselves with the guidance of the teacher, then try to handle and observe again. This cycle will greatly intensify the understanding and flexible application of the related knowledge, which is the very knowledge acquired by the hands-on practice. Meanwhile, it is hoped to be positive to the knowledge exploring ability and decision making skill.

Finally, in the after phase, the standardization of the experiment report is stressed to train the written communication ability and develop the merit of honesty and integrity. Corresponding to the deviation of the observed phenomena and data from the theoretically deduced one, students are asked to give their own analysis and judgement. This training is worthwhile for the development of the documenting ability, especially of how to formulate the available materials to present a rigorous reasoning.

To highlight the design-directed engineering education mode, we extend the validation experiments to the design-build-test projects step by step to ensure it is within the most students' ability, such as Forward and Backward Turning control of AC motor with PLC in 2006, Starting, Braking and Speed regulation of AC motor with VFC and PLC in 2007, and Motor Control Design of NC Milling Machine with VFC and PLC in 2009. The moderate challenge is more interesting and engaging for students, and valuable to strengthen the CDIO skills.

5. ASSESSMENT OF THE COURSE LEARNING

Students are assessed with experiment report, subjective report and final exam. The term score is made up of these three parts with 30%, 30% and 40% weighting respectively. This weighting allocation shows the relative importance of the various kinds of skill building trial and make students pay attention to the whole process rather than just the final exam.

Subjective report depends on the student's own interest within the discipline scope of the course. The key point is it is student that finds what is the most interesting to him and experiences the regular grant proposal drafting procedure through the literature collection, reading and summarization. Students are expected to learn how to evaluate the various opinions basing on the fundamental knowledge. This kind of scientific thinking is also an important competency of a qualified engineer.

Open-book type examination is taken in the final exam. Students are asked to give a principle analysis of the key operation step or key phenomena of every experiment. Again, it is the motor's running characteristics and the transmission control method and the related circuit that should be thoroughly understood and mastered. The aim of the test is to highlight the application instead of the memorization of the knowledge. The exam result shows the reasonable Gaussian distribution. Around 70-80 percent of the students can give a fit answer and one student a perfect one in 2006 and 2007 respectively.

6. STUDENTS BEHAVIOR AND FEEDBACK

The most notable effect of this reform is that the usual passive attitude to the experiment is changed to active participation. According to the lab registration card, during the open hours, there are more than 20% teams choosing to do additional test or repeat the experiment to confirm the result on their own, while only less than 5% in the last year. Moreover, compared with their performance during the former several experiments, more and more students can raise the meaningful questions about the experiment operation and phenomena in the last two ones.

For the first small scale design-and-build project, most of the students can do well under the supervision of the lab teacher. For the second, it went not smoothly at the beginning, maybe because it is scheduled near the final exam and students wouldn't spend too much time on it. After giving the hint that to a large extent the project is the integration of the former experiments, their interest was inspired and most of them became more and more involved. Finally, almost all teams can reach the basic design requirements. Just encouraged by this result, we increase the project difficulty level further in this term to integrate the requirement of another course, Numerical Control Technique.

In the end of the term, the college ever did a survey on the CDIO pilot courses with questionnaire and face to face discussion. In general, the feedback is most positive. Over 65% percent students thought this kind of education pattern is beneficial to them, while others feel hard to adapt to the higher requirement and course assignment compared with before. Moreover, during the break talk, which is an effective way to keep close contact with students and get timely feedback of their perception, some students told me that they really engaged in the design project, and the try and test process gave them a sense of accomplishment and immense satisfaction.

7. CONCLUSION

Adopting the EIP-CDIO engineering education pattern, several kinds of CDIO skills training developed according to the pilot course feature has basically achieved the expected outcome. But it should be pointed that the study stress is beyond around 30% percent students' capacity and makes them lagged behind. It is the unavoidable intellectual challenge brought by the reformation due to the result of long time examination-oriented education. So we must be clearly aware that the main difference between the present education and the before is among the different requirement of the competency, knowledge, attitude and comprehensive quality, varieties of professional skill training method, and the different level of the lecturer's theory, engineering experience, and teaching skill. Among them, the change of the training methods and the students' performance evaluation criteria is the most urgent.

After the four-year EIP-CDIO engineering education plan was started through all the courses since 2006 freshman, the lecture time will be decreased by 30%-40% percent, then students will have more time to engage in the real-world like projects arranged on three kinds of scale. We hope it would be helpful to relieve the stress to some extent.

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USING CDIO METHODOLOGY TO INTEGRATE DIGITAL COMPETENCIES IN TEACHER TRAINING

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ABSTRACT

This paper will point out that the CDIO principles and methodology can be used in another area then engineering education. CDIO has been used as a role model, in the LIKA-project for curricula development in teacher's education programs at four universities in Sweden. The objective with the LIKA-project is to integrate digital competencies in all teachers' education programs. The LIKA project looks upon digital competencies as processes for Learning, Information, Communication and Administration (LICA/LIKA). These processes need to be addressed from a didactical, technical and theoretical perspective. To assure the success of curricula development 10 key principles, like the ones outlined by CDIO, where accepted and signed by leaders of the participating university organisations. The experiences from the LIKA project could also be used as a feed-back to the CDIO community.

KEYWORDS

Teacher Education, Curricula Development, Application of CDIO, Digital Literacy, Digital Competencies, Learning Outcomes..

THE LIKA PROJECT – MAIN OBJECTIVES AND TARGET GROUPS

The main objective with this contribution is to report that the CDIO methodology [1], [2], [3] has been adapted to another field of higher education.

As a result of rapid changes in a digitalized society, an initiative was taken by the Swedish Knowledge Foundation (KKS) in 2005, with focus on ICT in Teacher training. KKS allocated 100 MSEK for projects during a period of sex years. The LIKA project was successful in the first call for proposals together with two other projects in Sweden to get funds for a project of six years of duration (2006 – 2011).

An inquiry from the Swedish Ministry of Education on a new teacher education programme was presented in December 2008 and the report is entitled Sustainable teacher education. [4] In the report, four overall perspectives have been found to be so essential that they should run through all teacher education.

These are: [4]
"- a scientific and critical approach
- a historical perspective
- an international perspective
- information and communications technology (ICT) as an educational resource.

All four perspectives are areas that need to be strengthened in teacher education.

ICT as an educational resource is an absolutely essential part of a teacher education programme attuned to the digitalization of society and school.

The implication of the inquiry will probably be that all teacher education programs in Sweden will be changed. The LIKA project is cited in the report, as an example of how to work with implementation of digital competence.

The LIKA project is a collaboration project between Royal Institute of Technology KTH, Royal College of Music in Stockholm KMH, Stockholm University SU and The Swedish School of Sport and Health Sciences GIH, all responsible for teacher education programs.

The project objective is to ensure digital competencies in teacher training. This requires a model for systematic curricula development. To be able to define and integrate ICT as a progressive part in programs and courses throughout the education, CDIO is used as a model and guideline. Newly examined teacher students have to have a tool box and a wide repertoire of pedagogic ideas about how to utilize ICT in their work at schools. This includes planning, executing and evaluating learning processes with digital tools. [5]

Project Target groups are: (i) Teacher educators, (ii) Teacher students, and (iii) In-service teachers in partner schools working as mentors for teacher students during periods of practice.

To reach the objectives, key activities in the LIKA project has been defined. These are program and course development, methodological development, access to research and experts in the field of ICT and learning, training for teacher educators, implementation processes, and evaluation and disseminate results.

LEARNING OUTCOMES AS A BASE FOR DESCRIBING PROGRAMS, COURSE OBJECTIVES AND EXAMINATION REQUIREMENTS

Around the world, the development of higher education is ongoing, to meet new demands from society and industry. Swedish universities are heavily influenced by what happens globally and now primarily in Europe through the so-called Bologna process. There are new and clearer requirements on higher education leading to employment in a profession and students should be able to be globally mobile both during their training and in the future professional life. Within the engineering field, this is significant, while primary and secondary school teachers, is still characterized by a more local relevance.

Both engineering and teacher training are leading to a professional degree. These degrees are regulated in Swedish Higher Education Ordinance system, where the examination requirements are formulated in the so-called Learning Outcomes, LO.

As support for the formulation of LO national authorities, accreditations bodies and various interest groups has formulated requirements for knowledge, skills and attitudes.

Examples from the engineering field are:

- Australian Council for Educational research ACER [6]
- ABET2000 in the U.S [7]
- Washington Accord [8]
- EUR-ACE labels [9]
- Tuning project [10]
- Dublin Descriptors [11]
- Engineering Subject Centre UK [12]
- CDIO initiative [1].

All these examples are trying to define and produce conceptual frameworks of expected desired learning outcomes in the field of engineering. These examples also assume that the goals of higher education should be formulated in Learning Outcomes.

ADAPTION OF THE CDIO PRINCIPLES INTO THE LIKA PROJECT

As stated earlier, one of the key activities, within the LIKA project is the work with a systematic integration of digital competencies in programs and courses.

Programs and courses have been put through a due diligence process, to define why, what, where and how digital competencies should be integrated as progressive generic and transferable skills. [13]

The CDIO method serves as a guideline in this work. It is not to be used as a blue print but as a methodology and a structured model to support the implementation work in the context of the LIKA project. [14]

The objective with the LIKA project is to ensure that teacher student graduates has proficient competence to use ICT in a broad sense to enhance learning in all K12 school settings. The Swedish Curriculum for the compulsory school system states that teachers should "prepare the pupils for participating in and sharing the joint responsibilities, rights and obligations that characterize a democratic society." [15] In order to take active part in society of today, citizens must be equipped with the digital competencies a digitalized society requires. Hence, the LIKA project stresses digital competencies, on a societal, institutional and individual level.

How does the CDIO syllabus [1], treat ICT competencies?

In the CDIO syllabus the generic skills are defined in two main categories;

- personal and professional skills and attitudes
- interpersonal skills: teamwork and communication

The two main categories have then an underling structure in two levels with more detailed formulated generic skills. In total the CDIO syllabus contain approximately 40 generic skills.

To what extend does the CDIO syllabus cover digital competencies, digital literacy, information literacy or ICT skills either as personal, professional or interpersonal skills? Just a few will explicit point out these competencies. For example in 2.2.2 Survey of Print and Electronic Literature CDIO point out *"information search and identification using library tools (on-line catalogs, databases, search engines)"* and in 3.2.4 Electronic/multimedia Communication *"Preparing electronic presentations, norms associated with the use of e-mail, voice mail, and videoconferencing. Various electronic styles (charts, web etc)"*

In many others, digital competencies is implicit a requirement for fulfilling the learning outcome. For example in 2.1.2 Modeling. *"Mostly all modeling and simulations, requires skills to use computers in one or another way, which implicit needs some digital competencies of the user."*

CDIO CONTRIBUTION FOR DEVELOPMENT OF A LIKA MATRIX

One important contribution from KTH into the LIKA project is the use of the CDIO model. The experiences KTH has from the CDIO work has largely inspired and formed the LIKA project. The work with identifying and integrating digital competencies in teacher training requires program and course analyses and development. The CDIO method serves as a guideline for this work within the LIKA project, meaning that program and courses has to be put through a translucent process which aligns with the method process used in the LIKA project.

The Swedish School of Sport and Health Sciences (GIH) has during the last 15 month (Sept 07 – Dec 08) carried out a rewriting process where all courses, 16 in a total, in the Teacher Education Program. This work has been done in parallel to the Bologna process work to gain synergy effects and to stress the importance of seeing digital competencies as a generic skill that needs to be examined during teacher training. In parallel to the processing of the curriculum, the project has worked out a syllabus and a matrix, meant to serve as support for systematic integration work. The LIKA syllabus and matrix are dynamic and changing as digital competences are defined and developed. It provides opportunities for faculty members to identify the progression of competence as knowledge are and skills are tagged as generic or specific and to see where they are introduced, examined and applied.

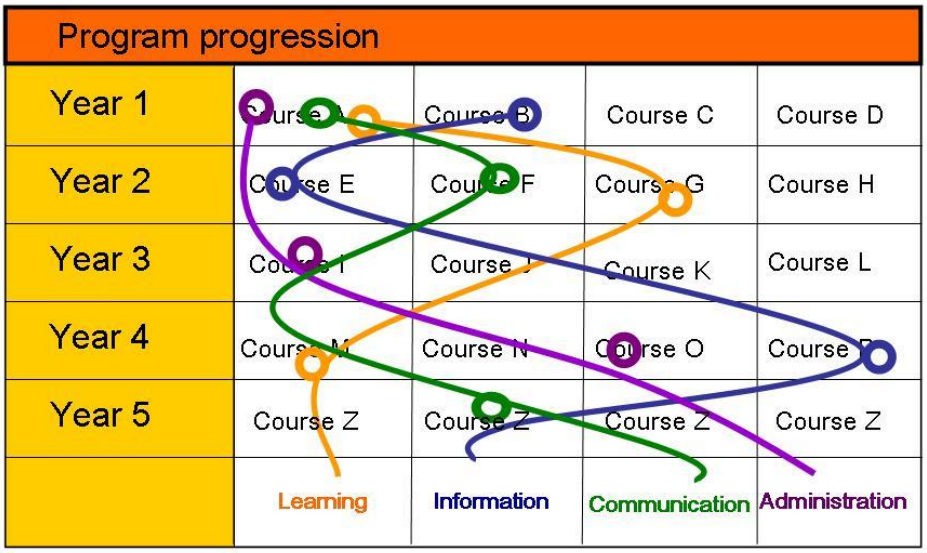

Figure 1, Systematic Integration

The LIKA matrix

The LIKA project looks upon competences as representation of a dynamic combination of knowledge, understanding, skills, abilities, judgment and approach.

Skills are abilities formed in learning activities which can be divided into ‘subject specific’ and ‘generic’. All skills range from a low to a high level.
I.e. *Low:* discuss, explain, describe, tell, etc.
High: rank, create, show, design, decide, analyze, etc.

Skills listed below in the matrix are interchangeable due to the technological development and the rapid change in society.

The progression has to be planned within each educational program.

Table 1 The LIKA Matrix Digital Competence in a Technical Perspective

Digital competence	**Learning processes**	**Information processes**	**Communication processes**	**Administration processes**
Technical competence *A digital technical competence implies that teachers can decide when and what digital tool to use in a pedagogic environment. The person should have technical skills and be continually updated within this area.*	**Skills* (examples)** Virtual formal and informal learning environment settings Digital portfolio DV cams Film editing Games Hart rate monitor Open Learning resources Wearable digital devices Reference library Simulations Software (Open source, Free ware, commercial programs) Virtual recourses Identifying and classifying tools Digital recycling	**Skills* (examples)** Search engines Search tools Databases, statistical and science databases Webb publishing Webb design Creative commons and other Search techniques Advanced Web design Advanced databases Data mark-up (xml) Legal aspects Ethical aspects	**Skills* (examples)** Collaborative online communication environments Collaborative online writing tools Community systems Digital environments PLE/LMS Legal and ethical aspects Mobile communication Communication tools and options for collaborative work Information security aspects Legal and ethical aspects	**Skills* (examples)** Administrative programs Collaborative online documentation Systems for administration, like schedule, registering absence, grading, assessment System and tools for shared documentation Legal and ethical aspects Administrative programs Information security Risk analysis Legal and ethical aspects

Table 2 The LIKA Matrix Digital Competence in a Didactical/Pedagogical Perspective

Digital competence	Learning processes	Information processes	Communication processes	Administration processes
Didactic pedagogical competence *A digital didactic pedagogical competence is to be able to judge when, what, why and how ICT should be used as a pedagogic and methodological support for learning.* *Teachers should be able to choose methods and digital tools suitable to the content, environment and the context.*	**Skills* (examples)** Use of digital tools and learning objects to support teaching, learning and pedagogic development. ICT support for learning (write, read, communicate, explore) Information grows into knowledge Examination forms Multimedia/modal creating Creative production Reproduction, meta-cognition Adaptation to learning styles Experiential learning Adaptation/including Interactive learning Choosing form of examination adapted to own teaching model	**Skills* (examples)** Who is the owner of texts, pictures etc. Be conscious about the need of analysis of the sources Information search Discussions about citations vs. plagiarism, cutting and pasting Adapt teaching about analysis of the sources to different student ages Applying analysis of the sources on the Web	**Skills* (examples)** Digital social competence, like netiquette, norms, communication codes Women's and men's language Mechanisms within interactive and asynchronous communication Communication ethics, like what to disseminate or not, bullying Consequences of internationalizing and globalization Distance education International collaboration Presentation and communication through digital media The use a communication platform Planning teaching when a communication platform is used Adaptation of communication to disabled students Individualization	**Skills* (examples)** Administrative ICT routines Digital archives Digital documentation of students learning processes and results Digital grading Adapt/adopt digital documentation for specific needs

Table 3 The LIKA Matrix Digital Competence in a Theoretical Perspective

Digital competence	Learning processes	Information processes	Communication processes	Administration processes
Theoretic competence *A digital theoretic competence implies that teachers has knowledge about ICT-pedagogic theories and methods for teaching and learning, and is able to value how a different theoretical aspect affects practical professional pedagogic activities. A digital theoretic competence also requires knowledge about research within the field of ICT and learning.*	**Skills* (examples)** Learning theories Theories about computer-supported collaborative and multimodal learning, Theories about hyper-textual (non-linear) thinking ICT in multidisciplinary, interdisciplinary and research based learning environment	**Skills* (examples)** Information theories Theories about computer-supported information-searching Theories about valuing information The principle of public access to official documents Information theories Value theories	**Skills* (examples)** Communication theories Theories about children's and youths' communication Theories about children's and youth's development Applied theoretical discussion	**Skills* (examples)** Organization theories Activity theories Theories about monitoring systems

The table 4 is used as a work sheet to ensure a progressive integration of digital competencies in courses at The Swedish School of Sport and Health Sciences.

Table 4 The LIKA Work Sheet

Perspective Digital competence	Processes L I C A	Course	Learning Outcomes	Progression
Technical competence	**Skills* (examples)**	X1	Formulate by: Knowledge and understanding Skill and ability Attitude and approach	Course X1 Course X2 Course X3 Course Z1
Didactical Competence				
Theoretical Competence				

Examples

Progression for learning processes from a technical and didactical perspective

Student graduates will be able to apply the soft and hardware for motion analysis, and show the learning process influences from a didactic perspective.

Progression

Take down the progression forward and how can it be traced. (Example: X1-Z1 level)

After course X1, the student will be able to handle and apply the camcorder and transfer video to computer unit.

After course X2, the student will be able to apply and manage, and produce videos for motion analysis and to demonstrate analytical ability. The student should be able to describe the specific responsibilities of teachers for students' privacy protection in relation to video recording and photography.

After course X3, the student will be able to plan and assess and show in what context, video and video analysis can enhance individual and group learning processes.

After course Z1, the student will be able to create, asses and analyze the effects of video and motion analysis programs in a situated learning context, from a didactical perspective.

DISCUSSION

CDIO principles and methodology focus on the development of engineering curricula with the objective to graduate engineers who can engineer. The CDIO syllabus has been designed so that knowledge, skills and attitudes can be formulated in learning outcomes. The learning methods of the engineering program and courses are designed to fulfil learning outcomes. The course design matrix has successfully been used to assure coverage, progression and assessment.

As shown in this paper, the CDIO principles and methodology is now used as a role model in teacher's education. The LIKA project has adopted and modified the CDIO principles and methodology to secure that digital competencies will described as learning outcomes, learned and assessed in all branches of teacher training.

GIH has advanced most in the review process of the curriculum for the specific purposes of making digital competence visible. Work is still in a initial stage and far from all who work with program and course development, use of the produced models. In contrast, the CDIO aroused great interest among teacher trainers, as methodological model and support.

The LIKA project has chosen to use the term digital competency as it grasps over a wider field than the more common used term digital literacy, which is more closely associated with text, reading and writing. In this respect, the work also highlights the difficulty of balancing between the general and the specific in formulating learning outcomes for generic knowledge, skills and attitudes.

It's too early to make any assessment on graduates, but the process is in place, major changes have been made and the implementation phase has started. Digital competency is on the agenda, which hopefully will lead to a more rapid change in the educational system, from pre schools to universities, to meat the demands of competencies formed by a digitalized society.

The process is ongoing and not just within the LIKA partner universities. LIKA also participates within the national network for ICT in Teacher Education and has a genuine interest in international collaboration to improve the knowledge in the field.

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USING CDIO TO REVAMP THE CHEMICAL ENGINEERING CURRICULUM

Sin-Moh Cheah

SINGAPORE POLYTECHNIC

ABSTRACT

This paper discusses how the CDIO framework is used to reengineer a curriculum revamp for the Diploma in Chemical Engineering at Singapore Polytechnic. A brief introduction to the "traditional" way chemical engineering program is being taught is presented followed by a discussion on rising importance of including general transferable skills and chemical product design skills in the educational landscape and its impact on the chemical engineering curriculum. The shortcoming of the present course in its coverage in terms of the requirements of CDIO Standards and Syllabus were discussed. The approach taken to revamp the curriculum, which resulted in a new course structure, is presented, followed by brief descriptions on work done for selected modules, namely *Introduction to Chemical Engineering*, *Plant Design Project*, *Chemical Product Design* and *Chemical Reaction Engineering*. Key learning points from the revamp exercise were discussed, how some of the challenges were being overcome, followed by discussion on plans formulated to continue the curriculum revamping effort. Lastly an overview was given on how recent development on education for sustainable development as well as the integration of process and product designs can affect the education of chemical engineers, and how the CDIO framework can be utilized to continue to drive the reform in chemical engineering education.

KEYWORDS

Chemical engineering, course structure, chemical product design, process plant design

CHEMICAL ENGINEERING EDUCATION IN THE POLYTECHNIC

A key objective of a chemical engineering education is to synthesize the many subjects studied into the design of a system, component, process, or experiment. The hallmark of traditional chemical engineering education in the universities is that of chemical process design, often with a requirement that students complete a plant design project in their final year of study.

Teaching of chemical engineering in the polytechnic closely mirrored that of degree programs in universities, albeit in a simplified version pegged to the diploma level, which is a 3-year program. The various chemical engineering disciplines are taught in a modular fashion. A notable feature of polytechnic education is probably the more extensive hands-on experience of operating various pilot plants, large and small, compared to the universities. Other than that, polytechnic graduates can pretty much expect to deal with familiar topics but at a more conceptual level when joining the university.

Much like the university, chemical engineering education in the polytechnic also include chemical process design, whereby students are required to complete a chemical plant design project based on a given problem statement to produce a given commodity chemical. Students often work in team to come up with a process design to achieve the required production. Students typically carried out literature survey of available processes and upon selecting one, proceeded to carried out computer simulation for all the process flow streams and the equipment contained in the selected process, complete with a environmental and safety analysis of the design.

The traditional focus on chemical process design, coupled with a largely modular course structure, meant that the polytechnic's chemical engineering curriculum is delivered via various modules each addressing a particular discipline of chemical engineering, relying on the integrative nature of plant design project to bring together the various concepts learnt. The obvious downside is that students tend to compartmentalize their learning, and are often unable to utilize the relevant disciplinary knowledge in solving their plant design problem. It was also observed that students tend to rely on trial-and-error in computer simulation to give them a "design" without much interpretation of the simulation results. It is further noted that chemical engineers typically carry out simulation and equipment design work for an individual piece of equipment as part of plant modification or upgrading work (for example, debottlenecking). It is very rare for diploma-level graduate to ever be involved in intensive plant-wide design work.

CHANGES IN CHEMICAL ENGINEERING EDUCATIONAL LANDSCAPE

Two major changes in the education of chemical engineers had taken place over the last couple of years: (1) Emphasis on General Transferable Skills; and (2) Emergence of Chemical Product Design.

Chemical product design is beginning to emerge as an important discipline in chemical engineering. This is largely the result of changing competitive landscape in the chemical processing industry. Today's chemical industries have been facing dramatic social, economic and technical challenges, on a global and local scale. Globalization, for example, has brought about rapid changes in businesses and technologies, resulting in organizations making deep and rapid changes in the scope of their activities and the strategies adopted to remain profitable and achieve sustainable growth. With advances made in information technology, green chemistry and nanotechnology, etc, many of the chemical products of today and tomorrow do not have much in common with those of twenty years ago. Production of commodity chemicals had been overtaken by high value-added specialty chemicals. The portfolio of skills and technical knowledge required by chemical engineers, as well as the working environment, has therefore changed tremendously, which increasingly focused on soft skills (or 'higher order' skills or general transferable skills) in teamwork, communication, appreciation of multi-cultural diversity, etc. Like those in other engineering disciplines, there was a growing dissatisfaction among the chemical industries with chemical engineering education. Much of the criticisms had been levelled at the inadequacy of soft skills among chemical engineers or chemical engineering graduates. A concise review of this had been presented by the author [1].

In their seminal paper, Moggridge and Cussler emphasised the need for chemical product design and elaborated on the expanded role of chemical engineers, highlighting the necessity for them to work in teams in a joint effort of product design through participation in the whole enterprise from conception to manufacture [2]. Chemical product engineering is now being cited as the next paradigm for chemical engineering, and an increasing number of universities now offered chemical product engineering-related courses [3].

CDIO AND DIPLOMA IN CHEMICAL ENGINEERING CURRICULUM REVAMP

The above change drivers served as the impetus for revamping the chemical engineering curriculum. In this regard, the CDIO framework [4] fits in well with the strategic intent of the revamp, which is to introduce students to skills in conceiving, designing, implementing and operating chemical products, systems or services, in a manner that integrates the various chemical engineering disciplines along with other general transferable skills.

A study of the chemical engineering curriculum coverage vis-à-vis the CDIO Standards and Syllabus was undertaken. Overall, at the course level, the various CDIO skills such as teamwork, communication, plus broad aspects of personal skills and attitudes, as well as engineering reasoning and problem solving, experimentation and knowledge discovery are loosely covered in various modules. More importantly, the study revealed several areas where the curriculum is lacking, namely a module on introduction to engineering (CDIO Standard 4), and overall skills in conceiving, designing, implementing and operating an engineering product or system (CDIO Syllabus Part 4). Although some aspects of these skills are practiced in the execution of a student final year project, there is no systematic framework that guides this process and as a result the approach varied considerably from project to project depending on the supervisor. As such, the execution of final year project needs to be fine-tuned to enhance features of the so-called Design-Build Experience (DBE) in CDIO parlance. Opportunities also need to be created to introduce DBE to students at an early stage in their study rather than just at the last phase in the form of final year project (CDIO Standard 5). Also needing to address are skills in system thinking and appreciation of ethics in practice of chemical engineering.

The study also showed that more can be done to integrate the various core chemical engineering modules taught in a modular manner (CDIO Standard 3). The various CDIO skills should be embedded into the core chemical engineering modules and learnt alongside the technical subjects (CDIO Standard 7). These skills can be enhanced and reinforced in the laboratory activities by re-designing the experiments to be more engaging and enriching for the students (CDIO Standard 8).

There is also a need to provide new workspaces to cultivate the developments of skills in conceiving, designing, implementing and operating a chemical product or system (CDIO Standard 6). Although the curriculum is rich with hands-on opportunities for students, these activities all centred around the operation of pilot plants. When it comes to final year project work, students have to make do with existing facilities in the existing laboratories, which often lack both privacy as well as proper facilities such as storage space, printing and communication equipment. Insufficient attention had been paid in the past to such needs. Lastly, from the study it is also clear that lecturer competency need to be build up (CDIO Standards 9, 10 and 11), especially in chemical product design.

From the study, it is obvious that new modules need to be introduced. To make room for the introduction of new modules in an already-crowded curriculum, existing modules were revised, merged or otherwise removed. Overlapping contents were removed, while similar concepts were trimmed and converted to independent learning. The outcome of the curriculum revamp is the modified course structure for teaching chemical engineering, which is shown in Figure 1.

Next step is the study to review how the various CDIO skills can be infused into the curriculum. In this regards, the course management team worked closely with the polytechnic's CDIO Working Committee, to develop an appropriate CDIO Syllabus suitable for diploma-level students. Subsequently, a CDIO Syllabus for chemical engineering was produced based on the original CDIO template [5]. Next, the team proceeded with the

selection of three CDIO skills (namely, teamwork, communication, and personal skills and attitudes) for infusion into the DCHE curriculum. A set of underpinning knowledge for these three skills suitable for the polytechnic's context were developed. A mass training for all academic staff was conducted, followed by a focused training on the underpinning knowledge for a group of trainers. A detailed gap analysis was then carried out to identify shortfalls in the coverage of these three skills in the existing curriculum.

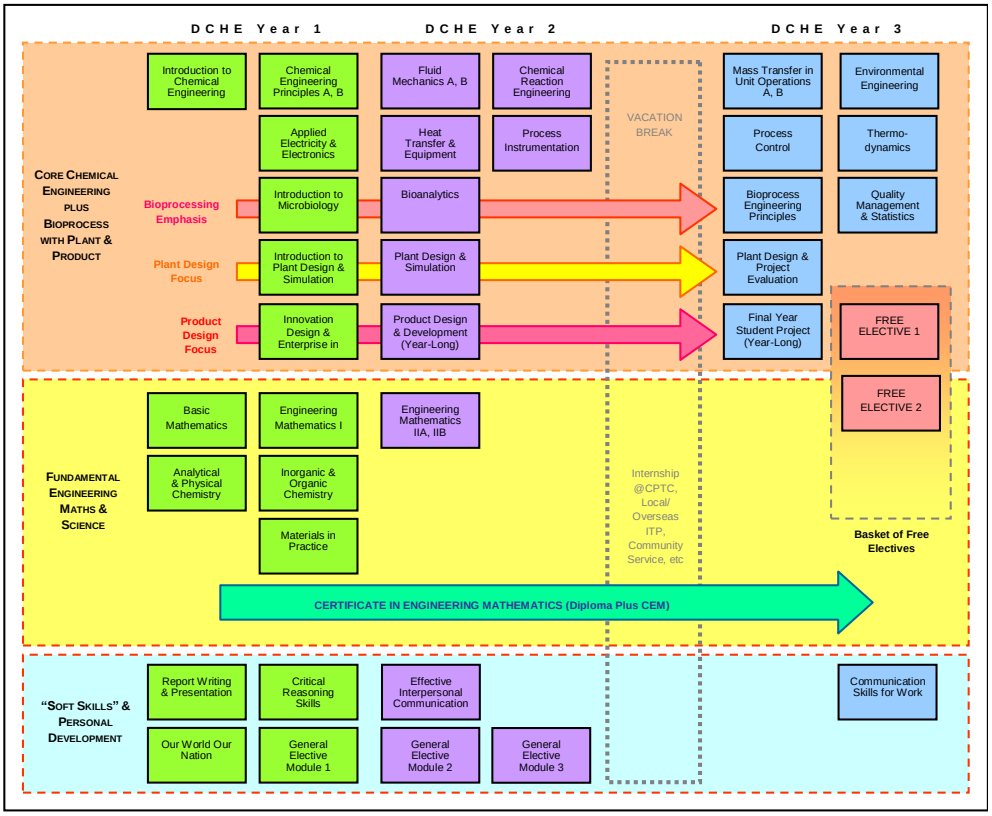

Figure 1. Revised Chemical Engineering Course Structure

A pilot module, representing a core chemical engineering discipline with laboratory experiments, was then selected for trial application. The team recognised that the laboratory experiments, compared to lectures and tutorials, are rich in hands-on experience, thus can best be leveraged to provide the greatest opportunity and largest context on which infusion of CDIO skills can be initiated. Along with the integration of CDIO skills, the team also reviewed ways to more closely integrate the various chemical engineering disciplines while maintaining the modular design of the curriculum.

Introduction to Chemical Engineering

This is a new Year-1 module, introduced to familiarise students with the chemical engineering profession, chemical industry, plus roles and responsibilities of a chemical engineer. The module was features activities designed to offer appreciation to the kind of job that a typical chemical engineer does. The module also introduces students to DBE project early in their course of study, by challenging them to come up with a simple product design and evaluate its performance. Students were also exposed to the requirements of the three selected CDIO skills of teamwork, communication, and personal skills and attitudes. Details of this work will be presented in a separate paper [6].

Chemical Product Design

The introduction of this Year-2 module serves to provide the much needed extra dimension in chemical engineering education to move it away from just chemical process design. For this module, the team decided to adopt the approach introduced by Moggridge and Cussler [7] as it had much in common with Part 4 of the CDIO Syllabus. The authors outlined a simplified 4-step product design procedure centred around the concepts of 'needs', 'ideas', 'selection', and 'manufacture' which is widely used in business development and manufacturing engineering. The development work for this module will be the subject of a future paper.

Chemical Process Design via Plant Design Project

From the earlier discussion on chemical process design, it is clear that this does not satisfy the Conceive, Implement and Operate concepts of CDIO, as all the students experienced was computer simulation exercises. The revamp of the teaching of chemical process design therefore centres on how to make the plant design exercise more meaningful to our students, other than satisfying the needs of those who intended to further their studies in chemical engineering. To this end, the team decided to break-up the plant design project into "bite sizes", spreading it over the entire duration of the 3-year program. This begins with an appreciation of process flowsheeting in Year-1 and exposure to process simulation. Plant design and simulation was subsequently integrated into various modules in Year-2 and Year-3, rounding of the exercise with a project in the last stage of study in Year-3.

Chemical Reaction Engineering: Integration of CDIO Skills

Lastly, we focus on the revamp of *Chemical Reaction Engineering* to be the pilot module to showcase how various CDIO skills can be infused into a highly technical core chemical engineering module. Extensive research has shown that students learn best when they perceived a clear need to know the material being taught [8]. It is also clear that the best opportunity lies not in the classroom but in the laboratory, where students are to work in teams. Technical know-how and competences in soft skills are all integrated into the same learning environment, as competences are considered to be context-dependent (i.e. as contextualized competences) and should be learned and assessed in the technical context [9]. As such, the teaching of communication should therefore be embedded in, and inseparable from, students' application of technical knowledge. The laboratory activities for this module are therefore revised using real-life work scenario so that students can experience the needs to master the various CDIO soft skills. Emphasis is placed on the three selected CDIO skills of teamwork, communication, and personal skills and attitudes. Details of the work done on this area are covered elsewhere [10].

KEY LEARNING POINTS FROM THE CURRICULUM REVAMP EXERCISE

Several important lessons can be learnt from the curriculum revamp exercise.

Without a doubt, the single biggest challenge to the revamp effort is that of staff buy-in. The CDIO Initiative must not be seen as another management fad that will come and go; something lecturers pay lip service to without putting in serious effort to carry out any meaningful changes in the modules. Continued effort is necessary to convinced everyone that the current revamp is an ongoing process in the spirit of continuous improvement, and the CDIO Initiative is no more than a framework that fits the broader objective of the revamp. Since it is an internationally-led effort by reputable universities, its sustainability should be assured. To encourage buy-in, lecturers are also encouraged to use the CDIO Initiative as

the platform to conduct educational research, in line with the career progression system in the polytechnic. Management support is also frequently sought to sponsor deserving lecturers to attend CDIO conferences or collaborators' meetings overseas.

Also, in initiating the curriculum review, it is clear from the onset that improvements are required in the way many module syllabi are written. Based on Bloom's taxonomy, many existing syllabi were mainly written at knowledge and comprehension level rather than more performance-outcome-based. Many module coordinators are relatively new and do not fully grasp the concept of outcome-based education (OBE) and hence had difficulty with writing syllabi in terms of learning outcomes.

A related issue is the preparation of assessments. There is an apparent disconnection between module syllabi, choice of assessment methods and what is being assessed. Often assessments are prepared largely independent of what is being written in the syllabi. Students are often tested on knowledge and understanding, rather than competency to perform a given task. This is one big area where one can expect most lecturers will have problems in. Difficulty also existed in assessment of soft skills, as lecturers tend to focus only on the technical content of students' output. Part of the reason was the lack of time, another being the lecturers themselves do not know "what to look for". Needless to say this is the most important area to address, as the correct learning objectives are what drive the curriculum design and the assessment methodology. More staff development workshop may be needed to address this issue.

On the effort at integrating the curriculum, one of the most important challenges faced is that many lecturers tend to compartmentalize their own teachings; hence it is not entire surprising that students also compartmentalized their learning! One contributing factor to this is the modular nature of the course structure and assessment system. A module's "success" is measured largely by the passing rate of students taking that particular module, scoring on questions related to that module. Knowledge of another module is necessarily assessed in the other module's own assessment system. The other is the lack of communication between the lecturers themselves. It is also the tendency of lecturers to cover as many topics as possible. In the lecturer's mind, all current topics are individually self-classified as essential. If anything is to be done is to extend them! Getting individual lecturers to reduce the module content to include some aspects of integration with other topics posed a big challenge.

Curriculum integration can only be effectively achieved if each lecturer is aware of what the other lecturers are teaching. The practice of rotating module teaching using different lecturers after a few semesters will help facilitate common understanding between them. Getting each lecturer to include several questions relating the concepts in the module that they are teaching to topics beyond the module also serves to provide much-needed linkages between modules. For example, a tutorial on the topic of heat exchanger operation can include a question of temperature measurement and control such as sensor selection, serving to illustrate how the concepts learnt on the module *Process Instrumentation* can be in the module *Heat Transfer and Equipment*.

And as expected, gap analysis turned out to be a time-consuming process, and several rounds of iterations are required before an acceptable outcome is attained. The results from the gap analysis showed varied level of understanding among the lecturers on what needs to be done to infuse CDIO skills into the curriculum, despite the workshops and briefings. Some module coordinators appear more or less to get it, but others apparently do not. For instance, several lecturers apparently thought that one had achieved infusion of teamwork in their respective modules, simply by dividing students to work in groups for their laboratory experiments. In another instance, a lecturer reported that students are taught time-management because the lecturer concerned had reminded them to submit their reports on

time. Similarly, misconception among lecturers is also rather common on what constitute a DBE. Many are of the opinion that having students complete a final year project automatically 'qualifies' the curriculum as meeting the CDIO 'requirements'. It took significant effort to change these mindsets, via constant reminders and frequent briefing sessions. The successful implementation of the pilot module is often used to illustrate how the integration of general transferable skills into a core chemical engineering module can be achieved.

On the plus side, gap analysis also highlighted several good practices among lecturers in their individual effort to engage students in one way or another. Among other things, gap analysis revealed a wide variety of approaches for example radar chart, peer assessment, 2-tier Q&A, etc. All in all, the efforts spent on the gap analysis exercise are very worthwhile, as it functions, for the first time, as a mechanism that forces each lecturer to seriously think through the learning objectives of the respective module and the laboratory exercises or assignments that contained in the module. An obvious advantage is that it highlights some laboratory experiments that merely require students to verify already known theories. To a large extent, most laboratory experiments, though not specifically embedding any general transferable skills, had now done away with theory-proving activities.

Lastly, though not least important, is that of staff competency. Two areas are of concern here: one concerns competency in general transferable skills and one concerns competency in chemical product design. The former posed some problems initially in terms on the perceived ambiguity among lecturers on how, not being 'experts' in the areas of soft skills, especially that of system thinking, can they effectively design activities involving these skills and assessing them. The use of a pilot module of *Chemical Reaction Engineering* as briefly explained above followed by sharing of key learning points through workshops had served to allay the fears of these lecturers.

However, unfamiliarity with techniques of chemical product design is arguably likely to cause anxiety among lecturers. The current pool of lecturers is being trained in 'classical' chemical engineering which lacked practical experience in chemical product design and development. The teaching of chemical product design using chemical engineering principles is a relatively new concept for majority of chemical engineers. This is because these products, which include performance chemicals, pharmaceuticals, formulated products such as household, beauty or personal care products, and processed foods; have historically been the domain of chemists, material scientists and food technologists while chemical engineers focused on manufacturing processes [11]. Although preliminary training in this area had been provided, it will require some time before lecturers are comfortable with these skills and are able to use them fluently in their teachings.

THE PATH FORWARD

We are just at the beginning of the curriculum revamp, whereby the revised curriculum with CDIO skills integrated into selected modules being rolled out in April 2008. The team took part in a campus-wide evaluation of Singapore Polytechnic's CDIO implementation effort, and engaged students as co-participants in providing feedback to the team on the effectiveness of the curriculum revamp effort. Details of the methodology employed are covered elsewhere [12]. At the time of this paper, we had obtained feedback from students taking the modules *Introduction to Chemical Engineering* and *Chemical Reaction Engineering*. While the work done for these modules are discussed elsewhere [6], [10]; suffice to say that the student feedback had been encouraging, and they had served as important pointers to guide the revamp and design of other modules to include the CDIO skills. We will undoubtedly continue to monitor student performance and obtain their feedback as we moved along.

At the micro level, more chemical engineering core modules will be targeted for revamp. Much can be done to the infusion of the first 3 skills (teamwork, communication, and personal skills and attitudes) into the various core modules other than *Chemical Reaction Engineering*. For the next phase of the implementation plan, several other modules had been selected for the continued infusion of these 3 skills. Starting with Year-1, the importance of these skills will be introduced to students via carefully-designed laboratory experiments. These will then be further reinforced in Year-2 modules with the aim that by Year-3, students will be able to utilize these skills in their laboratory works.

Additional CDIO skills had been selected for integration into the modules. These are Experimentation & Knowledge Discovery, System Thinking, and Professional Skills and Attitudes. Additional modules had been identified for the inclusion of these skills in the curriculum. The team will continue to re-design more laboratory practicals using various task scenarios for students. As chemical engineering education is very broad-based in nature, both in the polytechnic and university undergraduate level, introducing scenario-based activities for the 5 experiments in one module does not necessarily cover all possible workplace situations. Furthermore, it has been shown that such approach did serve to provide students with some degree of appreciation of their job scope and environment. With other modules providing somewhat different scenarios, it is hoped to cover as many different workplace scenarios as possible for our students.

More modules will be required to include cross-module integration. The previous integration effort largely centres on introducing additional questions on topics other than the module in question into the laboratory exercises, typically in the report submission section. With the revised approach to plant design project, it can be expected that more integration between the core chemical engineering modules will take place via design and simulation assignments. These plant design and simulation assignments are also fertile ground for the reinforcements of core CDIO skills of teamwork and communication. More can be also done to also cross-link core chemical engineering principles into lectures and tutorials, as well as assignments or case studies. In the pipeline is a proposed integrated assignment that spanned several modules for example *Fluid Mechanics*, *Process Instrumentation*, and *Heat Transfer and Equipment*. Such an approach may also be applied for those modules without laboratory practicals.

In April 2008, a new module on chemical product design had just been introduced into the Year-2 curriculum. Already in progress at the time of this paper is work to forward integrate chemical product design with the student final year project. Traditionally final year project in chemical engineering are largely proposed by lecturers. When opportunities arise to collaborate with external research institutes, these initiatives (called industry-sponsored projects) are incorporated as final year projects as well. More recently, the team introduced the so-called student-initiated projects, whereby students can suggest suitable topics where they would like to work on. This has limited success as students in general lacked the skills to conceive meaningful, executable projects. With the introduction of the new module on chemical product design, it is hoped that more projects can be initiated by students.

However, it must be recognized that not all ideas may proved to be feasible or implementable. As such, a fall measure is needed and this means lecturers are required to continue to propose projects for students without a workable proposal when they entered Year 3. Also, there remains the need to remain in touch and in support of the chemical industry by continuing to work on industry-sponsored projects. By its nature, these projects usually lack the CDIO components of “conceive” and/or “design” components as the project objectives had been largely determined by the company sponsoring the projects. Often students are enlisted to help in conducting experiments on behalf of post-graduate students or company R&D personnel. The intended learning outcomes are different for different type

of projects. In industry-sponsored projects, industry partners obviously had a different attitudes and expectations toward project outcomes compared to our own lecturers. Similarly, post-graduates or doctorate students, with a more focused approach and time on hand, not to mention a dissertation at stake, tend to be more participative in the project work compared to our own lecturers. As such, the work remaining to be done is to develop separate assessment criteria for the different categories of final year projects. It is important that students are assessed based on different criteria relevant to the nature of the project.

As lecturers become more familiar with chemical product design, the team can also move into the study of its integration with the 'traditional' chemical process design. In fact, Amundson has long highlighted the need to integrate product design with process design [13], arguing that chemical engineering will serve as the "interfacial discipline" of the future, bridging science and engineering in the multi-disciplinary environments where new technologies will be brought into being.

At the macro level, the team will be looking at the setting up of a CDIO workspace conducive for students to carry out their final year projects with DBE. The challenge here centred on the limited resources available in campus. Although in general no new workspaces are needed for the integration of various general transferable skills, there is a real need for visible workspaces for new pilot plants to cater to the needs of new and emerging disciplines such as biofuels and clean energy, and pharmaceutical and bioprocessing. Increased focus these areas had already placed a demand on the available laboratory space, and thus new location need to be sourced for the provision of the envisioned CDIO workspace.

For the longer term, the team will continue to study the changes that is affecting the chemical engineering industry in general, and in the education of chemical engineers in particular vis-à-vis the ongoing reform in engineering education. Already gaining accelerated attention is education on sustainable development. The chemical engineering profession had staked its position to support sustainable development following the Melbourne Communiqué by the Institution of Chemical Engineers U.K. in 2001. Similarly, the U.S. National Research Council (NRC) has identified sustainability education as one of the eight Grand Challenges confronting the chemical industry. It is therefore inevitable that 'next phase' for the Diploma in Chemical Engineering curriculum revamp to focus on the integration of sustainable development in its modules.

With all these development, the role of chemical engineers will no doubt take on yet another new dimension. The introduction of chemical product design in the DCHE curriculum is timely as product design has been identified as one of the engineering tools that form the architecture for sustainable development [14]. Grossmann emphasized that chemical engineers need to adopt broader approaches to the life cycle assessment of products and processes in order to predict more accurately their long-term sustainability [15]. With its focus of life-cycle analysis, the team believed that the CDIO approach, with its Conceive-Design-Implement-Operate framework, lends itself readily to incorporate the requirement of sustainable development into its chemical engineering curriculum. Hence the team is confident that its graduates will be able to play a proactive role in the development of new products that meet the requirement of sustainability.

CONCLUSION

The Diploma in Chemical Engineering is indeed in turbulent yet exciting times. With the multi-prong approach adopted, the CDIO framework will serve the course well into the foreseeable future with the ongoing curriculum redesign effort. The lessons learnt from the initial phase of curriculum revamp are useful to help fine-tune subsequent change effort. Given all the prevalent developments, there is no doubt that our graduates need to be

equipped with the necessary skills to handle the challenges that confront the chemical engineering profession. Indeed, a recent review by Cobb et al concluded that the description of what really is a chemical engineering continues to evolve – and that chemical engineers must be life-long learners [16]. The outcome of the revamp will not be known until the first cohort of students graduate from the course (and this will only happen after the academic year 2010/2011) and gain employment in the chemical and allied industries. The team will prepare an extensive employer survey to find out if the curriculum revamp had met its intended objectives.

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USING TECHNOLOGY TO ENHANCE LEARNING OF DIGITAL VIDEO BROADCASTING (DVB)

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ABSTRACT

To appreciate the technology behind Digital Video Broadcast (DVB) system, its differences with the analogue system, and the additional features that can be supported, some level of understanding of the concepts and terminologies defined in the DVB standard is required. The challenge is that these concepts are typically very theoretical and dry. Students often find the concepts hard to visualize. Practical sessions were conducted using a real DVB system to demonstrate the process of preparing video and audio signals for broadcasting. However, as students listened (largely passively) and observed the instructors demonstrating the operation, the impact to their learning was limited. Many still could not answer the basic questions related to the DVB system posted at the end of the lesson.

In 2003, a project was launched to re-design the DVB practical lesson. The module development team set two main objectives for their task; to encourage active participation by providing students with hands-on experience, and to enhance students' understanding of the important concepts behind DVB technology. To achieve the objectives, all students needed to be involved in the whole process of digital video broadcast; from pre-broadcast processing which involves the preparation of the raw video and audio footage for transmission, to actual broadcast through sending the processed signal to a DVB transmitter, and finally tuning the receiver to verify if the broadcast is successful. Using an existing commercial DVB system would be too costly and impractical. The team therefore decided to leverage on NP's mobile e-learning platform and built two of the systems in-house; a Pre-Broadcast Signal Processing Software module, and Transport Stream Analyzer software. These software modules not only perform functions similar to commercial broadcast equipment, they also contain additional features that are designed specifically for learning purposes. The customized software modules could be installed on every student's notebook allowing them to perform their own pre-broadcast processing. Students were now able to work independently at their own pace, creating different programs and sending them for broadcast using the transmitter. In the process, students got to troubleshoot and solve problems, and as a result strengthen their understanding of the concepts behind DVB technology. To help students relate what they have learnt to real systems, the newly designed practical lesson also required students to record and analyze the engineering information carried within the programs broadcasted by MediaCorp using the Transport Stream Analyzer. This encouraged students to explore beyond the scope of their curriculum. They showed greater enthusiasm and were motivated to find out more when discrepancies were found in the live broadcast from MediaCorp.

The re-designed practical lesson and the use of customized software had significant impact on students' learning. They were more active during practical sessions and had demonstrated deeper understanding of the concepts involved. This is evidenced by the fact that while the assessments have become more challenging, students have been able to demonstrate their competence.

KEYWORDS

Technology-enhanced learning, active learning, experiential learning.

INTRODUCTION

"Digital Audio Video Technology" (DAVT) is a 3rd year elective module offered by Ngee Ann Polytechnic's School of Engineering under the Diploma of Electronics and Computer Engineering. This module is applied in nature with an aim to provide students with the latest developments in Digital Audio and Video Technology namely, Digital Audio & Video Broadcast systems, data and transmission. One key learning outcome of this module is to develop students with the ability to apply their knowledge and skills to real engineering situations.

Like most traditional engineering modules, DAVT adopted a lecture-tutorial-practical approach with lesson designs that are essentially teacher and content-centered. But it was observed in recent years the lack of in-dept knowledge student has in this topic. Many could recall definitions, facts and do computations very well, but lack deeper understanding and the ability to apply the concepts into real engineering practice. A review of the lesson design showed that there is a gap in the teaching approach adopted and the learning preference of our youths today.

Research suggests that the current generation of students are kept visually and emotionally engaged by various sources such as internet gaming and digital media [1]. They are technologically-driven, prefers experimental and structured type of learning [2]. Staying passive in class is a challenge for them. The teacher-centered approach adopted in DAVT lectures provided few opportunities for students to be actively involved. Due to constraints imposed by cost and complexity of the system, some practical sessions were also designed the same way with instructor demonstrations rather than student's hands-on practice. This mismatch saw students being less engaged and tending to adopt a surface approach to learning, memorizing content primarily to pass the examination.

This paper discusses the changes made in the teaching approaches and learning experiences of DAVT to encourage a deeper learning approach and an appreciation for the value of the knowledge as applied in the real world of broadcast.

THE MODULE

The syllabus of DAVT is categorised into two main sections; Digital Audio Technology and Digital Video Technology. The changes were made to the Digital Video Technology section of the module.

In this section on Digital Video, students are expected be able to describe the fundamentals of analogue television technology, the digitization process of the video signal, the basics of video compression techniques and standards, the main features of DVB system and the DVB services multiplexing and modulation techniques. In addition, they are also expected to be able to apply what they have learnt in real engineering situations.

KEY CHANGES NEEDED

The changes in the teaching and learning approaches have taken into consideration the learning styles of the current students – a generation that learns better when they are actively engaged in purposefully designed activities that are properly scaffold to guide students in their learning. The key changes identified addresses specific needs in the following areas:

1. Engage students through doing and exploration to stimulate their interest in the module.
2. Provide students with more experiential learning experiences to help deepen their understanding of the concepts.
3. Create an environment that encourages students to explore the topics at their own pace and time.
4. Include real life and concrete examples to help students understand the relevance and applications of the concepts.

THE DEVELOPMENT OF DVB LEARNING TOOL

To provide students with a more experiential learning experience, having a hands-on session with a real DVB broadcast system would be ideal. By working through the entire process from pre-broadcast processing which involves the preparation of the raw video and audio footage for transmission, to actual broadcast through sending the processed signal to a DVB transmitter, and finally tuning the receiver to verify if the broadcast is successful, allows students to appreciate DVB technology in greater dept. Unfortunately the equipment and computer software required are very costly and it is not practical to purchase a set for each student. Furthermore, these systems are real operational systems that are complex and are not suitable for teaching and learning purposes.

As a result, the module team collaborated with their partners from the industry and came up with a learning tool that is used together with a commercial DVB system and a low-cost DVB receiver from the industry partner. The key development in this setup involves two software packages; a Pre-Broadcast Signal Processing software module and a Real-Time Transport Stream Analyzer software module.

The developed hardware and software packages are used extensively in the practical and lecture lessons as well as during the students' self-learning time at home (e-learning journey of the module starts here!).

EXAMPLE OF CHANGES

This section details 3 key examples of the changes made.

Changes to the Practical Lessons

With the newly developed learning tool, the teaching plan of the practical lessons was modified with three new practical lessons being added that include the following features:

- A hands-on opportunity for every student during the practical hours (actively learning and using the various hardware and software modules with the given structured lab procedures)

- Tasks without specific instructions are included to encourage students to think and apply their knowledge to complete the task.
- Questions are included at the end of the lesson to help students reflect on what they have learnt.
- Discussions between the students and the lecturer on the topic are actively encouraged

Table 1 shows the original teaching plan which included only a one hands-on session on Video Technology (Analogue TV Lab). The DVB equipment demonstration was done entirely by the instructor for a class of 20 students.

Table 1
DAVT-Video Section Teaching Plan **(OLD)**

Week No.	**Lecture (2-hour) & Tutorial (1-hour)**	**Laboratory (2-hour)**
8	Video Topic 1: Basics of Television Transmission and Reception	Audio Mini Project (for Digital Audio Section)
9	Video Topic 1: Basics of Television Transmission and Reception	Audio Mini Project (for Digital Audio Section)
10	Video Topic 2: Digitization of Video Signal Video Topic 3: Principles of Video Compression	Analogue TV Lab
11	Video Topic 3: Principles of Video Compression Video Topic 4: Video Compression Standards	Analogue TV Lab
12	Video Topic 4: Video Compression Standards	DVB Equipment Demonstration
13	Video Topic 5: Digital Video Broadcasting (DVB)	DVB Equipment Demonstration
14	Revision	Revision

Table 2 shows the re-designed teaching plan with three new practical sessions being developed. The DVB equipment demonstration session was re-designed to include not only the equipment demonstration but also time allocated for exploration. Students are free to explore these new equipment in groups to experience “What is Digital Television?”. This experience helps stimulate their interest in Digital Video and the subsequent practical session.

Table 2
DAVT-Video Section Teaching Plan **(NEW)**

Week No.	**Lecture (2-hour) & Tutorial (1-hour)**	**Laboratory (2-hour)**
8	Video Topic 1: Basics of Television Transmission and Reception	- Digital Video and DVB equipment demonstration and briefing - Free time for students’ self-exploration & discussion
9	Video Topic 1: Basics of Television Transmission and Reception	Analogue TV Lab
10	Video Topic 2: Digitization of Video Signal Video Topic 3: Principles of Video Compression	Analogue TV Lab
11	Video Topic 3: Principles of Video Compression	Digital Video

	Video Topic 4: Video Compression Standards	Processing Lab
12	Video Topic 4: Video Compression Standards	Digital Video Processing Lab
13	Video Topic 5: Digital Video Broadcasting (DVB)	DVB Lab
14	Revision	DVB Lab

Note: Teaching Plan for weeks 1 to 7 were left out from the teaching plan above as it relates to digital audio section which will not be discussed.

Figure 1 shows the hardware and software modules developed for the DVB lessons which have also been incorporated into a commercial system.

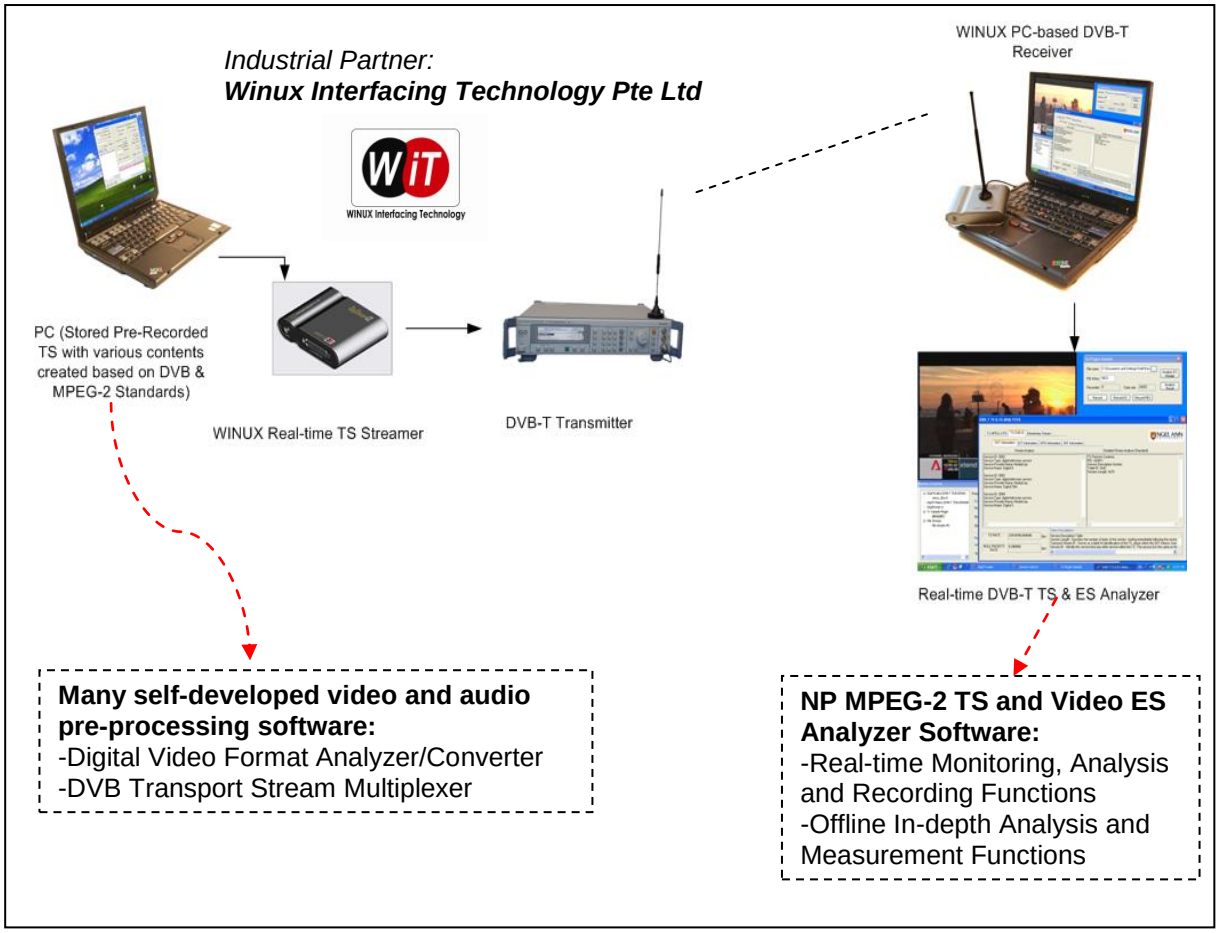

Figure 1. Portable Digital Video Broadcasting (DVB) System with Customised Learning Software Modules

The customized software modules can be installed on every student's notebook. This allows them to perform pre-broadcast processing and post-broadcast analysis. Students can now work independently at their own pace, creating different video programs and sending them for broadcast using the transmitter to see how the concepts and theories are being applied. In the process, students get to troubleshoot and solve problems which helps deepen their understanding of the concepts behind DVB technology.

To help students relate what they have learnt to real systems, the design of the new practical lessons incorporated a section where students record and analyze the engineering information carried within the programs broadcasted by "MediaCorp TV" (Singapore's local Digital TV service provider) using the Transport Stream Analyzer. This encourages students

to explore beyond the scope of their curriculum. They showed greater enthusiasm and are motivated to find out more when discrepancies such as the absence of some information in the live broadcast from MediaCorp TV.

The re-designed practical lessons and the use of the customized software has had significant impact on students' learning. They are more active during practical sessions and have demonstrated deeper understanding of the concepts and interest in the module as seen from a sampling of student's feedback extracts below.

> "This is a very interesting module. i now understands what goes behind the scene when we are watching televisions or listening to the radio."
>
> *by student A, Module Experience Survey, July 2008**

> "This module is best learned wit the experiments.. and alot of working is exactly very understandable and standard."
>
> *by student B, Module Experience Survey, July 2008**

(NB: *Names of students have been anonymised.)

Changes to Lecture Sessions

The lecture design had also undergone some changes to include more concrete and real life examples to keep the students engaged. Specifically the two key improvements made to the design of the lecture are presented in the sections below.

Included more multimedia materials

More pictures and video streams (including those downloaded from YouTube) that are related to the video topics are used during lecture to help illustrate various concepts. With the use of real and concrete examples, students are more engaged and had shown greater interest in the topics covered.

Use of problems and questions during lecture to guide learning

The lecture hour has been divided into blocks of 15 to 20 minutes. At the end of each block, students are given simple questions to attempt. They have to work out the answers with their peers and present them during class. The questions are designed to be simple and straight forward so that most students would be able to work out the answer within a short timeframe.

The design also helps to encourage students to be more attentive during lectures as they need the knowledge to solve the questions. It also provides an opportunity for the students to discuss with their peers and lecturer which breaks the monotony of a one-way transmissionist lecture. Apart from a few students who prefer to learn more passively, the majority have commented that they learn more from this more active learning lecture design.

Self-directed Exploration via e-tools

As explained in the book by Clark and Mayer [4], computer simulations and games are proven to stimulate learning and are good for e-learning and self-learning at home. The learning tool (described above) developed by the module team which comprises a fully functional DVB (Digital TV) receiver and analyzer software is a useful tool that allows

students to explore the advanced features and functions of the new TV system that are not covered in the curriculum. Students are able to loan out a set of learning tool and explore the topics in greater dept at their own pace anywhere, anytime with the aid of their laptop.

EVALUATION

The module survey conducted in 2005 as shown in Appendix A indicated that only 79.17% percent of the student felt that the lecture, tutorial and practical sessions have increased their understanding of the module. This survey was conducted before the changes in teaching and learning approaches were made. A focus group discussion was conducted and students' feedback indicated their preference for more hands-on sessions as seen from the focus group discussion report extract below.

> *"Students had commented that they preferred more lab or practical works to help enhance their understandings of the module. The current plan has included lab works but they were some demonstrated lab sessions by staff due to lack of equipment."*

After the change as outlined in this paper, student feedback on the experience was obtained by conducting a module survey for the July 2008 semester. 36 students have rated their experience on seven dimensions as seen in Table 3 below.

Table 3
Student Rating on Learning Experience

Dimension	Rating
The module helped me develop useful skills and knowledge	89%
The module stretches my thinking.	89%
The teaching and learning approaches are appropriate for this module/project	94%
I received timely and useful feedback in a group/individually on my progress in this module	81%
The module materials including online resources were useful	83%
The module activities enhanced my overall learning	81%
Overall, this module provided a good learning experience	89%

Percentage rating indicates students who have selected "Agree somewhat", "Agree" and "Strongly Agree" in the rating scale

In general, student responses were strongly positive towards the changes in the module's learning design.

In addition, the change has also allowed the module team to raise the standard of assessment on topics related to DVB technology. Prior to the change, questions on DVB concepts were primarily recall-type, as shown in Appendix B. After implementing the change, the examination paper had more application and analytical type questions included. With an increased level of understanding, students have been able to attempt these questions and the passing rate of the module has not been affected.

CONCLUSION

The new learning design of our DVB module had been well received by the students. Greater interest was stimulated through the additional hands-on sessions. The learning tool developed also encouraged students to explore beyond the curriculum, helping students develop desirable attitudes such as self-directed learning. This e-learning design is currently being trialed by a small group of students. The module team intends to develop this further to help expand and extend its usage to benefit the greater community of students.

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APPENDIX A – MODULE EVALUATION SURVEY 2005

Survey conducted when the module was taught using the traditional approach.

	Module Design, Content & Organization	**Strongly Agree & Agree**	**Disagree & Strongly Disagree**
1	As a result of my learning experience in this module, I have greater confidence in my ability to explain the basic concept of the digital audio and video technology.	**81.94**	**18.06**
2	The relevance of the module (DAVT) to the whole course (Diploma of ECE/ETE) has been demonstrated.	**91.67**	**8.33**
3	The curriculum in the module is taught at a reasonable level of difficulty.	**84.72**	**15.28**
4	The sequencing of the topics in the module is appropriate and provides for students to build on previous knowledge.	**81.94**	**18.06**
	Teaching, Learning, Assessment	**Strongly Agree & Agree**	**Disagree & Strongly Disagree**
5	The module provides opportunities for active participation and learning.	**83.33**	**16.67**
6	The teaching methods used by lecturers to deliver lectures, tutorials and laboratory sessions are appropriate.	**87.50**	**12.50**
7	At the beginning of the semester I was informed about how I was to be assessed and examined in the module.	**81.94**	**18.06**
8	Overall, the learning sessions (tutorials, Laboratory sessions) have substantially increased my understanding of the module.	**79.17**	**20.83**

Question 8 of survey, "Overall the learning sessions (tutorials, laboratory sessions) have substantially increased my understandings of the module." had only 79.17% of students responded with "agreed" and "strongly agree".

APPENDIX B – EXAMINATION QUESTIONS

Table below shows examples of the type of questions set on topics related to DVB concept before and after implementing the change.

Year	Question	Question Category
AUG 2006 (old learning design)	In Digital Video Broadcasting (DVB), the data (audio and video) streams are packetized into PES (Packetized Elementary Stream) and then into TS (Transport Stream) packets based on MPEG-2 systems standard before transmission. State the two main differences between MPEG-2 Program Stream and MPEG-2 Transport Stream formats.	Recall
AUG 2007 (old learning design)	In DVB, MPEG-2 Transport Stream (TS) format is chosen as the data transmission format. State all the data information types that are found in TS and give any two factors that determine the total TS transmission bit rate.	Recall
AUG 2008 (after new learning design was implemented)	Figure 2 shows the process of broadcasting a video scene in European DVB-T (Digital Video Broadcasting – Terrestrial) standard.	Recall, Application and Analysis

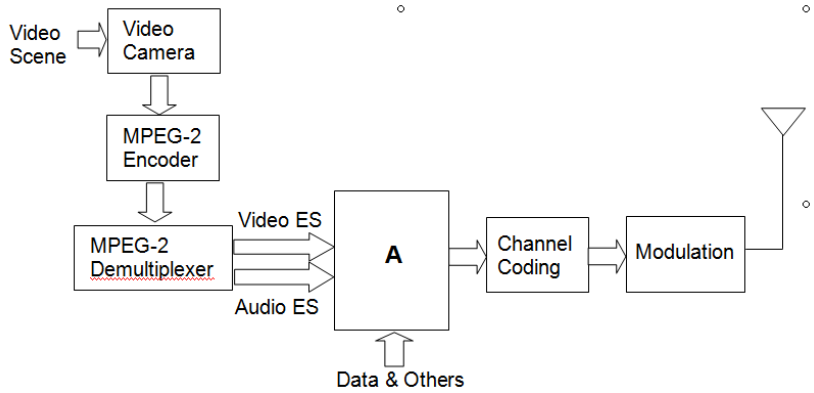

Figure 2

(i) As shown in Figure 2, the output video signal captured by the video camera is passed to an "MPEG-2 Encoder". State the name of the video signal at the output of the encoder and give two important data or information that is added to the video signal during the encoding process.

(ii) Assuming that the MPEG-2 video ES at the output of the "MPEG -2 Demultiplexer" has a resolution of 704×576 pixels, chroma format of 4:2:2 and each sample is 8 bits long, calculate the number of macroblocks and blocks in one frame (include both luminance and chrominance samples).

(iii) If the MPEG-2 video ES has an encoded rate of 3.8 Mbits/sec, calculate the average size of one MPEG-2 video frame in bytes and find the compression ratio.

(iv) State the name of the block labelled with symbol "**A**". What are the two compulsory tables that must be transmitted together with the video ES, audio ES and other information?

(v) Calculate the number of data packets produced in 30 msec intervals at the output of block labelled with symbol "**A**" if the output net data rate is 16.58824 Mbits/sec.

USING THE CDIO SYLLABUS IN FORMULATION OF PROGRAM GOALS – EXPERIENCES AND COMPARISONS

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ABSTRACT

This paper presents experiences and results from large scale and systematic use of the CDIO Syllabus for developing program goals and formulating learning outcomes at Linköping University (LiU), Sweden, and Technical University of Denmark (DTU). The approaches are based on the use of tools for program design such as ITU-matrices and skill progression matrices. During the process local adaptations of the Syllabus have been made in order to meet regulations by authorities in higher education as well as to cover programs in related areas as natural sciences. The experiences are that the CDIO Syllabus is a very useful tool in this process and that the way of organizing the management of the education programs is important for success as well as support from students, faculty members and stakeholders.

KEYWORDS

Program goal, curriculum design, learning outcomes, ITU-matrix, skill progression matrix

INTRODUCTION AND BACKGROUND

The CDIO model for development of engineering education puts a strong emphasis on formulation of program goals and learning outcomes, as seen in Standards 2 and 3 of the CDIO Standards [1]. A lot of effort has been spent on this topic since the start of the CDIO Initiative, a number of results have been presented; see e.g. [2] – [7], and several documents and tools for this purpose have been developed. The development of program goals and specification of learning outcomes is also a key component in the Bologna process [8], which requires that programs and courses have clear and comparable learning outcomes. In addition several other stakeholders can benefit from

such documents, like e.g. students, faculty members, industry, and governmental institutions. The purpose of the paper is to present experiences from large scale development of program goals and learning outcomes using the CDIO Syllabus and related tools. The paper will present experiences from Linköping University (LiU), Sweden, and Technical University of Denmark (DTU), and discuss similarities and differences in the approaches.

There are many factors that are essential for making such a development process successful, and some of these factors will be discussed in the paper. This includes a strong and documented support from the university leadership, as well as interest and engagement from faculty members and students. The development process has hence been a combination of a top-down and a bottom-up process. It has been found necessary and useful to extend and develop some of the original documents and tools. For example, one reason for this has been the ambition to cover various different disciplines in engineering and also non-engineering programs offered at the university, like e.g. natural sciences. Another reason has been to meet the national requirements concerning sustainable development. The process has also been useful in clarifying the difference in objectives of a bachelor and master degree of engineering, respectively.

The development processes at LiU and DTU have both similarities and differences, and one of the aims of this paper is to present and discuss the two different approaches. For example has systematic introduction of the CDIO concept been introduced in renewed programs at DTU from year one and at LiU at several educational levels at the same time. Another notable difference is the use of the CDIO tools to express progression within the programs.

ORGANIZATION

In this section the organization of studies and programs will be shortly presented in order to present a framework of comparison and discussion for the implementing processes at LiU and DTU. The engineering education at LiU is organized with Program Boards which consist of faculty members, representatives from industries as well as student representatives and are organized in the following subject areas: Computer Science and Engineering and Media Technology (DM), Electrical Engineering, Physics and Mathematics (EF), Industrial Engineering, Management, and Logistics (IL), Chemistry, Biology and Biotechnology (KB) and Mechanical Engineering and Design (MD). All Program Boards administer programs at different educational levels, like Bachelor Programs and Master Programs in Engineering, as well as programs in related areas like natural science, computer science, mathematics and industrial management. The majority of the students follow five years engineering programs, and most of the efforts reported here are devoted to this category of programs. The Program Board has an overall responsibility for the programs which includes strategic considerations, evaluation and quality assurance, and continuous improvement of the programs. This means that the Board also decides on the Syllabus, Curriculum and Course Plans for each program and the board is advisory to the Dean and the Faculty Board on issues within the range of the Program Board. All education programs undergo a yearly revision process in which program goals and learning outcomes of the individual courses are reviewed.

The Chairmen and the administrative responsible Directors of Studies of the five Program Boards meet the faculty management staff, including the Dean, and students

representing the Student Union regularly once a week to discuss common questions covering undergraduate studies as well as related topics. The purpose of the group, which is denoted LGU, is to provide a platform for discussion of all relevant aspects of undergraduate studies at the faculty of Engineering and Sciences (see Figure 1). Agreements reached in LGU are advisory to the Dean and to the Faculty Board.

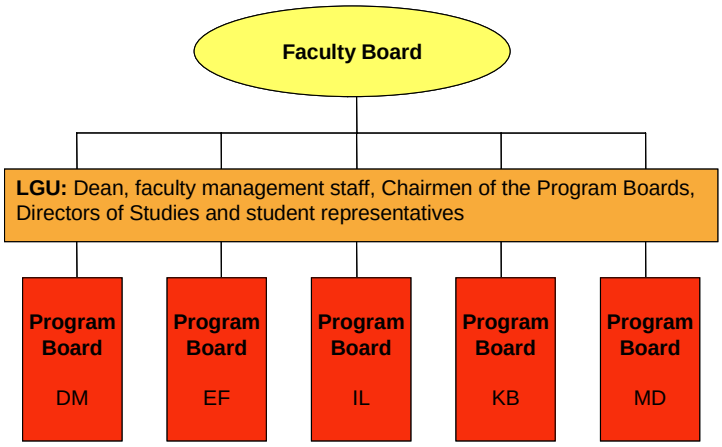

Figure 1: Organization at the Faculty of Engineering and Sciences at LiU.

The Program Boards order suitable courses from the different departments, and there is a discussion about course aims and contents between the Program Board, the department, and the examiner. However, the ideas about using the CDIO model for development of engineering education are not restricted only to a certain course but also to a whole program which has requested other approaches to engage the faculty staff members. The changes expected by the Bologna declaration was suitable in time for rethinking our engineering education and the CDIO model was found very helpful in development of program goals and learning outcomes. All members of the faculty staff were engaged in rewriting all Course Plans and workshops were arranged by staff at the Dean's office.

DTU educates engineers in two separate streams of education: The Bachelor of Engineering (B ENG) is a 3½ year program, and qualifies the student to go directly into industry to jobs in e.g. production units, project management or control and support functions. The Master of Science in Engineering (MSC ENG) is a 2 year program, which follows the 3 year Bachelor of Science in Engineering Program (BSC ENG). The student graduating with a Master's degree may continue to research as a PhD student or go to industry. Hence, DTU has adapted fully to the Bologna system. For each of the study programs at DTU the Dean has appointed a program coordinator who in co-operation with the study board undertakes the practical organization of teaching and assessments forming part of the exams. The program coordinator has a supporting work group with representatives of teachers and students and this work group has been very active in the process of changing curriculum and implementing CDIO at DTU. There are a number of departments at DTU and each department has a study board. Most study programs

comprise of courses from several institutes and several study boards are involved in each program. Thus, the program coordinators play an important role. Every department has an Advisory Board consisting of representatives from industries which eventually will employ the newly-educated engineers. The Advisory Boards comment on the development of existing and new study programs and DTU uses the feed back for adjustments to ensure that the engineers get the right qualifications. Twice a year DTU invites all teachers and program coordinators to a seminar where ideas, challenges and best practises from teaching at the CDIO courses are discussed. This commits the teachers to maintain the courses. Several times a year all the program coordinators meet with the dean to discuss challenges and exchange ideas with each other. The program coordinators have continuous meetings with their supporting work group of teachers and students from the program. Everyone involved in the CDIO programs at DTU are encouraged to take part in the international CDIO conferences to get new inspiration and share best practices with people from all over the world. The students are continuously asked about their opinion about courses etc. in different kinds of evaluations. The results of these evaluations are taken note of by teachers and program coordinators and are incorporated in the development of the programs.

CDIO IMPLEMENTATION

Linköping University is one of the four original collaborators in the CDIO Initiative. Most of the efforts during the first years were spent on the engineering program Applied Physics and Electrical Engineering, and brief summaries of the outcomes of the development of this program can be found in [12] and [13]. The CDIO ideas gradually spread within LiU and were adopted by other programs and in other disciplines as reported in [14] and [15]. In 2006, the Board of the Faculty of Engineering and Sciences decided, as a part of the adoption of the Bologna process, that all program goals and learning outcomes should be based on the CDIO Syllabus. A condition for progress and success in this work has been a clear supportive statement from the faculty management staff, an organization that can follow up the agreements, as well as a clear commitment from many members of the faculty staff to engage in the development process and a positive feedback from the engineering students. The statement from the Board of the Faculty of Engineering and Sciences makes a framework for the five Program Boards, each covering several programs in related disciplines. A prerequisite for success is also the attitude about these issues amongst the students. The Student Union has been supportive in the process and the evaluations from students have been very positive. A survey amongst alumni from nine different engineering programs representing different disciplines clearly supports the effort to strengthen the engineering identity [11]. Parts of the CDIO model have also been adopted at other universities (in addition to the universities being CDIO collaborators) in Sweden in various ways. One of the most important factors was the use of the CDIO Standards in the national evaluation (of five years engineering degree programs) that was carried out by the Swedish National Agency for Higher Education. Some observations concerning the outcomes of the use of the CDIO Standards in this evaluation are presented in [18].

At DTU it was a management decision to implement the CDIO principles consecutively – starting in 2008 with the first year courses, and completing the process in 2011 for the full bachelor of engineering program. A work group with the Dean of Education, representatives from the students, teachers and program coordinators from the involved programs and the administration discussed how DTU should adapt to CDIO and produced a detailed plan of action [17]. The plan of action has been the central

document used by everyone involved in the implementation process at DTU. Traditionally, the BSC ENG and MSC ENG programs at DTU contain a very high degree of freedom for the students to compose study profiles and elective courses. The B ENG programs are more defined with respect to the course work and practical work the students have to fulfil. At DTU the B ENG programs are now being reformed along the CDIO philosophy. Until now CDIO has been implemented in six programs covering Mechanical, Chemical and Biochemical, Civil, Architectural, Electrical and IT Engineering.

PROCESSES AND TOOLS FOR EDUCATIONAL PROGRAM DESIGN

Adaption of the CDIO Syllabus

The ultimate goal of the process is to develop documents that in a clear way defines the goals of the program and shows how the program goals are connected to the learning outcomes in the individual courses and the examination. The process of formulating program goals has two very important components. First, similar to all types of development projects, it is necessary to have a systematic approach, and second, it is necessary to have suitable tools that support the process. A complete description of the CDIO Syllabus can be found via [9], and the main sections can be seen in Figure 2. We will here discuss the modifications of CDIO Syllabus that have been carried out at LiU and DTU respectively, but other examples can also be found as for example in [19].

In the Swedish system for higher education the overall most important document is Högskoleförordningen (The Degree Ordinance) [10], which specifies expected knowledge and skills for various types of educations, including engineering programs. The Degree Ordinance can however be mapped to the CDIO Syllabus, see [6], and hence the Board of the Faculty of Engineering and Science 2006 decided that learning outcomes and program goals should be based on the CDIO Syllabus. In Denmark, the overall control with the B ENG programs is held by the Danish Ministry of Education. Educational programs are regularly evaluated and accredited by the National Agencies, ACE/EVA. The implementation of CDIO at DTU's B ENG programs has been a great help in preparing the whole organization for planned accreditations in the future.

The CDIO Syllabus represents a long list of desired knowledge and skills and it has been used both at DTU and LiU as a tool for educational design. The extensive use of the CDIO Syllabus within LiU has motivated some extensions of the original version of the Syllabus.

- The Degree Ordinance puts strong emphasis on sustainable development, and this is expressed by the formulation "… including economical, social and ecological sustainable development". These aspects are naturally covered by Section 4.1 in the Syllabus, but in order to make this requirement more visible the quoted formulation from the Degree Ordinance has been included in the local version of the Syllabus.
- The Industrial Engineering and Management program is one of the biggest engineering programs at LiU. The program has specializations in for example marketing, logistics and financing. In the program plan it is expressed that one of the main goals for the engineers graduating from this program is to be able to be leading in the process of implementing the outcome of the engineering work into business activities. This can be seen as an extension of the scope of the role of an engineer

as it is expressed in the original version of the Syllabus, and to stress this fact the title of Section 4 of the Syllabus has been modified accordingly.

- The Faculty of Engineering and Science has also a number of educational programs in natural sciences (physics, chemistry, biology, and mathematics). For these programs, the product development and system building context is less appropriate, and for this purpose a modified version of Section 4 has been developed with this type of programs in mind. The product development framework is there replaced with a more research oriented one.

At DTU the Syllabus was simplified to a version (nick-named the DTU Syllabus) which was simpler and hence easier to use for faculty members unfamiliar with the CDIO principles. The most detailed level of skills in the original syllabus has been left out and the DTU Syllabus was concentrated to a two-sheet version. The DTU Syllabus is characterized by being shorter (less detailed skills), more operational (operational skills according to Blooms taxonomy), not only designed for mechanical/ design engineering fields (the same syllabus need to fit all B ENG programs at DTU), and adapted to a B ENG program (some skills were too advanced and were left out)

The process for educational program design

The development process at LiU can be described as a combination of a top-down and a bottom-up process. The bottom-up process was described in some detail in [5], and the aim here is to concentrate on the top-down process and how the processes can be linked together. The top-down approach starts from the management level, including the Board of the Faculty of Engineering and Science and the Dean. Closely connected to the Board is LGU, see above, consisting of the Chairman and the Director of Studies from the five Program Boards, student representatives, and the Dean.

The starting point of the top-down process was to describe, in a few sentences, the properties and attributes that should be characteristic for an engineer graduating from a five years engineering program at LiU. The outcome of this step was summarized under the heading “The LiU Engineer”, and organized according to the four sections of the CDIO Syllabus. The next step in the top-down process was to formulate the program goals in more detail, and also this was done according to the structure of the CDIO Syllabus. Since Sections 2 – 4 of the Syllabus are independent of the subject area of a particular program the program goals in these sections should be applicable to all engineering programs. In order to distribute the efforts the task to formulate goals for these sections was distributed among the Program Boards. In addition to the shared work load this meant that all people involved in the process were motivated to study the Syllabus in detail. The outcomes of this step were presented and discussed during a workshop for all members of LGU, and the formulations were revised in order to obtain coherent formulations of the program goal for Sections 2 – 4. Even though the first section of the Syllabus is closely connected to the subjects of a particular education program, it also for this section possible to express goals that are common for all programs. For example, mathematics plays an important role for all engineering programs, and LiU has high ambitions concerning the contents of mathematics in the engineering education. Therefore, it was agreed that all programs should have similar formulations of the mathematics related goals. In general it has been found important and useful in this process to include also Section 1 of the Syllabus, since it defines the basis of the program in terms of mathematics, natural sciences and engineering topics.

In order to be able to quantify the progression of knowledge in various areas Section 1 is a natural starting point.

It is important to stress that it is not only the goal document itself that is a valuable outcome of the goal formulation. Also the process itself, in the form it has been carried out, has been valuable, since it has generated fruitful discussions about the common vision and ambitions of the engineering education at LiU, but also clarified similarities and differences of the different programs.

For each of the study programs DTU has formulated one sheet that sums up the competences imparted. For the B ENG programs the competences are split up in general qualifications achieved by all B ENG's at DTU and specific skills obtained from the individual program. All the general qualifications can be mapped to Syllabus categories 2-4. DTU has attempted to homogenize categories 2, 3 and 4 between the study programs in different fields but it is not necessarily easy or straightforward as there are variations in the required skills in the different industries e.g. the industrial expectations to written communication might differ in civil and chemical engineering.

As at LiU mathematics at DTU is a highly prioritized field in all engineering programs. No matter which branch of engineering the students choose they need to gain a certain level of mathematics. The Department of Mathematics at DTU has designed one common course that fits all the B ENG programs. This has the advantage that it provides all the students with the same mathematical basis although some programs e.g. IT and Chemical Engineering request the possibility of different mathematics. This is an ongoing discussion.

The bottom-up process is described in [5], and only the main aspects will be discussed here. The process starts at the course level and involves topics like the expected learning outcomes of the course, the organization of the learning activities, the examination etc. In the Swedish system the official document for a course is the Course Plan. This is a mandatory document and specifies the learning outcomes, the examination and grading, literature etc, and all Course Plans are formally approved by the Program Board. The Course Plan has a more or less fixed structure, and for practical reasons additional information is collected in a Course Information administrated by the faculty member responsible for the course. In addition to the Course Plan the Board of the Faculty of Engineering and Science has decided that each Course Plan should be complemented by a so called ITU-matrix. The purpose of an ITU-matrix, introduced in [5], is to describe the course in relation to the CDIO Syllabus. In practice this means that, for each individual course, the faculty member responsible for that course is supposed to fill in a matrix, of the type shown in Figure 2. In the ITU-matrix, the I-column represents topics that are introduced in the course, but not subject to examination. The T-column represents knowledge and skills that are taught in the course and also subject to examination. Finally, the U-column represents knowledge and skills that have been acquired in previous courses and are considered to be pre-requisites. These will of course be included indirectly in the examination, like e.g. mathematics in an engineering course. In order to keep the effort at a reasonable level, it was decided to work at the X.Y level of the Syllabus. In the process of filling in a matrix the complete Syllabus, i.e. also lower levels (X.Y.Z), can be used in order to find examples of what a particular level represents.

		Introduce	Teach	Utilize	
	TSRT19, Automatic Control I	**I**	**T**	**U**	**Comments**
1	**TECHNICAL KNOWLEDGE AND REASONING**				
1.1	KNOWLEDGE OF UNDERLYING SCIENCES			X	calculus, algebra, physics
1.2	CORE ENGINEERING FUNDAMENTAL KNOWLEDGE	X	X		analysis and design of control systems
1.3	ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE				
2	**PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES**				
2.1	ENGINEERING REASONING AND PROBLEM SOLVING	X	X		modeling of systems and signals
2.2	EXPERIMENTATION AND KNOWLEDGE DISCOVERY		X	X	experimentation using laboratory processes
2.3	SYSTEM THINKING	X	X		general thinking throughout the course
2.4	PERSONAL SKILLS AND ATTITUDES			X	individual work during problem solving
2.5	PROFESSIONAL SKILLS AND ATTITUDES				
3	**INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION**				
3.1	TEAMWORK			X	laboratory exercises in groups of 2
3.2	COMMUNICATION			X	written report
3.3	COMMUNICATION IN FOREIGN LANGUAGES	X		X	introduces English control vocabulary
4	**CONCEIVING, DESIGNING, IMPLEMENTING AND OPERATING SYSTEMS IN THE ENTERPRISE AND SOCIETAL CONTEXT**				
4.1	EXTERNAL AND SOCIETAL CONTEXT	X			the role of control in systems, products
					and processes
4.2	ENTERPRISE AND BUSINESS CONTEXT				
4.3	CONCEIVING AND ENGINEERING SYSTEMS	X	X		fundamental limitations in control systems
4.4	DESIGNING	X	X		design of control systems
4.5	IMPLEMENTING	X			implementation on laboratory processes
4.6	OPERATING				

Figure 2: Example of a course level ITU-matrix from LiU.

In the second step of the bottom-up process, the course based ITU-matrices are put together to form ITU-matrices for entire programs and specializations within programs. Further aspects of this step are discussed in [5]. An example of such a matrix is shown in Figure 3.

Mechatronics	1.1	1.2	1.3	2.1	2.2	2.3	2.4	2.5	3.1	3.2	3.3	4.1	4.2	4.3	4.4	4.5	4.6
Analytical mechanics	U		T	TU		T	T		U	U	U						
Modeling and simulation	U	TU	IT	T	TU	TU	U		U	U		I		IT		IT	
Automotive control systems	U	U	T	U	U	TU		U		U		T		TU	TU	TU	
Applied therm. and fluid dynamics	U	TU		T			I		I	I							
Digital signal processing	U	TU	IT	T	TU	TU	U					I	I	IT		IT	I
Control theory	U	U	T	T	TU	TU	U		U	U		I		T	T	I	
Real time and concurrent progr.	U	TU	I	T	U	T	T		U	U	U			T	T		
Project - Applied mathematics	TU			TU	TU		TU	TU	U	IT							
Automatic control project course	U	U	TU	TU	U	TU	TU	TU	TU	TU	U	I	I	TU	TU	TU	I
Flight dynamics	ITU	TU					TU			U							
Multi body dynamics and robotics	U		T	T					I	U							
Computational fluid dynamics	ITU			T	T					U							
Vehicle dynamics and control	U	U	T	T		T			U	U							
Aerodynamics	ITU	TU		T													
Diagnosis and supervision	U	U	T	T		T				U							
Digital control	U	IT		IT	TU	IT	U		U	TU		I		IT	IT	I	

Figure 3: Example of a program level ITU-matrix from LiU.

At DTU, the starting point in the bottom-up process was that every teacher responsible for a course formulated the learning outcome of the course in 8-12 bullets. The bullets are also used as measuring points for the exams so the students get the highest grade if they demonstrate that they have fully met all the learning outcomes. After formulating the learning outcomes for the courses, the program coordinators for every B ENG program at DTU arranged discussion meetings with all teachers teaching at the first 4 compulsory semesters. At these meetings, the Syllabus skills were mapped against the compulsory courses in a Skill Progression Matrix in order to get an overview of how and whether the skills in syllabus were present in the pre-CDIO programs. The teachers had to judge which skills and to which level of Bloom's taxonomy, they brought the students in their course. The results from these meetings constituted the basis for restructuring the programs when implementing CDIO. After the implementation of CDIO at DTU, all the courses at the different study programs have been mapped again in a new Skill Progression Matrix (Figure 4). The learning outcomes from the individual courses all together can now be mapped against the competences imparted for the full study program and the skills in the DTU Syllabus.

Describing progression

Characterizing and quantifying knowledge and skills is a complex task with many dimensions and, to the best of our knowledge, there is no universal and generally accepted way of dealing with this task. The aim of this part of the paper is to present and discuss the approaches that have been used within The Faculty of Engineering and Sciences at LiU and within DTU, rather than discussing this vast topic in general. As mentioned earlier all program goals and learning outcomes are based on the sections of the CDIO Syllabus, which has been found to be a suitable way to define a structure for knowledge and skills. An alternative is of course, the structure offered by the Dublin Descriptors, which uses the structure: *Knowledge and understanding, Applying knowledge and understanding, Making judgements, Communication skills, and Learning skills*.

To describe progression within a subject or an education is an important issue, both in general but also implied by the Bologna process. Progression of knowledge and skills in engineering education involves many aspects and dimensions, and it is a challenging task to describe progression in all its dimensions. The sequence Introduce-Teach-Utilize that is used in the ITU-matrices at LiU represents one way of quantifying progression within the topics defined by the structure of the CDIO Syllabus. Considering a sequence of courses within a particular area one finds that the marks in the ITU-columns shift from left to right, i.e. a course early in the education has more marks in the I-column and a related course later in the education has more marks in the right column. Another feature that can be seen is that courses in the early years often have fewer sections of the Syllabus marked, while courses in the later years have more sections marked. This is most evident in project courses and courses with extensive laboratory exercises, in which most of the section of the Syllabus are relevant. DTU has expressed the progression in the study programs by integrating Blooms taxonomy in the Skill Progression Matrix (Figure 4). The interpretation of the levels is given in Figure 5. The courses given in the first four compulsory semesters are mapped against the skills in DTU Syllabus category 2-4. The numbers and colours in the cells reflect to which level the students are taught in the given course e.g. 1: Knowledge, 2: Comprehension, 3: Application, 4: Analysis and 5: Synthesis. As seen in Figure 4 no skills are taught to level 5 as it is a B ENG program which never reaches the level of Synthesis.

DTU Syllabus	*2.1*	*2.2*	*2.3*	*2.4*	*2.5*	*3.1*	*3.2*	*3.3*	*4.1*	*4.2*	*4.3*	*4.4*	*4.5*	*4.6*
Calculus and algebra 1	1						1	1				1		
Structural elements and their function (1)	2		2			1	1/2	1				1		
Urban Planning and Design	2		2	2		1	1/2	1				1		
CAD, sketching and 3D-modelling						1						1		
Theory and Practice of Architectural Engineering	2		2	2	2	1	1/2					1		
Material science		2					1/2	1				1		
CDIO project		3	2	2		1								
Calculus and algebra 2	2						2	2						
CAD, sketching and 3D-modelling	2					2								
Theory and Practice of Architectural Engineering		3		2	2	3	2					2		
Structural elements and their function (2)	3	3	2			3	2	2			1	2		
House Building and Building Design	2/3	3	2	2	2	2/3	2	2	1		1	2	1	
CDIO project		3	2	2								2		
Physics							3	3				3		
Structural design and design models (1)	4		3		2		3		2			3		
Urban context & large scale structures	4		3	4		3/4	3					3		
Systematical planning with CAD-system and Visualization						3							1	
Background for architectural engineering	4			4	3	4	3					3		
Basic building design: indoor environment, services and energy	4						3	3				3		
Geometry	4						4	4						
CDIO project	4		3		2	3/4					2	3		
Systematical planning with CAD-system and Visualization	4						4							
Background for architectural engineering			3	4	3	4	4					4		
Structural Design and Models (2)	4					4	4	4	2			4		
A Concert hall	4		3	4		4	4					4		1
Basic building design: indoor environment, services and energy	4		3		3	4	4	4				4		1
CDIO project	4		3		3	4					2	4		

Figure 4: Example of a skill progression matrix from DTU.

Bloom level	0	1	2	3	4	5
Color						
		Knowledge	Comprehension	Application	Analysis	Synthesis

Figure 5: Interpretation of the levels in the skill progression matrix in Figure 4.

The different colours help the visualisation of the progression. As at a geographical map the blue colour indicates “deep water” and the red colour “high level”. It guarantees that all material is introduced and taught before being used. The progression and repeated use of taught material (at different levels) in the B ENG programs at DTU is also ensured by securing continuous communication among the teachers teaching at the same semester as a supplement to the work carried out by the group of teachers and students that supports the program coordinator as described earlier in this paper.

DEVELOPMENT AND MAINTENANCE

One result of the efforts is a mutual vision of “The LiU Engineer” for all engineering programs. The program goal development aims to fulfil this vision. It is a risk that this ambition tends to raise the demands on the student above reasonable requirements and, therefore, it is necessary to get feedback from stakeholders, alumni and teachers to continue the development process. Do all students actually meet these demands? Another question raised is to which extent every part of the CDIO Syllabus has to be achieved within the different programs with different profiles. This is a present work which has to be carried out carefully since it should reflect the essence of the program.

Since LiU has extended the CDIO Syllabus to manifest special demands from Högskoleförordningen (The Degree Ordinance), the relevance of the Syllabus continuously must be updated with new demands of this dignity. To clear the differences between the engineering programs and the related programs in natural sciences the extended version of the CDIO Syllabus has been used. This has turned out to be useful to describe these differences in a systematic way and starts to be spread nationwide.

The Swedish government discusses the introduction of a new economic resource system partly based on achieved quality, where goal fulfilment has been discussed as one possible condition, and in this respect, the CDIO model is an important tool to prove the outcome. This implies that further adjustments of the method have to be made. Furthermore, there is also an ongoing discussion in Sweden about introducing an accreditation system and it will be necessary that the local system is consistent with this. The EUR-ACE framework for the Accreditation of Engineering Programmes, for instance, has defined six program outcomes that must be fulfilled for accreditation including Knowledge and Understanding, Engineering Analysis, Design and Practice as well as Investigations and Transferable Skills [16]. Even these goals are defined with progression from the bachelor level to the master level and cover aspects of theoretical

knowledge, practical skills as well as personal and interpersonal skills. Depending on the accreditation system that is decided on, the local program goals have to adapt.

Next step in the process is to assure the progression of the examination and form for examination connected to program and course goals. A feedback system connected to the thesis work based on the students own reflection on the achieved knowledge and skills is prepared and introduced in the near future at LiU.

CONCLUSIONS AND LESSONS LEARNED

Experiences and results from large scale and systematic use of the CDIO Syllabus for developing program goals and formulating learning outcomes at Linköping University (LiU), Sweden, and Technical University of Denmark (DTU) have been presented. The approaches have based on the use of tools for program design such as ITU-matrices and skill progression matrices. During the process local adaptations of the Syllabus have been made in order to meet regulations by authorities in higher education as well as to cover programs in related areas as natural sciences. The experiences are that the CDIO Syllabus is a very useful tool in this process and that the way of organizing the management of the education programs is important for success as well as support from students, faculty members and stakeholders. The main lesson learned is that the large scale adoption of the CDIO model is a multi-faceted process that requires mutual engagement and respect for other adopters´ views. This takes more time than expected. To achieve the desired outcome all groups involved should be able to work concentrated during continuous periods of time instead of shorter time slots. This since new adopters of the ideas sometimes find the concept difficult to accommodate and need the support and discussions from a team of faculty members. Due to new demands from different stakeholders the conditions for the CDIO development process changed during implementation. This made it not possible to say when the work actually was done. It can also be noted that the process is helped if respected persons from outside the own organization, i.e. other universities or industry, regard the initiative as a successful concept and declares a willingness to adopt it.

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