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Kristina Edström, Natha Kuptasthien,
Angkee Sripakagorn, Janne Roslöf,
Ingunn Saemundsdottir
& Maria Siiskonen (eds.)**

The 16th International CDIO Conference

Proceedings – Full Papers
Volume 1(2)

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Research reports from Chalmers University of Technology
Gothenburg, Sweden 2020
ISBN Printed: 978-91-88041-27-2
Digital: 978-91-88041-28-9

CDIO Initiative
Proceedings of the International CDIO Conference
ISSN 2002-1593
This is volume 1 out of 2 volumes

Editorial

The CDIO approach is an innovative educational framework for producing the next generation of engineers. The aim is an education that supports students in acquiring deep working understanding of technical fundamentals while simultaneously developing the necessary professional skills required of a practising engineer. This is done by providing students with dual-impact learning experiences that are based upon the lifecycle of an engineering project, the Conceiving – Designing – Implementing – Operating (CDIO) of real-world products, processes, and systems. Throughout the world, more than 180 institutions have adopted CDIO as the framework of their curriculum development.

The Annual International Conference is the central meeting of the CDIO Initiative, and it includes presentations of papers as well as specialised seminars, workshops, roundtables, events and activities. The 16th International CDIO Conference was planned to take place in Bangkok, Thailand, on June 8-12, 2020, hosted by Chulalongkorn University and Rajamangala University of Technology Thanyaburi. However, the travel restrictions due to the COVID-19 pandemic necessitated a change of format from a physical to an online conference. The online conference was hosted by Chalmers University of Technology, Sweden, June 8-10, 2020.

The theme of this year was Sustaining Change. The theme is visible in the keynote presentations and paper presentations. A roundtable session was focused on the changes to engineering education pedagogy driven by the move towards online learning technology that was radically accelerated by the pandemic. The rich topical program facilitated lively discussions and contributed to the further advancement of engineering education.

The conference included three types of contributions: Full Papers, Project in Progress contributions and Roundtables. The Full Papers fell into three tracks: Advances in CDIO, CDIO Implementation, and Engineering Education Research. All contributions have undergone a full single-blind peer-review process to meet scholarly standards. The Projects in Progress contributions describe current activities and initial developments that have not yet reached completion at the time of writing.

Initially, 208 abstracts were submitted to the conference. The authors of the accepted Full Paper and Projects in Progress abstracts submitted 134 manuscripts to the peer-review process. During the review, 429 review reports were filed by 116 members of the 2020 International Program Committee. Acceptance decisions were made based on these reviews. The reviewers' constructive remarks served as valuable support to the authors of the accepted papers when they prepared the final versions of their contributions. We want to address our warmest thanks to those who participated in the rigorous review process. Due to the rapid change of the conference format, most of the Project in Progress contributions were encouraged to withdraw and resubmit to a future conference.

This publication contains the 64 accepted Full Paper contributions that were presented at the conference, of which 8 are Advances in CDIO, 46 are CDIO Implementation, and 10 are Engineering Education Research. These papers have been written by around 190 different authors representing 23 countries. In addition to the Full Papers,

6 Projects in Progress contributions were presented at the conference and are not included in this publication. Two working groups worked prior to and during the conference. We hope you find these contributions valuable for your own research, curriculum development, and teaching practice, ultimately furthering the engineering profession. We also hope that you benefit through the truly unique community of practice that exists within the CDIO Initiative. The participants present at the conference seized the opportunity to discuss and share with colleagues, as global awareness and partnerships are of significant importance in the education of the next generation of engineers.

Gothenburg, 10 September 2020

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ADVANCING CDIO CURRICULUM MODEL FOR THAI ENGINEERING AND NON-ENGINEERING PROGRAMMES

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ABSTRACT

Rajamangala University of Technology Thanyaburi (RMUTT), Thailand has adopted a thematic approach to Advancing CDIO Curriculum Development comprising Mapping – Enhancing – Innovating – Sustaining in collaboration with Singapore Polytechnic, Singapore. This paper focuses on mapping and enhancing approaches to curriculum design and development first to occur. In 2018, RMUTT launched a policy at the institutional level for curriculum development for a total of 34 programs comprising 6 engineering and 28 non-engineering programmes. CDIO workshop was conducted for 200 program committees from 7 faculties to prepare them for reimagining the curriculum redesign. For the mapping approach, a trend analysis was conducted to identify future-ready competencies and future graduate attributes and correspondingly develop relevant programme outcomes. For the enhancing approach, two new mandatory courses, namely, Introduction to the Profession and Multi-disciplinary Project (MDP) courses, were introduced. These two courses were developed in accordance with CDIO standards 4 and 5 by offering a design-build-test learning experience to the students. Other CDIO skillsets such as professional competencies, personal and interpersonal skills are integrated into the program systematically. This paper aims to share similarities and differences of graduate attributes and program outcomes between engineering and non-engineering focus in the Thai industry context. The implementation of mapping and enhancing approaches will also be discussed.

KEYWORDS

curriculum development, mapping CDIO skillsets, enhancing multi-disciplinary project, Standards 1, 2, 3, 4, 5

INTRODUCTION

Major milestones of RMUTT curriculum design and development can be grouped into 3 phases. Phase one was from 2013-2015 when Conceive, Design, Implement, and Operate (CDIO) Framework was first introduced for rethinking engineering education. Only 2 programmes had fully implemented at the program-level in 2013, namely, Industrial Engineering and Chemical Textile Engineering (Kuptasthien et al., 2014). In 2014, 6 non-engineering programmes from

the faculty of Mass Communication Technology adopted the CDIO framework. These programs were Television & Radio, Photo & Cinematography, Printing Technology, Multimedia, Digital Media and Advertisement, and Public Relations (Tangkijviwat et al., 2018). In 2015, Thai Traditional Medicine College applied the CDIO framework to 2 programs; namely, Applied Thai Traditional Medicine and Health & Aesthetic (Sranujit and Kuptasthien, 2016).

The second phase was from 2016-2017 when RMUTT embraced a thematic approach to Advancing CDIO Curriculum Development comprising Mapping – Enhancing – Innovating – Sustaining in collaboration with Singapore Polytechnic (SP) (Lee et al., 2018). There were 5 programs that participated in redesigning future-focused curriculum comprising of Industrial Engineering, Multimedia, Hotel & Tourism Management, Innovation of Health Product and Architecture.

The third phase was from 2018-2019, when RMUTT launched a policy at the institutional level on curriculum development for a total of 34 programs comprising 6 engineering and 28 non-engineering programs. CDIO workshop was conducted for 200 program committees from 7 faculties to prepare them for curriculum redesign (Sripakagorn and Kuptasthien, 2019).

This paper aims to:

1) Show how mapping and enhancing approaches were implemented.
2) Share the similarities and differences of graduate attributes and program outcomes between engineering and non-engineering focus in the Thai industry context.
3) Discuss the result.

LITERATURE REVIEW ON CURRICULUM DESIGN

The key characteristics that CDIO is attractive to institutions worldwide are relative advantages, compatibility, simplicity, trial-ability, and observability (Kontio, 2017). Reasons for implementing the CDIO framework included (1) ambitions to make engineering education more authentic (2) needs for a systematic methodology for educational design and (3) desires for more design and innovation in curricula (Malmqvist et al. 2015). The success of CDIO implementation needs both top-down and bottom-up approaches. The top-down methodology can be a decision for the management team to adopt the CDIO framework regarding the compatibility of the institutional vision on education development goals. However, the challenges of CDIO implementation are a mindset change, a buy-in from faculty members, disagreement, and a double work regarding the national qualification standards and accreditation. To overcome these challenges, the bottom-up method is suggested (Lee et al., 2015). With the involvement of faculty members, program committees, and department heads, the changing process raises an intrinsic motivation, a strong commitment, ownership, and value of CDIO (Hallenga-Brink and Kok, 2016).

CDIO Syllabus and CDIO Standard are guidelines for curriculum design and development. Several leading universities have created their own models, methodologies, a process in executing the plan to redesign the existing curriculum or design and develop a new one.

Linköping University (LiP), one of the CDIO pioneers, early implemented CDIO into their Applied Physics and Electrical Engineering, Electrical Systems Engineering, Media and Communication Technology, and Logistics Engineering programs. The stakeholders involved include the faculty, the industry, and the students. The development of programs covered

three main areas of a survey on the CDIO syllabus, an introduction of LIPS models for design-build project management, and final approval of CDIO ideas with a strong focus on the graduates to become professional engineers (Bjerner and Granath, 2005).

At the Technical University of Denmark (DTU), the decision on CDIO adaptation was made by the management team. A benchmarking process of the existing Chemistry and Biotechnology program was performed to identify where CDIO elements were already present, and where the rooms for improvement were. For CDIO Syllabus benchmarking, a color mapping scheme with the integration of modified Bloom's Taxonomy and the introduce-teach-use ranking was suggested to gain the competence matrix interpretation (Vigild et al., 2007).

Later on, Gunnarsson et al. (2008) showed a comparison on a large scale implementation using CDIO Syllabus to formulate program goals and learning outcomes between LiP and DTU. The work exhibited processes and tools for educational program design, including local CDIO Syllabus adaptations to meet national higher education regulations, an introduce-teach-use (ITU), and skill progression matrices.

Armstrong and Niewoehner (2008) proposed an enhanced CDIO methodology to develop the student's skills and attributes required for professional engineers. To define program learning outcomes, a methodology encompassed a customised syllabus, a stakeholder's survey, an application of Bloom's Taxonomy, a consultation with accreditation criteria. The integrated curriculum can be planned with considerations of program learning outcomes, disciplinary learning outcomes, an existing curriculum benchmark with ITU, measurable attributes, a skills development plan, and CDIO standards.

A curricular reform with the CDIO framework at Shantou University, China, was based on an integrated, holistic approach to addressing the changing industrial demands. A design-directed structure was used to redesign 5 engineering programs with a special focus on Ethics, Integrity, and Professionalism, resulting in an EIP-CDIO initiative at the institution (Gu et al., 2007).

Popp and Levy (2010) published a method for mapping the curricula against any generic framework based on the CDIO syllabus and the Engineers Australia National Generic Competency Standards. The new methodology resulted in the ease of mapping and the reduction of the redundancy of the academic inputs.

Hellinga-Brink and Kok (2016) managed a CDIO implementation for 12 programs by track categorisation. The fast track was for the program that already implemented CDIO, the drawing board was for the program that needs to redesign the curriculum, and the quality track for the program that used CDIO for a quality improvement tool.

The key success factors for CDIO implementation at Singapore Polytechnic (SP) include support from management, a close collaboration of drivers, a customised CDIO syllabus by early adopters and education specialists, and CDIO standards interpretation for the local context. As an Asian regional leader, SP provides expertise to assist faculty in implementing the CDIO framework with SP 5-component model; namely, Introduction to CDIO Teaching and Learning Framework (Standard 1), Designing an Integrated Curriculum (Standards 2, 3, 7 and 11), Conceiving and Designing Innovative Products and Systems (Standards 4, 5 and 6), Designing Active and Experiential Learning Experiences to enhance students learning (Standard 8), and Programme evaluation to evaluate the impact of CDIO implementation (Standard 12) (Lee et al., 2015).

Expanding from engineering education, the CDIO framework shows a promising result with non-engineering implementation. Doan et al. (2014) developed Generalized CDIO standards to be utilized, along with suggestions from Crawley (2014). The non-engineering programs CDIO adaptation embraces the development of professional context, close work with stakeholders, disciplinary pedagogical development, and program evaluation. Malmqvist et al. (2016) exhibit applications of CDIO for non-engineering programs in Finland, Singapore, and Vietnam. The benefits of implementing CDIO were a better connection to working life practice, strong links between program development and quality assurance, and improvement of educational quality and an increase of design and innovation skills.

CDIO initiative has reached the 20-year milestone in 2020, new waves of challenges emerged rapidly with industry 4.0 and new sets of industrial demands. A thematic approach based on the core principles of Future-Focused, Purpose-Driven, Design-Led, and Quality-Minded educational development will ensure the success of higher education institutions. SP's Advancing CDIO curriculum development approach comprises 4 themes: Mapping; Enhancing; Innovating, and sustaining (Lee et al., 2018). This paper will elaborate more on the Mapping and Enhancing phases.

METHODOLOGY

RMUTT embraces the vision to be an "Innovative University" with the launch of policy at the institutional level for curriculum development. Thirty-four bachelor programs (6 engineering and 28 non-engineering) needed to be redesigned and aligned to the new vision. A 2-day workshop was conducted for 200 program committees from 7 faculties to prepare them for the curriculum redesign. CDIO master trainers acted as facilitators during the working process. They shared their experiences as CDIO practitioners on their own program, as well as encouraging discussions among the participants.

With an intention to conform to the Thai Qualification Framework (TQF), series of blank templates and documentation were planned ahead. The Mapping process covered a STEEP (Social, Technological, Economical, Environmental, and Political) analysis, a stakeholder survey, a skillset mapping, and an identification of new competencies, graduate attributes, program learning outcomes, and future careers. Fig. 1 shows the mapping process.

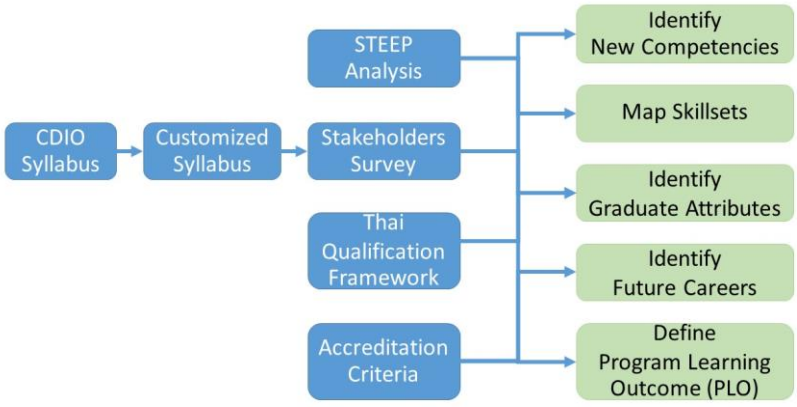

Figure 1. A mapping process

Stakeholders Survey

The CDIO Syllabus was customized to fit the context of RMUTT. A general questionnaire survey was designed by the CDIO master trainers and distributed to the program committee 2 months prior to the curriculum development workshop. The program committee may customise the questionnaire to match with their professional context—a stakeholder survey comprised of surveys from industry, alumni, and current students. The data were analysed prior to the workshop.

STEEP Trends Analysis

STEEP Analysis is a common tool for evaluating different external factors that have an impact on an organization (PESTLE analysis, 2015). This tool allowed the program committee to explore future trends and their implications and helped to predict what might happen in the future. Five categories in the STEEP analysis are Social & Demographic, Technology, Economic, Environment & Nature, and Political & Legal.

Thai Qualification Framework (TQF)

Thai curriculum is required to cover the 5 or 6 following learning domains (OHEC, 2010): Domain 1: Ethical and moral development, Domain 2: Knowledge, Domain 3: Intellectual, Domain 4: Interpersonal skills and responsibility, Domain 5: Analytical, communication and information technology (IT) skills, and Domain 6: Practical Skills. Different curriculum may have different sub-domains. Kuptasthien et al. (2018) identified CDIO-TQF mapping and their linkages. By implementing the CDIO framework, the TQF learning outcomes are also fulfilled.

Accreditation Criteria

The accreditation criteria were carefully considered during the redesign of the program. Therefore, the redesigned curriculum could also be accredited.

Identify New Competencies

Referencing the impacts of the future trends and future of work, the program committee identify new or emerging competencies the student should possess to be ready for the future reality.

Identify Future Graduate Attributes

Insights on the future reality assist the program committee to identify what are the desired future graduate attributes, which include knowledge, skills, mindset, and attitudes.

Mapping Skillsets

Graduate competencies and attributes were mapped with the CDIO Syllabus in order to determine which CDIO skillsets to strengthen and integrate into the program curriculum.

Identify Future Careers

With results from the stakeholder survey, new competencies, and future trends analysis, the program committee identify aspects of future career opportunities for the graduate.

Define Program Learning Outcome

The last step of the mapping process was to define the program learning outcome. Information obtained from all steps were then documented in the program curriculum file.

The Mapping phase can be viewed as an implementation of CDIO Standards 1 to 3, where the professional context was taken into account, with the involvement of stakeholders, to redesign the curriculum. The next step was the implementation of CDIO Standards 4 and 5. Normally all programs require a senior project as a part of graduation when the student is in the 4th year. With the vision of an Innovative University, a Play-Passion-Purpose concept (Wagner, 2014) was combined with the CDIO Standards 4-5 to portrait a 4-year transition from the freshman to the graduates, as shown in Fig. 2.

For the Enhancing phase, the program committee created 2 new courses, namely, an Introduction to Profession and a Multi-disciplinary Project (MDP) course. These courses provide design-built-test learning experiences to the students. The benefit of having all programs in the workshop together, faculty members from different disciplines can discuss the possibilities of the MDP. Templates were provided with the aim to integrate professional competencies, personal, and interpersonal skills into the courses systematically.

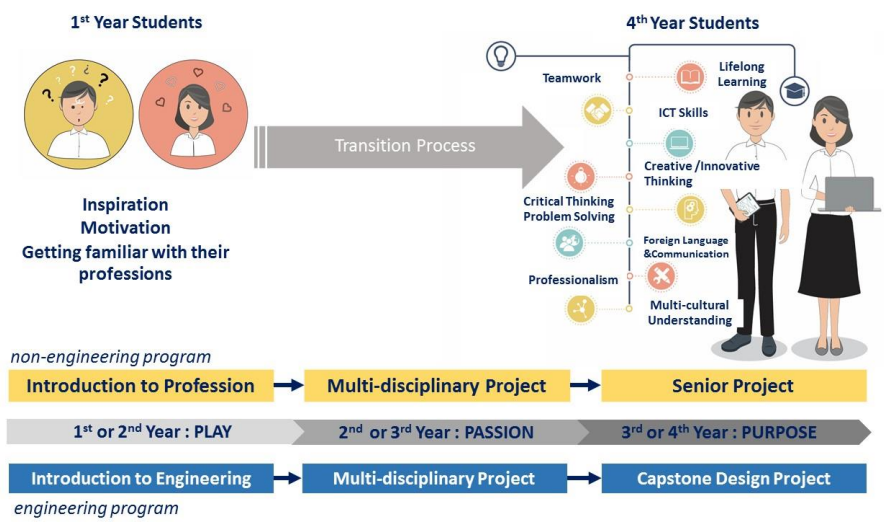

Figure 2. An enhancing process

RESULT AND DISCUSSION

Fig. 3 and Table 1 show graduate attributes from 34 different programs from 7 faculties. There were 28 programs that selected Creative Thinking as one of the graduate attributes, especially all programs in Agricultural Technology (3), Liberal Arts (2), Mass Communication Technology (5), and Fine and Applied Arts (7) faculties. There were 22 programs that chose Teamwork skills and Communications skills. Twenty programs chose System Thinking, especially all 6 engineering programs. All 8 programs in Business Administration faculty selected ICT skills as one of the graduate attributes, the same as the other 11 programs. There were 13 programs that chose Entrepreneurship, 12 programs chose Critical Thinking, and 12 programs chose Designing skills.

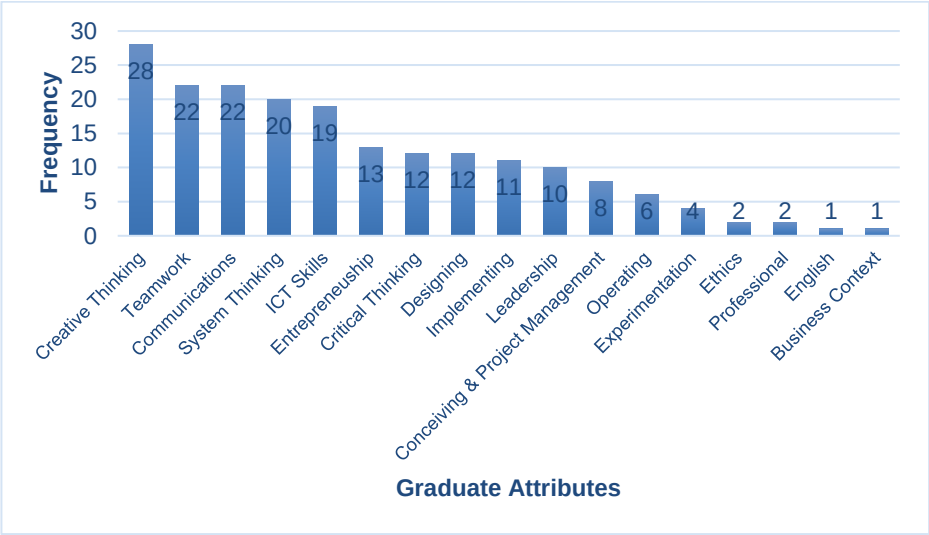

Figure 3. Frequencies of selected graduate attributes from 34 programs

Interestingly, Food Science and Technology and Advertising and Public Relations Technology programs indicated Ethics as one of the graduate attributes, which was further put into their integrated curriculum. Industrial Engineering and Digital Printing and Packaging Technology highlighted Professional skills. Only Food Science and Technology selected the English language. Industrial Engineering program would like to add Business Context in their integrated curriculum as well.

Table 1. Selected Graduate Attributes for 34 Programs at RMUTT

	Graduate Attribute	Analytical Thinking & Problem Solving	Experimentation	System Thinking	Creative Thinking	Critical Thinking	Ethics	Professional	Teamwork	Communications	English	Business Context	Conceiving & Project Management	Designing	Implementing	Operating	Leadership	Entrepreneurship	ICT Skills
Faculty of Agricultural Technology																			
1	Fisheries			●	●					●			●					●	●
2	Food Science and Technology				●		●		●		●				●				●
3	Landscape Technology				●								●	●			●	●	
Faculty of Engineering																			
4	Computer Engineering			●	●								●					●	
5	Industrial Engineering			●		●		●	●	●		●		●	●	●			
6	Electronics and Telecommunication Engineering		●	●	●	●			●	●									
7	Environmental Engineering	●		●	●				●	●				●					
8	Food Engineering		●	●					●	●							●		
9	Textile Chemical and Fiber Engineering	●	●	●	●	●							●		●				
Faculty of Business Administration																			
10	Business English			●	●				●	●			●				●	●	●
11	Computer Business	●		●	●					●			●	●					●
12	Economics				●	●			●	●									●
13	Finance	●		●	●	●				●			●						●
14	International Business	●			●	●			●	●							●	●	●
15	Logistics and Supply Chain Management	●		●		●										●			●
16	Marketing			●	●					●				●	●		●	●	●
17	Management	●		●	●				●	●							●	●	●
Faculty of Home Economics																			
18	Food Industry and Services	●		●						●				●	●		●		●
19	Food and Nutrition	●		●					●							●			●
20	Fashion Design and Clothing				●				●						●			●	
Faculty of Liberal Arts																			
21	Tourism				●	●			●	●				●			●	●	●
22	Hotel Management	●		●	●	●			●	●							●	●	●
Faculty of Mass Communication Technology																			
23	Photography and Cinematography Technology	●		●	●				●	●									●
24	Digital Printing and Packaging Technology	●			●	●		●					●		●	●			
25	Radio and Television Broadcasting Technology				●	●			●	●								●	●
26	Advertising and Public Relations Technology			●	●		●		●	●								●	●
27	Multimedia Technology			●	●				●										●
Faculty of Fine and Applied Arts																			
28	Innovation Contemporary Product Design			●	●									●	●				
29	Interior Design				●				●	●				●					●
30	Music				●				●				●			●			
31	Product Design		●		●									●	●				
32	Sculpture				●				●	●				●	●	●	●	●	
33	Thai Arts				●				●	●				●	●			●	●
34	Visual Communication Design			●	●	●			●	●									

There are some similarities between RMUTT Music and program and SP Music and Audio Technology (Malmqvist et al., 2016). They both need the operating skills or technical learning outcome relating to music and audio competences. Teamwork and Thinking skills were also the same for both programs. However, SP's Music and Audio Technology had oral and written communication skills, while RMUTT's Music program emphasised in Project Management to

be added in the curriculum. The similarity could also be seen with the RMUTT Multimedia program, where they highlighted thinking, teamwork, and ICT skills.

The study also found similarities between RMUTT and SP Food Science and Technology programs (Malmqvist et al., 2016). They both underlined Ethics and Responsibility as key attributes, along with Teamwork and Creativity. We found similarities between RMUTT and TUAS in business programs as they focused on training the students in business development, entrepreneurship with ICT skills, as well as and innovative attitude (Malmqvist et al., 2016). RMUTT's business programs have indicated different kinds of thinking skills, including analytical, creative, critical system thinking, along with teamwork and communications.

Table 2 shows the list of examples for the Introductory and MDP courses for different programs resulting from the Enhancing process.

Table 2. List of Examples of Introductory and MDP Courses

Program Name	Introductory Course	MDP (Disciplines)
Food Science and Technology	Introduction to Food Science and Technology	Food Product Development (Food Science, Packaging Design, Business)
Industrial Engineering	Industrial Design and Build	Innovative Product Design and Entrepreneurship (Industrial Engineering, Product Design, Entrepreneurship)
Environmental Engineering	Environmental Unit Operation	Waste Management (Environmental Engineering, Mechanical Engineering, Electrical Engineering)
International Business	Introduction to International Business	Global Business Entrepreneurship in the Digital Era (International Business, Marketing, IT)
Logistics and Supply Chain Management (SCM)	Warehouse Management	Information Technology in Logistics & SCM (Logistics & SCM, IT, Business)
Food and Nutrition	Perspective in Food and Nutrition	Food Innovation Contest (Food and Nutrition, Advertising, Art)
Hotel Management	Introduction to Hotel Management	Thai Food Innovation (Hotel Management, Food Science, Art)
Photography and Cinematography Technology	Media Production for Photography and Cinematography	Theatrical Film Production (Photography and Cinematography, Multimedia, Music Composition)
Digital Printing and Packaging Technology	Printing Technology	Entrepreneurship in Printing and Packaging Business (Printing and Packaging Technology, International Business, Thai Herbal Product Development)
Innovation Contemporary Product Design	Mini Project Innovative Product Design	Innovative Product Design (Product Design, Art, Business)
Visual Communication Design	Mini Project Visual Communication Design	Visual Communication Design (Visual Communication Design, Animation, Business)

CONCLUSION

Both engineering and non-engineering programs at RMUTT successfully adopted CDIO Syllabus and CDIO Standards 1-5 for redesigning their curriculum. The mapping process showed some similarities and differences regarding the disciplinary nature and the future landscape of the industries. With the ultimate goal of producing hands-on graduates in the

innovative era, the program learning outcomes were shaped by the mapping progression. In addition, all 34 programs created new courses for the purpose of enhancing their students' knowledge, skills, and attitudes in order to achieve their program outcome.

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ASSESSING CURRICULUM AGILITY IN A CDIO ENGINEERING EDUCATION

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ABSTRACT

Change and individualization are two aspects that are important in innovative higher education. In this paper, we argue for how the concept of curriculum agility can be used as a framework for engineering education that is able to meet societal, environmental, and technological challenges. To both anticipate and meet the needs of the rapidly changing world, engineering education needs to have an organization that allows for innovation, change, and adaptation, with the capacity to respond within a (much) shorter timeframe than traditionally seen in higher education. The structure and processes of such organizations should include the time needed to establish and decommission new educational programmes, and the flexibility within the programmes. The CDIO's Curriculum Agility Working Group has defined seven principles for curriculum agility and has analysed how these relate to the CDIO Standards. This paper describes how the principles can provide guidance on both a curricular and institutional level. The principles are mapped against the CDIO Standards, relating to what is required for an agile curriculum, in order to indicate how the Standards can be utilized to assess the flexibility and agility of educational programmes.

KEYWORDS

Curriculum Agility, Stakeholder Involvement, Change Management, Self-Assessment, Standards 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

THE NEED FOR AN AGILE CURRICULUM

Engineering education is constantly exposed to change. Global changes, irrespective of being environmental, societal, or technological does prompt internationally supplemented actions and responses. Other changes may be more local and context-specific. Regardless of scope, these changes demand informed, well-designed, adequate, and timely responses. Therefore, it is essential that Higher Education Institutions (HEIs) are able to provide education that helps global citizens to conceive, design, implement and operate solutions or actions that address current and future changes and challenges, globally and locally (Crawley et al., 2014).

Today, STEM-universities are generally very good at undertaking research that is both topical and a driver for change in itself. Many research projects are initiated by current societal challenges, and the research strategies at the universities are directed to new needs and opportunities. In addition, an increasing number of innovations, both social and technological, has been quickly changing the conditions for companies as well as for communities. As HEI students will face many new challenges and changes that have not been seen earlier, matching responsiveness is needed for HEIs, which will have an effect on their formats.

Flexibility and agility have been described and seen as necessary aspects of modern education. However, there seems to be no consensus on what curriculum flexibility and agility entail (Tucker & Morris, 2011). The term 'curriculum' in this paper is understood as comprising vision and rationale, aims and objectives, content, learning activities, teacher role, materials and resources, group learning, location, learning time, and assessment (van den Akker, McKenney, Nieveen, & Gravemeijer, 2006). The most common application of the concept is that curriculum flexibility is focused on adapting to, and facilitating, the changing needs of the students. It is primarily a way of addressing and responding to different student groups (e.g., non-traditional students) by increasing access to higher education (see Jonker, März, & Voogt, 2020) by means of addressing different factors such as, for instance, learning time, environment and preferences.

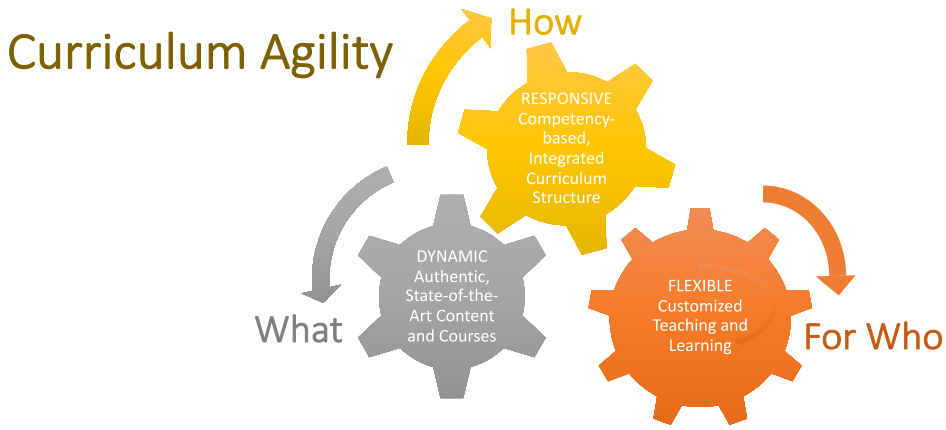

Figure 1. Curriculum Agility and its three controls (Brink, Admiraal, de Hei & Sjoer, 2020)

The overarching concept of curriculum agility described in this paper focuses on how higher education is able to (re)act to the rapidly changing needs that affect all aspects of the organization and processes of a higher education institution. Therefore, our definition of curriculum agility goes beyond flexible education and has a focus on adapting and adjusting to change from a holistic perspective. It consists of an educational structure organized to be sufficiently responsive, allowing educational content to be dynamic where needed, and offering this in a customized, flexible approach to the increasing diversity of students and their individual needs, see fig 1.

Many engineering programmes currently work actively on the responsiveness, dynamic content, and flexibility of their education (Brink et al., 2019). However, there are often different obstacles ranging from governing regulations, academic traditions, and views on educational content, to general systemic inertia that hinders the necessary improvements. The CDIO Initiative is an example of a framework that can help develop a curriculum and syllabus that adequately respond to the needs of society, thereby giving students the necessary graduate attributes to engage with future challenges.

This innovative work is illustrated in a case study of an Industrial Design Engineering curriculum that, based on the twelve Standards of CDIO, worked towards agility. In five Standards (2, 5, 8, 11, 12), they made implicit openings for agility more explicit, such as co-creation, intercultural competences, international multidisciplinary projects, and integrated assessment for learning (Hallenga-Brink & Sjoer, 2018). This case also showed the need for an institutional organization that truly allows for innovation and adaptation. The organization should have the capacity to respond to new needs within a (much) shorter timeframe than traditionally occurs, including the time needed for establishing new programmes as well as decommininging existing ones, including the dynamics and flexibility within programmes.

PRINCIPLES FOR CURRICULUM AGILITY

Our vision for the concept of curriculum agility — following the reasoning by Snow Andrade (2018) — is that we want *to ensure an education that not only meets but also anticipates the needs of a rapidly changing world.* This vision has been iteratively processed within the CDIO community, starting with a workshop on curriculum agility at the 14th International CDIO Conference in Kanazawa, Japan, followed by further development at the EU and UK-NI Regional meeting in La Rochelle, France in 2018. The work was then continued as a Working Group during the 15th International CDIO Conference in Aarhus, Denmark, where the concept was further elaborated. Initially, ten principles for curriculum agility were established. After Aarhus, the working group continued the work and agreed on seven principles.

The seven principles were defined to develop a tool for assessing curriculum agility. This paper intends to describe how agility can be determined at a curricular and institutional level and how curriculum agility is reflected in the CDIO Standards. The principles, which can be seen in table 1, have therefore been compared with the descriptions and assessment criteria for the 12 CDIO Standards (CDIO Standard 2.1) in order to decide if, how, and at what levels the standards address curriculum agility.

Table 1. The seven principles for curriculum agility

Principle	
Stakeholder Involvement	Structures and procedures at the institution for identifying and prioritizing new needs, inviting stakeholder involvement in change processes to ensure an effective process for carrying out changes.
Organization and Governance	Ensuring an organizational structure that can effectively address the administrative system and institutional and national regulations in order to implement and maintain curriculum changes.
Decision Making	Having an effective curriculum and course approval process: timeframes, steps required, number of persons involved, communication channels.
Entrepreneurial Management	Establishing and maintaining a *change culture*. Ensuring a culture rather than a "one-person engagement." Establishing how change can be achieved initiative-driven: proactive rather than reactive.
Programme and Course Design	Allowing flexibility in programme and course design: adjustable projects, designing learning outcomes for change and flexibility. Also providing opportunities for students to build their profiles.
Educational Innovation	Encouraging initiatives and innovation that promote education that is responsive and adaptive to change.
Pedagogy and Didactics	Promoting scholarship of teaching and learning among both teachers and students. Encouraging collegial teaching teams.

In the section below, the principles are clarified by exemplifying how they can be interpreted and used as rubrics from an institutional perspective.

Stakeholder Involvement is important in order to make sure input from different external and internal actors is collected, applied, and used to improve the results of the education and its organization. Stakeholders in STEM-education include (but are not limited to) representatives from industry and non-governmental organizations; government and communities; students; teachers. An HEI must have structures and procedures that allow for the exchange of ideas and input on requirements for education regarding different changes and needs. This principle also stresses active stakeholder participation in the co-creation of education and throughout its change processes. The principle focuses on how and by whom changes in the curriculum are done.

Organization and Governance is the principle that deals with how an HEI is organized and what (overarching) structures and procedures govern its operations and activities at a programme and curriculum level. The organization of the institution needs to be such that the curricula can be responsive to (rapid) changes in their domain. This means that the systems and process flows must give room for customization, interdepartmental collaborations, informed, and well-argued for adjustments of university rules and departmental agreements. It also entails systematic facilitation of and support for, successfully implementing the needed changes, both internally and externally, e.g., by professionalization, training, and guidance.

Decision Making is about the process that a programme uses for changes to the curriculum, comprising both steps and timeframes. An effective decision-making procedure for curriculum development is also evaluated regarding the roles involved (including chain of command), and how the processes and decisions are communicated for impact in the organization. The principle covers starting new programmes or courses, making changes in existing programmes and courses, and decommissioning programmes and courses. The decision-making principle is closely connected to the principle Organization and Governance.

Entrepreneurial Management can be described as a principle for establishing and maintaining an approach to change as a natural and continuous part of curriculum design among the leadership of the institution. It is a principle that encourages and facilitates entrepreneurial thinking for curriculum development. It promotes a willingness to act on new

and changing needs in society and secures it in the organization. The willingness to change should not be dependent on individuals as single drivers for change.

Programme and Course Design deals with how the curriculum and courses are designed and developed and how flexibility can be addressed in existing and new programmes and courses. As a principle, it is intended to highlight the need for designs that allow for changes and adjustments to current needs. The principle also looks both at dynamic content as well as individual flexibility, permitting students to take ownership of their learning, for instance, through course choices and alternative programme paths. The principle requires an institutional change promoting mindset and is linked to the principle of Entrepreneurial Management.

Educational Innovation promotes change at an innovation level. This means that the institution's organization and leadership allow and encourage new initiatives, connections, and experimentation in educational changes, regarding both contents as well as teaching and learning. The principle is connected to Entrepreneurial Management, focusing on didactics. The innovations can vary from incremental to disruptive, yet always helping education to become more agile by improving the responsiveness of the system, the dynamics of the content, and the customization of the students' learning.

Pedagogy and Didactics stress the importance of teachers making informed choices regarding suitable pedagogical and didactic approaches and methods for flexible education. Scholarship of teaching and learning (SoTL) encourages teaching staff to apply the newest insights and contribute to finetuning established teaching methods to flexible, inclusive education for a diverse and fast-changing student body. Collaboration in teaching teams is also encouraged as a means for educational development at the institutional level. Establishing and maintaining solid grounding via learning communities supports educational innovations and ensures the sustainability of programme and course design changes.

CURRICULUM AGILITY IN THE CDIO STANDARDS

In order to investigate how and to what extent the CDIO Standards meet the descriptions of the seven principles, the standards and principles were mapped against each other by participants of the curriculum agility workgroup. By comparing the description, rationale, and rubric for each Standard with each agility principle, an overview of the matching could be made (see table 2). At an overarching level, it became clear that the CDIO Standards allow (and to a certain extent stimulate) educational flexibility. It also became evident that the principles for curriculum agility require high scores in the self-evaluation rubrics for the standards. Even though curriculum agility is applicable to all standards from a holistic point of view, table 2 shows that several of the principles address curriculum aspects at another level than the standards do and are therefore not expressed in the standards.

Table 2. Mapping of the principles for curriculum agility against the CDIO Standards 2.1

Principles	**Standard 1**: The Context	**Standard 2**: Learning Outcomes	**Standard 3**: Integrated Curriculum	**Standard 4**: Introduction to Engineering	**Standard 5**: Design-Implement Experiences	**Standard 6**: Engineering Workspaces	**Standard 7**: Integrated Learning Experiences	**Standard 8**: Active Learning	**Standard 9**: Enhancement of Faculty Competence	**Standard 10**: Enhancement of Faculty Teaching Competence	**Standard 11**: Learning Assessment	**Standard 12**: Program Evaluation
Stakeholder involvement	Implicit	Implicit	Implicit	Implicit	Implicit	Implicit	Implicit	N/A	N/A	Implicit	Implicit	Implicit
Organization and governance	N/A	Implicit	Implicit	N/A	N/A	Implicit	N/A	N/A	N/A	Implicit	Implicit	Implicit
Decision making	Implicit	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Implicit
Entrepreneurial management	Explicit	Implicit	N/A	N/A	N/A	Implicit	N/A	N/A	Explicit	N/A	N/A	Explicit
Programme and course design	N/A	Explicit	Explicit	N/A	Implicit	Implicit	Explicit	Implicit	N/A	N/A	Implicit	Explicit
Educational innovation	Explicit	N/A	N/A	N/A	N/A	Explicit	N/A	N/A	Explicit	Explicit	Explicit	Implicit
Pedagogy and didactics	Implicit	Explicit	Explicit	N/A	Explicit	Explicit	Explicit	Explicit	Implicit	Explicit	Explicit	Implicit

In the following section, the connection (or absence of connection) between the principles and the standards is described, including comments on how explicit or implicit the principles are addressed in the standards and to what extent the principles are relevant or not.

Principle: Stakeholder Involvement

The involvement of stakeholders is essential in engineering education. This is especially true for CDIO education, which is manifested in the involvement of stakeholders' input in almost all CDIO Standards (except Standard 10, Enhancement of Faculty Teaching Competences). However, we argue that the standards can only be used in part to measure the agility or flexibility of an educational program.

The Stakeholder Involvement principle focuses on the involvement in the change process to ensure effectiveness, whereas the CDIO Standards are more focused on the involvement of stakeholders as informers to, or evaluators of, the education. As described in the standards, stakeholders ensure relevance and authenticity and provide feedback, reviews, and recommendations on different aspects such as learning outcomes (2), integrated curriculum (3), introduction to engineering (4), design-implement exercises (5), workspaces (6), learning (7,8) and assessment (11).

In addition, it can be argued, at least to some extent, that Standard 12, Program evaluation, embraces the principle sufficiently well and that scale 4, "There is documented evidence that program evaluation methods are being used with key stakeholders including students, faculty, program leaders, alumni, and working life representatives," is a good indicator for curriculum agility. However, it is not explicitly mentioned how stakeholders should be actively involved in the change process itself. It is therefore concluded that the standards involve aspects of means for the exchange of ideas and input and processes for identifying and prioritizing needs for change but not how to include stakeholders in the actual change process.

Principle: Organization and Governance

The standards focus on the vision of education, the design elements of the curriculum, its contents, assessment system, and evaluation cycle, along with working spaces and staff training. The principle Organization and Governance is at another level of abstraction and, therefore, does not allow for literal placement within the standards. However, in some standards, certain factors are important from the perspective of Organization and Governance for curriculum agility.

First of all, in order to allow curricula to be responsive to (rapid) changes in their domain, in Standard 12 it would be important to make the evaluation cycles short, well-timed, and/or have an iterative character, as to make swift changes possible and not held back by the quality cycle tempo. It would also be important to open up for informed and argued adjustment of university rules and departmental agreements within the Governance.

Secondly, to give room to customization and facilitate the innovation process by professionalization and training, it is important in Standard 10 to facilitate teachers' development of competencies in flexible education (within active and integrated learning) such as coaching, guidance, and reciprocal learning. These are not always part of the regular teaching professionalization programmes within HEIs.

Thirdly, stimulating interdepartmental collaborations will help both in Standard 2, to be able to teach the personal and interpersonal skills within multidisciplinary projects, and Standard 3, to make sure the walls between faculties and departments are prevented from forming barriers for integrated learning opportunities for students. Implicitly, these remarks fit within the standards' descriptions and rationales, but they are not explicitly mentioned and could thus be 'forgotten' in the self-assessment on the CDIO Standards, not leading to the desired curriculum agility.

However, two standards do give good guidance for the Organization and Governance principle of an agile curriculum. Within Standard 6, it is emphasized to facilitate agile, multipurpose, adaptable workspaces that can grow with the changes in the industry as an HEI. And Standard 11 solicits an assessment policy that allows for integrated assessment on an integrated, dynamic body of knowledge and skills, something that is essential for curriculum agility to work.

Principle: Decision Making

There is little correspondence between this principle and the CDIO Standards. The principle focuses on structures and processes for decisions regarding curriculum development and other changes in the educational setting. The standards, on the other hand, are more focused on the aspects of teaching and learning in relation to the CDIO framework and ways of thinking about the necessary elements for an engineering education that follows the concept of conceiving, designing, implementing, and operating. There is no description of by whom and how decisions should be made regarding changes in the educational offerings and the curriculum.

However, it could be argued that Standard 1 and Standard 12 meet some of the ideas of the principle, as scale 5 in the rubric mentions "continuous improvement" and "systematic and continuous improvement" in both standards. Nevertheless, there is no explicit mentioning of how this should be carried out. As is clear in the description of the principle, it is the actual procedural design that is in focus and how this allows for a responsive and timely decision-making *process*. The conclusion is that this principle and the standards are addressing different aspects and can, therefore, be seen as complementing each other without any evident overlap.

Principle: Entrepreneurial Management

At first glance, one could perceive no association between the Entrepreneurial Management principle and the 12 CDIO Standards. To establish and maintain a proactive change culture in an organization is of fundamental importance when aiming to be agile. For this, to work the

culture and the strategy and processes of the organization have to be aligned. The principle Entrepreneurial Management describes attitude and organization at a management level, the demand for a surrounding structure that drive change rather than simply responding to it.

As stated previously, the standards focus on how education should be led with all its elements, from curriculum design to assessment systems and evaluation cycles, including physical spaces and personnel. Curriculum change, however, does require continuous improvement, and for this to take place, we notice that at scale 5, in standards 1 and 12, there is a connection when continuous development is considered. We could also reason that Standard 2 is partly related to this principle as there should be responsiveness in the stakeholder's view of what outcomes are anticipated.

Furthermore, we may argue that for standards 6 and 9, there could be an implicit connection with the principle. For both the principle and the standards, it is anticipated that students become involved in the design process of workspaces. Similarly, a constant dialogue with faculty should be part of the process of setting necessary actions for their continuous development. As Blackmore and Kandiko (2012) suggest, the implementation of change requires considerable time spent in gaining support and planning.

Principle: Programme and Course Design

Fundamentally, the CDIO educational framework (Crawley et al., 2014) focuses on programme design to better prepare engineering graduates for employment. Therefore, this principle maps well with the standards and explicitly with Standards 2, 3, 7, and 12. There are implicit connections with Standards 3, 5, 6, 8, and 11, but no real ones with Standards 1, 4, 9, and 10.

The explicit links with Standards, 2, 3, 7, and 12 are due to these Standards dealing directly with the learning outcomes, subsequent integration of skills, and corresponding pedagogical approaches that affect curriculum design to optimize learning. It is suggested that Standards 2 and 7 would require a curriculum evaluation meeting scale 3 or better in their respective rubrics to ensure they could match the ideals of this principle, with Standards 3 and 12 requiring a score of 5 and 4, respectively.

The links with Standards 3, 5, 6, 8, and 11 are more tentative, mainly because their respective descriptions and rationales do not mention programme or course design specifically, but their content implies they would be important to ensure flexibility in any redesign process. It is suggested that their corresponding curriculum evaluation rubric scores should be scale 4 or better for Standards 5, 6 and 11, and 3 or better for Standard 8, to match the ideals of this principle.

Finally, it is worth noting that the successful implementation of Standards 3, 5, 7, and 11 might actually restrict opportunities for students to build their own profile by reducing course choice or alternative programme paths and hence oppose the ideals of this principle.

Principle: Educational Innovation

Clear correspondence of this principle is seen with the standards related to teaching (9, 10, and 11). We may say that it is imperative that bottom-up initiatives, such as faculty suggestions for changes, are supported. Innovative learning spaces require enhanced faculty competence. Therefore, it is equally important that teaching competence is developed and assessed. This principle could be checked against support structures at the institution (e.g., workshops, SoTL

conferences, etc.). Considering that workspaces are naturally associated with teaching, Standard 6 also plays an important role as innovative education requires innovative workspaces.

When evaluating responsive education, reform initiatives not only apply to introduce CDIO but also adapting to changes in general. For this reason, the context of education (Standard 1) should consider fast changes to societal needs and demands. If educations do not respond quickly, they risk becoming hindrances to changes. For Standard 12, which suggests specific forms of stakeholder dialogues, evaluating the effect of changes towards agility could be relevant. In order to support education that is open and adaptive to change, constant responsiveness to demands, and a need to build an institutional habit of change is necessary, as Clark (2003) states. Change needs to be institutionally sustained after the transformation has taken place. Formal positioning and directorial influence are key points. Otherwise, initiatives will remain as marginal projects.

Principle: Pedagogy and Didactics

The principle can be described as the ability to make agility happen. In order to be able to respond to changing demands for engineering competencies, it is desirable that both curriculum design and the choice of pedagogies can be changed from one year to another. Several of the CDIO Standards are explicitly related to this. Standards 2 and 3 on Learning Outcomes and Curriculum design, which deal with design choices for the programme, and Standards 5-8, and Standard 11, which all deal with the implementation of the design choices, are clearly relevant. While scale 4-5 for these standards does not guarantee agility, it would be challenging to implement agility without high scores for these standards.

The Standard most relevant for the ability to do agility is arguably Standard 10, as it deals with the Enhancement of Faculty Teaching Competence. It is necessary that faculty staff have sufficient competence in order to be able to respond to pedagogically motivated design changes for the teaching-learning activities. Scale 4-5 is probably required for a continuously evolving agility to be possible. The remaining standards are also of some relevance, at least implicitly, as all 12 Standards address different aspects of design and implementation of the curriculum. Standard 9 may be of interest if there are new technologies or theories that need to be introduced in the education, which may require that Faculty Staff learn about new content. Also, Standards 1 and 12 frame the standards and describe the processes where the need for new content and competencies may be identified. Standard 4, which deals with Introduction to Engineering, is likely to be the least important to address in terms of agility.

CONCLUSION

The idea behind the CDIO framework with its Standards and Syllabus is to provide a solid basis for a modern engineering education that is “constantly improved” (CDIO Vision). The purpose of the CDIO approach is to educate students who are “ready to engineer” (Crawley et al., 2014, p.11). This means that the students must be able to meet the changing demands of society and the work field and to develop products and tools that match the needs of today and tomorrow. Therefore, it is quite obvious that it is the intention of a CDIO-based education to be flexible and adaptable to societal, environmental, and technological changes.

When examining the Standards, it is also clear that the adaptation to change and the need for stakeholders’ input to curriculum design and curriculum content are aspects that are

emphasized in how the Standards have been formulated. In this paper, we have compared the Standards to seven principles for curriculum agility, and there is evidence that all Standards meet several of the principles. Curriculum agility can, therefore, be seen as part of all Standards and that this is explicitly expressed in the description, rationale, or rubric of the individual Standards (except for Standard 4 that only implicitly corresponds to one of the principles).

Nevertheless, our discussions led to a consensus that there are aspects expressed in the principles for curriculum agility that are lacking in the Standards, and some of the principles are vaguely supported in the formulations of the Standards. A reason for this discrepancy is that some of the principles address issues at an institutional and organizational level that is beyond the scope of the Standards. It is also evident that there is a divergence in focus in the Standards and in the principles. That is, the descriptors for curriculum agility naturally have a much higher resolution and a stronger focus on the principles. Consequently, it is clear that some of the principles and the Standards focus on different aspects and that they can be seen as complementary to each other rather than synonymous.

When it comes to assessing the agility of a programme or curriculum, it is clear that the Standards can give direction, especially when matching the highest score in the rubric of the Standard but do not guarantee it. For a more thorough assessment, other, more precise indicators need to be used. In the mapping process, some of the principles actually have proven to give direction to how to approach some of the Standards. The principles have been formulated in an attempt to look at curriculum agility from the different relevant educational and organizational levels. Several of these aspects cannot, and should not, be addressed in the CDIO Standards. Instead, some of the organizational aspects need to be understood and negotiated at a local or national level, depending on how the HEI is organized and governed.

The findings in this paper indicate the need for additional methods to assess curriculum agility as a complement to what is possible through the current CDIO Standards. For that reason, we propose continued work on the principles together with the development of a self-assessment tool that can be used by HEIs to evaluate their potential for designing curricula that meet current and future needs in an ever-changing world.

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THE GLOBAL ENGINEERS LANGUAGE SKILLS (GELS) NETWORK: AN UPDATE

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ABSTRACT

In 2015, three language teachers working with student engineers at different European universities founded the Global Engineers Language Skills (GELS) network. The teachers' aims were to investigate and categorize necessary and desirable language and communication skills for engineers and ensure that these findings actively support the teaching and learning of additional languages in technical universities and engineering departments. We presented preliminary results of our work at CDIO's international conference in 2016. In this paper, we summarize the network's development since then, interpret the results of our investigations, and describe our work to disseminate our results and promote effective language and communication skills for engineering students. We also summarize our more recent work on enhancing the GELS framework of skills, applying for Erasmus+ KA2 funding, developing the GELS network from three to thirty universities through training events, integrating intercultural communication skills in our work, and teaching and learning through the medium of English.

KEYWORDS

Communication, Language for Specific Purposes, Intercultural Communication, Standards 2, 3, 7, 8, 10, 11

INTRODUCTION

A history and definition of Language for Specific Purposes (LSP)

In the aftermath of World War II, the United Nations and the Council of Europe sought to encourage understanding and enhance communication between various countries through better knowledge of each other's language and culture. The translation of specific vocabulary

into various languages was nothing new, but it is from this time that the number of student exchanges grew significantly in Europe, and more consideration was given to the specific language and communication (LC) needs of professionals (Dudley-Evans & St John, 1998). Although English was advanced as the lingua franca in many domains, research in Language for Specific Purposes (LSP) has been carried out in a number of languages (see Gollin-Kies et al., 2015, pp. 233-241).

There are numerous approaches to LSP, and varying definitions have been proposed. The definition and approach that have been the best guide for our work come from a 2015 article on current perspectives on LSP, where the domain is described as:

> "… 27 involv[ing] the teaching and learning of the foreign language for professional/working purposes in order to facilitate interaction on the part of a working person … at the international level. The interaction may extend along a continuum from passive interaction, as in the case of reading technical materials in the target language, to active interaction, for example, travel to other countries in order to participate in joint projects in the language. For this reason, cultural concerns are a fundamental component of courses alongside general, albeit formal language instruction and situational vocabulary, grammar, and functional structures." (Garcia Laborda & Litzler, 2015, pp. 6-7).

In the 1960s, Halliday et al. (1964) paid special attention to the vocational needs of workers in international settings. However, there was a focus on technical vocabulary and potentially demotivating lists of words to learn. A more thorough needs analysis system emerged in the 1970s with Munby (1978), which is generally considered the first example of a communicative approach in LSP. Hutchinson and Waters (1987) followed suit but focused rather on the learners' needs and motivations. Since then, it has been noted that LSP teachers' needs have largely been forgotten (e.g., Richards, 1997), and that more research is needed in the domain of LSP and teacher education (e.g., Basturkmen, 2014).

An introduction to the GELS network

The Global Engineers Language Skills (GELS) network is an informal group of Language and Communication (LC) teachers working at technical universities and engineering departments. Our goal is to improve LC teaching and learning in our institutions by working together with a clear and confident focus on the specific communication needs of engineers. We LC teachers working with student engineers are often poorly placed on recognizing their broader learning needs because we seldom have a technical background or have tenured positions at universities (Tual et al., 2016). However, LC training is vital for engineers (e.g., European Society for Engineering Education, 2019). To integrate it more effectively in engineering education, we need a clearer picture of 1) what engineers really do and how they need to communicate, and 2) how engineers' typical communication tasks can be a source of inspiration for meaningful teaching and learning in the LC classroom.

The GELS network was established in 2015 with two aims: 1) to better prepare engineering students for international study and future employment by having a clear idea of engineers' specific language and communication needs, and 2) to provide opportunities for LC teachers working with engineers to network, share expertise and good practice, and ensure continued professional development. To fulfill these aims, teachers from the GELS network set themselves the following four objectives:

1) Identify the communication skills most frequently required by engineers in the workplace by means of surveys

2) Create a progressive framework of communication skills specifically for engineers that prepares students for the CDIO's Communications syllabus

3) Develop a catalog of teaching and learning activities based on the framework

4) Disseminate the framework and the catalog to LSP teachers working with engineers.

The following sections of the paper summarize the GELS network's development according to these individual objectives.

SUMMARY OF THE GELS NETWORK'S DEVELOPMENT

Objective 1: Identify the communication skills required by engineers

Online surveys were chosen as the most effective method for collecting quantitative data from engineers. The primary survey included seven questions, in which respondents were asked about their use of additional languages for professional purposes, their most common communication tasks, and the importance of language skills for their organization's recruitment process. The survey was disseminated via social and professional networking websites, and all who were qualified in engineering and/or worked on the design, construction or maintenance of engines, machines, ICT, or structures were invited to respond to the survey. For a more detailed description of the data collection process, see Rinder et al. (2016).

To date, 219 engineers from various backgrounds and working in various engineering disciplines have taken the survey and shared their experiences. Analysis of the data in Rinder et al. (2016) indicated that engineers primarily needed language skills for their participation in meetings, telephone conversations, casual correspondence, and writing short documents. Furthermore, additional language skills were primarily used for interacting with colleagues, but also clients, suppliers, and the organizational head office.

A new analysis of a greater data set shows similar results. An important question addressed in the GELS survey concerns the situations in which LC skills are needed. The answers to this question (see Figure 1) provide insights into the communicative contexts frequently encountered by engineers and offer indications for the kind of formal and informal registers required for such situations.

The different communication situations presented in Figure 1 can be seen as part of a continuum regarding their interactivity, which consequently affects the communication modalities relevant to them. Analysis of our data shows that LC skills are primarily used for reading documents, more often short documents (n=173; 79%), and writing for specific audiences (e.g. casual correspondence (n=165; 75%), formal correspondence (n=155; 71%), brief documents (n=155; 71%), and long documents (n=134; 61%)).

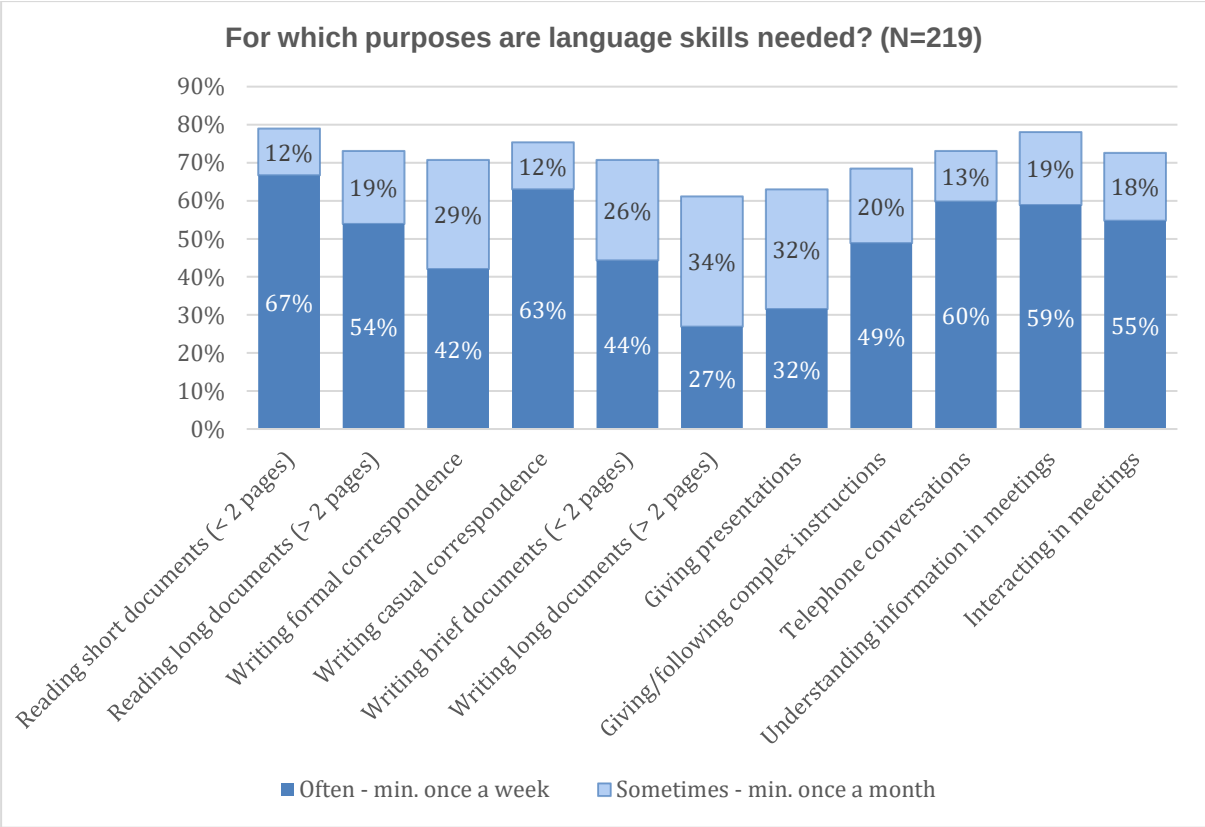

Figure 1. Answers to the question *How often do you do the following in any language?*

Engineers also have to find ways to present information for a variety of purposes. Interestingly, our results show that formal correspondence appears to be much less frequent than casual correspondence. In similar regard, delivering oral presentations (n=138; 63%) appears to be less relevant than might be expected. This shows that LC courses focusing on formal correspondence and presentations may not be ideal for preparing student engineers for the world of work. The data also suggests that LC courses and assessment for engineers could be improved by including more dialogic exercises, such as telephone conversations (n=160; 73%) and interactions during meetings (n=159; 73%).

Another important factor affecting communication situations is the specific interaction partner(s) (see Figure 2). The results of our survey show that engineers' communication partners in additional languages are primarily colleagues (n=134, 61%), followed by clients (n=107, 49%), suppliers (n=74, 34%), "others" (n=60, 28%), and the head office (n=57, 26%).

We can also infer from these results that engineers primarily need to be able to share their technical knowledge and understanding with their peers. Such communication among colleagues is likely to require a neutral register; however, this is a generalization and does not take into account cultural and organizational differences (Moll, 2012).

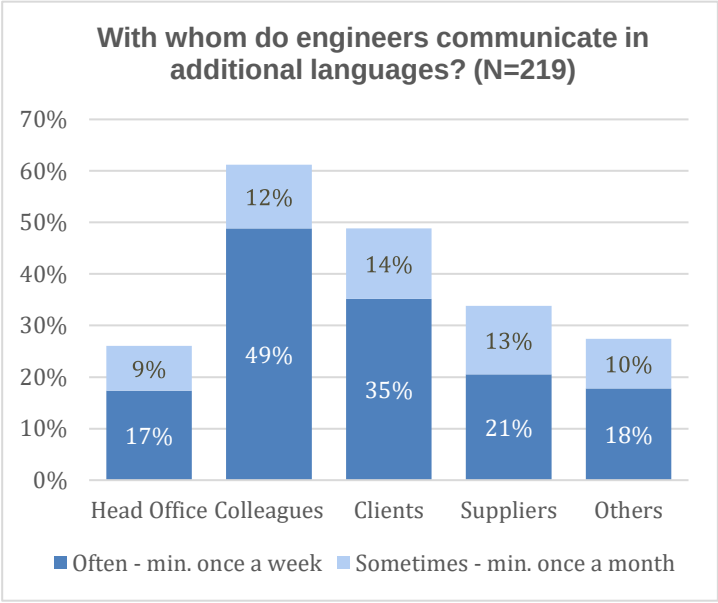

Figure 2. Answers to the question *With whom do you communicate in additional languages?*

Objective 2: Create a progressive framework of LC skills

The GELS framework is intentionally similar to the self-assessment grid of the Common European Framework of Reference for Languages (CEFR) (Council of Europe, 2001): it is language-neutral, the vertical axis (A1 – A2 – B1 – B2 – C1 – C2) represents progress in proficiency from "basic user" to "independent user" (Council of Europe, 2018), and the horizontal axis includes five broad communication skills: listening, reading, spoken interaction, spoken production, and writing.

The GELS framework aims to prepare additional language learners and users for the Communications topics outlined in the CDIO syllabus and the demands of studying and working within the field of engineering in international and intercultural contexts. For a detailed description in English of the GELS framework's creation and compatibility with both the CEFR and the CDIO syllabus, see Rinder et al. (2016); for French see Sweeney-Geslin et al. (2016).

We updated the GELS framework in 2016 to highlight the importance of both audience awareness for writing tasks, and distance communication when speaking and listening. GELS network members are currently working on additional "layers" of skills specifically for e-communication and intercultural communication (see Objective 4).

Figure 3 presents a section of the GELS framework (for the full updated version, see The GELS network, 2019). As shown in the figure, the GELS framework is similar to the CEFR's descriptor scales to the extent that the tasks focus on outcomes rather than the vocabulary and grammar needed to achieve them (Council of Europe, 2018). However, the GELS framework is adapted to the needs of engineers, paying consideration to pertinent tasks such as correspondence, reading for detail, dealing with logical proofs, and problem-solving.

	A2	B1	B2
Reading simple → complex texts	I can read simple paragraphs and can infer meaning where necessary in more complex text. I can follow instructions given in simple everyday correspondence.	I can understand correspondence and recognize distinctive differences in a register. I can scan texts for information and learn from instructive texts on familiar engineering topics.	I can find the answers to specific questions in texts on familiar but complex topics. I can read journalistic texts on a range of subjects and follow potentially complex arguments and counterarguments.
Spoken interaction face-to-face & distant communication and networking	I can exchange more detailed personal and professional information and can cope in brief, routine situations with my peers. I can inform others about common difficulties.	I can use a range of simple language to deal with formal and informal situations and suggest solutions. I can interact in a conversation about my work and ask questions to develop the topic of conversation.	I can interact effectively on a range of topics within my engineering field and address specific problems. I can substantiate my opinions with evidence, negotiate with colleagues, and interact effectively to reach a consensus.

Figure 3. A section of the updated GELS framework (The GELS network, 2019).

Objective 3: Develop a catalog of teaching and learning activities

Once we established the GELS framework, we encouraged LC teachers to create teaching and learning activities and lesson plans inspired by it. This work was undertaken in various department meetings held at our partner universities and as part of GELS training or other professional development events. A selection of these activities is shown in Figure 4, and a full catalog will be shared on the BADGE project's Open Educational Resources (OER) platform.

A1	Spell out short field-specific terms, e.g. KTH, EDF, IoT, MP3, 75%, CO_2.
A2	Telephone to report a broken item of equipment and ask for assistance.
B1	Make a list of recommendations for e-communication for an engineering firm.
B2	Synthesize previous research on an engineering-related topic.
C1	Participate in a negotiation exercise as part of a conference call.
C2	Rewrite a research paper/ degree project/ thesis as a press release.

Figure 4. A sample of teaching and learning activities based on the GELS framework

Objective 4: Disseminate the work to LSP teachers working with engineers

In this section, we present a summary of our training events, our work on the intercultural communication needs of student engineers, our policy on English as a Medium of Instruction (EMI), and the Becoming A Digital Global Engineer project (BADGE).

Developing the GELS network

The GELS network now counts LC teachers from 30 technical universities and engineering departments among its members (for more detail, see The GELS network, 2019). We have developed the network through associations made at international conferences, where we have presented our work (e.g., CDIO 2016), and we have also organized a number of training events to attract new members (see Figure 5). The aim of our first training events was to present the findings from our surveys, share the initial draft of the GELS framework, and receive feedback from LC teachers. We consequently improved the framework and encouraged teachers to begin using it to plan progressive LC courses with engineers' communicative needs in mind. In more recent workshops (2017-2019), the focus of our work has gone beyond LSP as we seek funding for our future work. Some of our work is summarized in the following sections.

2015	University of Cambridge, UK	Two-day event
2016	Aalto University, Finland	One-day event
	Poznan University of Technology, Poland	Two-day event
2017	KTH Royal Institute of Technology, Sweden	One-week event
2018	Aristotle University of Thessaloniki, Greece	One-week event
2019	IMT Mines Albi-Carmaux, France	Three-day event

Figure 5. Summary of the GELS network's training events

Introducing intercultural communication competence (ICC)

The value of intercultural communication competence (ICC) for engineers in an ever more interconnected world has become increasingly apparent as the industry, research, accreditation bodies, and professional organizations have highlighted the lack of graduates' global competence (e.g., Atadero et al., 2018; European Society for Engineering Education, 2019). For us, intercultural communication competence comprises effective and appropriate communication with individuals of diverse backgrounds. ICC competence encompasses not only language and the appreciation of additional languages (Arasaratnam-Smith, 2016), but also behaviors and interactional strategies (Fantini, 2009). Taking a closer look at the professional realities of engineers in the 21st century, one can clearly see how the engineering world is full of diversity: work teams, organizations, customers, clients, and users come from intercultural backgrounds and have different norms and expectations of what constitutes "good" communication practices. Therefore, the perspective of engineers as isolated entities in their own world is passé, and if we teachers want our students to succeed, we have to prepare them for the new global realities encountered by today's engineers.

The Global Engineers Language Skills (GELS) network, as its name indicates, focuses on additional LC skills, and this is indeed what originally brought its members together. However, we recognize the need to include cultural dimensions in student engineers' training, and this has always been a feature of our discussions at GELS meetings and training events. The expertise brought in by new GELS members in recent years has led to a shift in our outlook, whereby the cultural dimension of LC training has gone well beyond that of national cultures to encompass the multilayered dimensions of culture.

One example of our discussions is about the concept of VUCA (Volatility, Uncertainty, Complexity, and Ambiguity), which we have found very useful to guide LC teachers wanting to better prepare their students for a professional environment. The VUCA world can be described as "the new de-globalizing world, the era of "post-globalization" (Shliakhovchuk, 2019, p.14), and in order to navigate a VUCA world, students need to be culturally intelligent so that they can communicate in a fast-moving, unpredictable, multilayered and unclear environment. All of the above obviously requires excellent LC skills, but these must develop alongside ICC and other soft skills if effective communication is to be achieved.

Teaching and learning through the medium of English (EMI)

The GELS network supports the teaching and learning of languages in technical universities and engineering departments. We have demonstrated how all LC teachers can successfully include LSP in their courses for student engineers and, similarly, we encourage students to make use of their full range of language competencies (including, e.g., home language and other languages learned in school) in academic and professional contexts. This does not mean, however, that we ignore the reality of English as a growing lingua franca in both industry and academia. Indeed, we are sensitive to the opportunities and challenges that have been created by the exponential rise in the use of EMI in non-English-dominant universities (Wächter & Maiworm, 2014) and the diversity of linguacultural backgrounds encountered at universities.

GELS network teachers have discussed these opportunities and challenges at training events, and three members (Nicola Cavaleri from the University of Cambridge; Anna Krukiewicz-Gacek from AGH University of Science and Technology, Krakow; Divya Madhavan from CentraleSupélec Paris) have produced guiding principles for effective EMI. The aim of these principles is to protect the value of cultural diversity in our classes and on our campuses through sustainable shifts in language policy, as the following examples demonstrate:

- An EMI curriculum should focus on equipping its participants with the confidence and skills required in a global world using English as a lingua franca

- An institution's EMI vision should be made transparent so that all key players ascribe to the same clear purpose, and participants understand its implications, benefits, and challenges

- A needs analysis should be conducted to ascertain the requirements of all key players before an EMI policy is implemented.

For the complete list of guiding principles, see The GELS network (2019).

The Becoming A Digital Global Engineer (BADGE) project

Under the coordination of IMT Mines d'Albi-Carmaux, France, 14 institutions from the GELS network (from Croatia, Finland, France, Germany, Greece, Italy, Lithuania, Poland, the Russian federation Spain, Sweden, and the United Kingdom) have successfully sought Erasmus+ KA2 funding to help develop the GELS network's work. BADGE is an extension of the GELS network's founding aims. Its members create pertinent, practice-oriented, and innovative ways for student engineers to learn the linguistic, intercultural, and communicative skills needed for their international studies and future careers. The multinational and multidisciplinary teams, including teachers and students, work on eight intellectual outputs (Ios) connecting different aspects relevant for engineering competence in our globalized, digitalized world (see Figure 7).

IO1	Communication course for future engineers
IO2	Sustainable writing skills
IO3	E-communication skills
IO4	Global competence and entrepreneurship
IO5	Architectural voices: student-produced podcasts and videocasts
IO6	Soft skills for engineering students
IO7	Global competence through IT and serious games
IO8	EMI for teachers

Figure 7. Intellectual outputs of the BADGE project

The progress of the individual intellectual outputs is continually assessed for relevance by experts from engineering faculty and industry and will be further developed into learning materials and lesson plans for LC teachers. These materials will be hosted on a multilingual Open Educational Resources (OER) platform that will also provide the opportunity for students to collect digital badges by completing individual courses. By collecting five badges, students will be able to earn a certificate attesting their LSP, ICC, and digital skills, which can be included in their Europass Diploma Supplement, thus making their skills clearly visible for potential employers.

CONCLUSION

The GELS network started as three teachers with two broad aims: 1) to find out how engineers communicate, and 2) to ensure that these findings actively support the teaching and learning of additional languages in technical universities and engineering departments. Since our presentation at the 2016 CDIO conference, GELS has grown into a network of LC teachers from thirty universities. Our shared enthusiasm for and expertise in e.g., Languages for Specific Purposes, Intercultural Communication, English as a Medium of Instruction, and Project Management have ensured that we continue to fulfill and further develop our original aims of ensuring sound LC training for student engineers. However, the world is changing rapidly, and we will have to combine our strengths to find new avenues to address current and future developments affecting engineers. With the GELS network's original vision expanding into new directions, we aim to continue to provide relevant LC materials capturing the complex realities of the engineering profession of the 21st century.

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TRACKS FOR CHANGE, FLEXIBILITY, INTERDISCIPLINARITY AND CREATIVITY IN ENGINEERING EDUCATION

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ABSTRACT

This paper describes the early stages of the developments of Tracks, an initiative to create, implement and evaluate a new educational model where the structure of the education is developed to give students the opportunity to create multi- and interdisciplinary competencies, meet their expectations and need for a more individualized study plan and shorten the lead times for changing the education to embrace new technologies. The new education model is based on the creation of tracks with different themes lying between existing programs not belonging to a specific department or school. The idea is to create individual and flexible study opportunities by introducing Track-courses within the themes. These courses address specific challenges that may be broad societal and profound research-driven. Tracks also include large investments in Chalmers' learning environment. The paper focuses on Tracks as a large change initiative, strategies to manage the complexity of this change as well as development philosophy and working methods in the early phases of the initiative. Change at universities has been discussed previously, but this is a unique opportunity to study how large change may be managed over time, including both the content of the education and the learning environments. Through action research, where interventions may be done to influence the initiative, it is possible to develop practical contributions for other universities in need of similar development. The research has been conducted over approximately a year and includes data from interviews and action research, where the authors are the main people working with this initiative. The close contact with the data gives a unique understanding of how different activities within the initiative influence the outcome. Thus, this paper will contribute to the understanding of how large institutional change initiatives are facilitated by a flexible and agile approach contrasting the traditional and somewhat slower university culture.

KEYWORDS

Educational change, multidisciplinary, agile, flexibility, educational management, Standards 1, 5, 7, 8

BACKGROUND

In 2017, Chalmers University of Technology (hereafter Chalmers) decided, in discussion with its owner foundation, to invest in three large flagship initiatives to make sure that the university would be at the forefront of education, research, and utilization in ten years. As a university, Chalmers has a strong reputation but realized that although a long history and successful work

within these three main areas, it is also important to dare to develop into the future requirements of both research, education, and utilization. An open call for all employees at the university encouraged people to suggest large programs that would develop Chalmers accordingly. From the over 60 suggestions that were submitted, a process to sort out three main candidates was initiated in 2018. This process included several workshops, meetings, discussion etc. with relevant stakeholders within each focus area. Finally, the boards of the university and the foundation made the decision to implement the initiatives Tracks, Chair (Chalmers AI Research Center), and Genie (Gender initiative for excellence).

An important part of the anchoring of the ideas was to make a trend analysis and connect the suggestions both to the current issues in society but also to try to understand where the university needs to be in the future. For the educational development, it was concluded that there are new and different requirements on the students graduating. Additionally, there are new demands and expectations from the young people starting their educations at the university. The lead times at the university are long compared to technology development. Moreover, to solve current issues, there is a significant need for a multidisciplinary understanding and competence to collaborate around solutions for complex issues, see, *e.g.*, Kamp (2019) and references therein. The proposal for developing the education was finally a combination of two different ideas that had been submitted on developing the education and the learning environments at Chalmers.

Although Tracks also includes a significant investment in learning environments, this paper focuses on the educational part of Tracks. The aim of the paper is to contribute with perspectives of how, with which strategies, a large educational change initiative may be managed over time.

TRACKS INITIATIVE

The idea behind Tracks is to work with a new educational model, including opportunities for students to develop multi- and interdisciplinary competencies, possibilities for the students to create more individualized study plans, and to decrease the lead time for changing the education. Such a model should also be implemented, evaluated, and adjusted within the initiative. This initiative is created as a complement to the existing education, which means that it is an opportunity for both teachers and students to work differently and include other aspects than possible in the current rather strict educational program based format. The organizational residency for the students is still the educational program they are admitted to, and they still get their ordinary degrees. Students take Tracks courses as parts of their electives or as extra-curricular activities.

The main idea is to create tracks between existing programs, see Figure 1, to make sure that they do not belong to any specific department or school at the university. This is to avoid disciplinary barriers and to ensure that the Tracks initiative is open to all students and teachers regardless of organizational affiliation. Each track has a theme, and theses themes change regularly to make sure that the content of Tracks is connected to current societal issues and contemporary research. Moreover, within each track, there are several courses within each specific theme. It gives students an opportunity to either take one Tracks course with a specific project or follow more courses within one of the tracks to get a specialization within that theme and to gain skills for solving real societal challenges (Alpay & Jones 2012) The Tracks courses are also changed regularly and updated to meet the fast changes of the world of today (Mazzucato 2018).

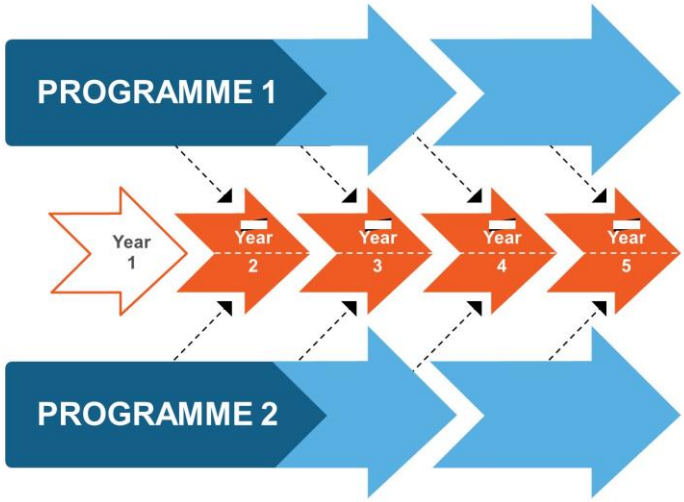

Figure 1. Students with different educational backgrounds study together in tracks laying between existing educational programs.

Tracks Courses

National and local regulations state that the educational offering (programs and courses) must have established and approved program and course plans at least six months before the start of the academic year. In order to comply with this, "umbrella courses" with general course plans, aims and learning outcomes are created in the study administrative systems. The courses' general learning outcomes deal with abilities to identify and master problems with open solutions spaces, handle uncertainties and limited information, lead and participate in the development of new products and systems, work in multi- and interdisciplinary teams, communication, and ethical aspects etc. Tracks courses' specific content and learning outcomes are defined in connection with course start. Thus, umbrella courses allow for flexibility and are used to develop and teach Tracks courses without having to create a whole new course in the course administrative system.

The basic educational idea of Tracks is to offer project-centered learning supplemented with short courses (modules), on-line learning, self-study and mentoring to obtain necessary technology and scientific knowledge and skills, *cf.* the New Engineering Education Transformation (NEET) at MIT (Crawley, Hosoi and Mitra 2018). In addition, the courses are supplemented with teaching and training of professional skills covering project management, work in multi- and interdisciplinary teams, ethics, and equal opportunities. Tracks courses include the entire process, from needs and ideas to a model or prototype in an implementable condition that can be evaluated. Such a model or prototype may consist of a service, an algorithm, or a product that can be physical or digital. The courses are, thus, platforms for a training development methodology, developing professional engineering skills as well as to deepen science, math, and technology knowledge throughout the education (Alpay &Jones 2012).

Currently (academic year of 2019/20), there are three Tracks themes in a first pilot;

- Sustainable Transportation,
- Health & Sports Technology and
- Artificial Intelligence.

Examples of courses within these themes are; Structural battery composites: Realization and multifunctional performance, Optimize subsystems for electric vehicles, Design of sustainable infrastructure and urban transformation, Projects in Music engineering: Awareness of sound and AI Ethics through Fiction. These courses range from 10 weeks to one semester and correspond to 7.5 ECTS. The development costs are funded by Tracks while the ordinary course budget model covers the delivery, including assessment.

Teaching support

An important part of Tracks is to create support for teachers and faculty teaching diploma (certificate) courses on challenge-driven education, multidisciplinary team projects, and teaching in modern physical and digital learning environments for experiential learning.

Tracks is also an initiative to develop Chalmers' learning environment. In order to meet the needs of Tracks, a prominent and flexible learning environment is created with project spaces both physically and digitally. The environment will include computer resources for artificial intelligence, such as machine learning, workshops, and hybrid virtual-physical environments where students can build, test, and evaluate prototypes.

The goal of the second stage of Tracks is within three years to have five ongoing themes and about 60 courses during one academic year. This will include at least 500 students and around 200 active teachers as well as about five supportive professional skills modules and two faculty teaching diploma courses and major learning space of 1,500 square meters, including workshops, labs, project space, studios, and open creative spaces.

Management

The university management decided to have team leadership for Tracks consisting of an experienced educational leader and a skilled and well-thought-of project manager. The leadership was appointed in February 2019 and focused immediately on early incremental developments, implementations and refinements. Consequently, the first Tracks courses were launched in the summer and fall of 2019.

The initial strategy was to set up a flexible and agile structure to manage the response from different groups of stakeholders such as faculty, students, and management. In this structure, there are different levels of flexibility where the teachers are enabled the most freedom to create other opportunities than they are used to when developing their teaching. Initially, the focus has been on teachers who have engaged in activities organized as part of Tracks such as workshops to propose themes and, later, to develop courses within the themes. Teachers teamed-up and suggested courses that were reviewed with feedback and after minor revisions approved. The Tracks' management has put a lot of trust in the teachers. If the courses fit into the themes, attract students from many educational programs (disciplines), and address the professional learning outcomes, teachers have had great freedom to design and teach courses. At the same time, teachers received extensive help in managing the administration around the courses from advertising and informing students to registering and posting grades. The Tracks leadership has a continuous dialogue with teachers and administrators to develop the framework around the courses. This includes the development of courses, managing them in

the Chalmers study administration system and support with the regulations. In short, the strategy has been to manage Tracks in a similar way as the students are trained within the Tracks courses, *i.e.,* agile, with openness and flexible in time and place.

The response from the ambassadors is important feedback for the development of the initiative. However, to make sure the change process is not only driven by such feedback, but a thorough evaluation and reflection process is also developed. Moreover, when the Tracks pilot courses had started, and the scope increased, it was realized that management needed to be strengthened. A management team was then established consisting of the two leaders, a blended learning expert, a secretary of studies, a professional skills teacher, and a faculty training specialist developing the teacher pedagogical diploma courses.

External stakeholders are involved in development to provide advice, provide input, and verify that development is in line with plans. Furthermore, external stakeholders are important to ensure that the courses are relevant to the industry and that students are given opportunities to develop skills that are in demand. The major body for external stakeholder involvement is the advisory board, which consists of expertise in engineering education from academia and industry. External stakeholders are also directly involved in the courses, *e.g.,* as clients or external mentors.

PREVIOUS RESEARCH

Discussions related to the content and development of universities may include several different aspects. This paper, more specifically, studies how a large change initiative with the aim of keeping the university at the forefront of education is managed. The initiative includes both the content of the education and learning environments. Thus, management has to consider several stakeholders and their views on the change process. Moreover, studying change at universities could include several interesting aspects. Previously, It has been noted that universities are traditional organizations (Snow Andrade 2018). Despite changes in society, universities have managed to keep a traditional profile for a long time. Such a profile has also been used as an advantage to build on history and traditions. An additional aspect relates to research-intense universities where there are often tensions between teaching and research (Alpay & Jones 2012).

However, there are also discussions around the need for change and updates to the traditional way of running higher education (Graham 2018). Such updates can include several things from pedagogy to the actual content of the education. In 2011 the concept of Industry 4.0 was coined in Germany, and soon after, Universities 4.0 was developed as the necessary complement from the educational sphere. Universities 4.0 is about meeting the need for specific skills from Industry 4.0. Moreover, it is about rethinking the traditional way of teaching and expanding the opportunities for life-long learning, as discussed by (Hallenga-Brink & Sjoer 2017). Cheah and Leong (2018) further discuss that the things included in the education today, such as project work, will be both complex and multidisciplinary to a new extent in the future.

The problem is not only the fact that it has become necessary to develop universities, but the issue is also how it may be done in the best way strategically. It is not only the university organizations that are traditional, it may also influence the way of thinking within the university. The faculty delivering the education needs to be convinced that the change is necessary and see why it is important. The motivation may be different for different faculty members (Hallenga-Brink & Kok 2016), which makes it even more important to facilitate the process of

understanding the opportunities created by the change. That could be difficult to accept if such change is not aligned with the faculty's viewpoints, regular activities, or expectations (Rouvrais & Landrac 2012). Typical issues previously discussed are the inbuilt resistance to change and how to manage such resistance in an optimized way.

Other sources of resistance that may apply to higher education are, for example, "unwillingness to change habits, structural inertia such as embedded policies and procedures and group norms that influence individuals" (Snow Andrade 2018). Depending on the type and extent of change, it may be suitable with a bottom-up approach, a top-down approach, or a mix of these. It becomes a challenging management issue with conflicting and restraining forces. And one strategy to avoid that is to include industry partners and students to act as change agents (Rouvrais & Landrac 2012).

There are successful examples of changes in the education where universities have started with either a course or a program to be able to step by step adjust the education (Rouvrais & Landrac 2012). Recent developments show that both engineering and management practices will need a more agile approach to how decisions are made and projects managed in the future (Audunsson, Fridgeirsson & Saemundsdottir 2018). Consequently, both industry and universities need to adjust. Examples from Industry and Education 4.0 include, for example, peer-to-peer learning, active learning, flexibility in both time and place learning, project-based learning, actual experience learning, and responds to the needs of Industry 4.0 (Truong & Le 2018).

METHOD

Action research has become a method that may include a relatively broad number of approaches. As described by Coghlan and Brannick (2019), there are some characteristics that are especially interesting for conducting action research within your own organization. The cornerstones of action research are to do "research in action instead of about action; a collaborative partnership; concurrent with action; and a sequence of events and an approach to problem-solving" (Coghlan & Brannick 2019 p. 3). Conducting action research also follows four phases, including planning, taking action, evaluating the action, and finally, further planning based on the previous phases.

Furthermore, it is important to work in collaboration with the studied participants in contrast to keeping the studied participants as objects. This creates a partnership around the research that is continuously influenced along with the studied action. The third cornerstone is that the research should be "concurrent with action," meaning that the purpose is to make the action more effective at the same time as scientific knowledge is created. Finally, the method of action research gives an opportunity to work with the four phases mentioned above and, at the same time, solve practical problems occurring during the work. In collaboration with the members of the action research and the organization, it is possible to find information and experiment to learn and solve issues within the process. Such issues may be both intended and unintended, depending on the situation. However, all the collected data is contributing to building up scientific knowledge and theory around the learning outcomes.

This paper is a study of the first pilot round of the Tracks educational part. The planning phase for the first year of the Tracks initiative has been rather short and effective. The guiding star has been the purpose of creating more flexible interdisciplinary courses open for all students at Chalmers. Because of the traditional structure of the university, the degrees of freedom are

still limited also for this initiative, and creating new courses had to follow the ordinary organization and structure. This meant that to be able to create new courses for a first pilot-round, it was necessary to do this last-minute only weeks after the whole initiative started. This unintended quick start immediately led into action for the educational part of Tracks.

The phases of planning and action have then been run in parallel with somewhat overweight on the action because of the nature of the setup for the Tracks courses. To enable more flexibility, these courses can start at any time of the year with the result that there are courses in all phases, from planning to evaluation and further planning. Consequently, all these phases have been active in parallel. For every course that finished, it has been possible to evaluate, discuss with involved teachers, and reflect on the outcome. The input from stakeholders such as faculty, students, and management have been included in other ongoing courses and in the planning of new once.

However, although reflection and evaluation have been done continuously, there has also been more thorough work on an evaluation plan, including all stakeholders of the courses. This work includes ordinary course evaluations with specific questions regarding the Tracks model, including experiences from the interdisciplinary work and forms for teachers. Moreover, the Ph.D. student will conduct structured interviews with students and teachers to collect qualitative data. It has been important to not only adjust the planning based on stakeholder feedback, and the results from the evaluation plan have been discussed in the management of Tracks. The study year, and therefore also the first pilot of Tracks, ends by the summer of 2020, and the focused evaluation will primarily be conducted at the end of the spring semester of 2020. Based on the results from the evaluation, a more intense phase of further planning will be conducted between the two first pilot rounds of Tracks.

This paper reports on data collected over approximately a year with all phases of action research represented to some extent. Data includes evaluation questionnaires and interviews, but primarily information from the managers of the Tracks initiative. With such close contact with the data, there has been a unique opportunity to follow how different actions have influenced the outcome.

There are some limitations of this paper. Firstly, it is possible that the teachers and students engaging in the first pilot round of Tracks are so-called early adopters. With an open and flexible approach to the early suggestions, there may be a bias towards a group of teachers and students who appreciate flexibility. Consequently, the results from the following study years may be different because the people engaged and involved have different perspectives and understandings of flexibility and an organization that differs from the ordinary structures at the university. Secondly, the authors of the paper are close to the data and the initiative. There are advantages but could also be a bias in the reflections on the results

FINDINGS AND DISCUSSION

From the first pilot round of Tracks, there are three main findings. These findings are described and discussed below.

Firstly, although it is early to make any final conclusions, initial experiences are very encouraging. An agile and flexible management structure is found to be appropriate for the aim of the initiative. Considering the size of the initiative and the expected impact, important progress has been made over a short time period. This includes a thorough process where

new courses and new educational content have been created within existing governmental and local university degree ordinances.

It is possible that the fact that Chalmers is well-functioning with established quality assurance systems and routines for educational management and developments actually facilitate change similar to what Graham (2018) noted for “current leaders” in engineering education. Thus, it has been possible to create the necessary flexibility for Tracks within the existing framework. Furthermore, Chalmers has a history of educational developments including development and implementation of CDIO, educational for sustainable development and entrepreneurial learning, ethics and constructive alignment (Malmqvist, J. et al. 2010, Enelund, Knutson Wedel, Lundqvist, & Malmqvist 2013, Kohn Rådberg, Lundqvist, Malmqvist, & Svensson 2018). Because faculty and administration have been through such initiatives previously, there exists a sense of understanding for this type of change. On the other hand, several large educational initiatives may create resistance and resignation.

Secondly, teachers have been very active in proposing, developing, and running courses. They have appreciated the opportunity to do something new. Moreover, they have been able to realize ideas about teaching students in solving the major challenges and working with the students on research-related challenges. Students are equally enthusiastic. About 100 students follow the courses in this first pilot round. Students are satisfied, and Tracks is mentioned positively in the student body. Moreover, Chalmers’ industry partners are positive and already participate in several courses.

Tracks have mostly attracted teachers who have taught team projects and/or teachers that are previously known for their openness to educational reforms. For continuous development, it will be important to build on role models and successful examples. One important part of Tracks is to create support for teachers who will be involved in Tracks courses. The idea is that this support includes faculty teaching diploma courses, which will be part of the teachers’ pedagogical portfolios and, thus, merits in their careers. Moreover, the support aims to enable Tracks to reach a wider group of teachers.

Thirdly, there has also been some resistance within the organization. The experienced resistance has been related to administrative procedures. Still, it has been possible to find flexible solutions around necessary adjustments in the administrative systems. Such solutions have meant that support staff cannot follow ordinary procedures and templates. Initially, these solutions have, therefore, resulted in additional work. This has created concerns in the organization and unwillingness to change habits.

Educational development is often a slow process with many bureaucratic obstacles ranging from government and university regulations to academic traditions and disciplinary protectionism. The success lies in having a management structure that allows for innovation, change, and flexibility. Moreover, the structure needs to be able to sustain an enduring long-term process as well as be able to continuously improve and set new goals.

The educational organization and content need to be structured and on a well-known format to make sure that all stakeholders have relevant information and a common understanding of what the expected outcomes of the educations are. Consequently, the study administrative systems have developed over time to become stable and to have resistance to sudden changes. This has created an inflexible culture of how things should be done within the system. At the same time, there are increasing requirements from the industry and presumptive students for the educations to become more flexible and able to embrace new challenges and

solutions. Our findings have shown that it is possible to introduce this type of flexibility within the existing frameworks. However, the traditional administrative role has developed a competence for managing a stable study administrative system. Therefore, it will be necessary to also develop the management and the administrative roles to adapt a similar agile approach. If we aim to deliver an education that better prepares the students for addressing the current and future challenges, there is a need for the whole university to adapt similar skills and competences as provided through the education.

With this said, the findings also show that the development of Tracks has been dependent on certain individuals with an open mind and interest in change. This has been appropriate for the start-up phase when early success stories are important. However, in the longer perspective, the challenge will be to formalize the flexible perspectives asked for and, at the same time, keep the continuous development philosophy. As Snow Andrade (2018) discusses, there are several characteristics for keeping up successful transformation processes at educational institutions. Some of them have been applied in the early phases of Tracks, such as the long-term perspective of the initiative with leaders who adjust and work agile with input from the stakeholders. Giving the teachers freedom in their course development has been a deliberate way of establishing trust, which is also mentioned by Snow Aldrade (2018). For this initiative, it has been fruitful with a mix of a bottom-up and top-down approach. Top-down for establishing the importance of development and change and freedom in the bottom-up approach to engage the faculty. Reflecting on the method, it will be important with a continuous balance between these approaches to push and pull the organization forward in the development process.

CONCLUSIONS

Studying the Tracks initiative at Chalmers has shown how large institutional change initiatives are facilitated by a flexible and agile approach contrasting the traditional and somewhat rigid university culture. It will be continuously important to balance the new ideas with the known and established to reach the goals of the Tracks initiative.

Reflecting on the Tracks initiative in the light of the CDIO standards (CDIO Standards 2.1) focused on in this paper (1, 5, 7, 8) shows that through Tracks the students are trained in a multi- and interdisciplinary context which is also a real-world context (Alpay & Jones 2012). Such context improves the conditions for working with CDIO and developing an entrepreneurial mindset. Tracks is then an arena for their work with complex issues related to research, industry, and society. Simultaneously, the students' active work closely together with the faculty creates an understanding of engineering practice and learning, where the students recognize how and why they learn for the future. For the faculty, it also creates an opportunity for faculty competence development while working cross departments and in multidisciplinary teams that would not have had the opportunity to meet elsewhere.

Tracks give a unique opportunity to study and understand an example of implementing a CDIO-inspired curriculum at a university on a large scale. In this case, it was done by creating the same possibilities for all students at the same time to apply for these courses. It works as inspiration and opens up for change in general. During the duration of this initiative, it will be possible to develop and understand what are the most suitable improvements to make in education at large. All parts of Tracks will not be implemented broadly, but the most suitable developments are possible to integrate into the ordinary education offer. Instead of taking small steps, Tracks facilitates for the university to take larger steps in developing the educational

offer. In ten years' time, it is possible to be at the forefront of education without losing history, quality, and previous experiences in such a process.

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OPTIONAL CDIO STANDARDS: SUSTAINABLE DEVELOPMENT, SIMULATION-BASED MATHEMATICS, ENGINEERING ENTREPRENEURSHIP, INTERNATIONALISATION & MOBILITY

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ABSTRACT

An effort to update the CDIO Standards from version 2.1 to 3.0 was started in 2017 (Malmqvist et al., 2017) and further outlined in 2019 (Malmqvist et at., 2019). The aims were to incorporate external changes to the context of engineering education, to address criticism that had been raised against earlier versions of the standards, and to establish an extendable CDIO framework architecture. The work has resulted in that the original twelve CDIO standards, from now on named “core” CDIO standards, will be complemented by “optional” CDIO standards, that codify additional educational best practices that have been developed within the CDIO community in the same format as the original CDIO standards. Eleven optional standards have been proposed (Malmqvist et al., 2019). This paper accounts for the elaboration of the subset of the proposed optional standards that were recommended for further development by the CDIO Council in November 2019. These recommended optional standards are presented as full texts, i.e., including descriptions, rationale and rubrics. The described optional standards are: *Sustainable development*, *Simulation-based mathematics*, *Engineering entrepreneurship* and *Internationalization & mobility*.

KEYWORDS

Sustainable development, Simulation-based mathematics, Engineering entrepreneurship, Internationalization, Standards 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

INTRODUCTION

The CDIO standards were initially introduced in 2005 (Brodeur & Crawley, 2005) and presented more extensively by Crawley *et al*. (2007). The Standards constitute a set of principles or best practices underlying the implementation of the CDIO syllabus in an engineering program. The standards define the distinguishing features of a CDIO program, serve as guidelines for educational reform, enable benchmarking with other CDIO programs and provide a tool for self-evaluation-based continuous improvement.

Since 2007, the standards have been updated twice: CDIO standards 2.0 were adopted in 2014 (Crawley *et al.*, 2014) and the rubrics have been further modified (Bennedsen *et al*., 2016), resulting in CDIO standards 2.1. These modifications have been relatively minor and have not changed the scope or the main contents of the standards.

Nevertheless, Malmqvist *et al*. (2017) pointed out that as engineering education best practice and the context of engineering are continuously evolving, also the CDIO approach must be evolved. They further argued that the CDIO framework could become more flexible and open by introducing an additional category of standards, named “optional CDIO standards”, which would be added to the original twelve standards, now called “core CDIO standards”. Since then, several proposals for optional CDIO standards have been put forward (Malmqvist *et al*., 2019), and the CDIO Council has decided on a process for screening the proposals and working with them for possible inclusion in the CDIO framework.

In parallel with this work, the core CDIO standards are also being updated (see Malmqvist *et al*., 2020). One difference is that modifications to the core standards are undertaken with some caution, since they should be adopted in consensus and all CDIO programs are expected to aim for their fulfilment. In contrast, the optional standards are freely pursued by those CDIO members that find them relevant for their context and conditions, and appropriately reflecting their ambitions to lead the way.

In the remainder of this paper, we first account for the criteria that a CDIO optional standard should fulfil and the process for their proposal, review and acceptance-decision. Descriptions of a first set of optional standards are then provided. A discussion section suggests future work with some other proposals.

OPTIONAL CDIO STANDARDS FRAMEWORK

The optional CDIO standards framework consists of two elements: The first is a set of criteria that optional standards should fulfil, while the second is a process for proposing, reviewing and possibly adopting an optional standard.

Criteria

The criteria that a potential optional CDIO standard should fulfil were proposed by Malmqvist *et al*. (2017). A slightly revised version of their list follows:

- Address an important, typically emerging, need in engineering education.
- Be based on a novel, yet well codified, pedagogical approach, developed within or outside of the CDIO community.
- Be widely applicable, i.e. not be specific to a single discipline (e.g., civil engineering).

- Not be sufficiently addressed by interpretation of a core standard.
- Reflect a program-level approach, and not be obtainable by implementation in a single course.
- Reflect ongoing development in several CDIO programs.
- Provide inspiration and guidance for CDIO programs and institutions in taking the lead in the areas addressed by the optional standard.
- Support the definition of a distinct program profile, beyond basic CDIO implementation.
- Be assessable by the CDIO standards rubrics.

Process for Proposal, Review and Acceptance

Malmqvist *et al*. (2019) outlined a process to facilitate an open, transparent and controlled way for proposing, reviewing and deciding on the acceptance of optional CDIO standards. The process has four main steps. The first is that a proposal for an optional CDIO standard is codified in a paper that is presented at a CDIO conference and thus archived in the CDIO Knowledge Library. Any member of the CDIO community may submit such a paper. In conjunction with the conference, the proposal will be reviewed by the CDIO Council. The outcome of that discussion may be actions for further review and development to prepare the new optional CDIO standard, or the proposal can be rejected. The following year, the CDIO Council will analyze the review recommendations and possibly modifications made in response to them and decide on the acceptance of the proposal. Figure 1 is a graphical representation of the process.

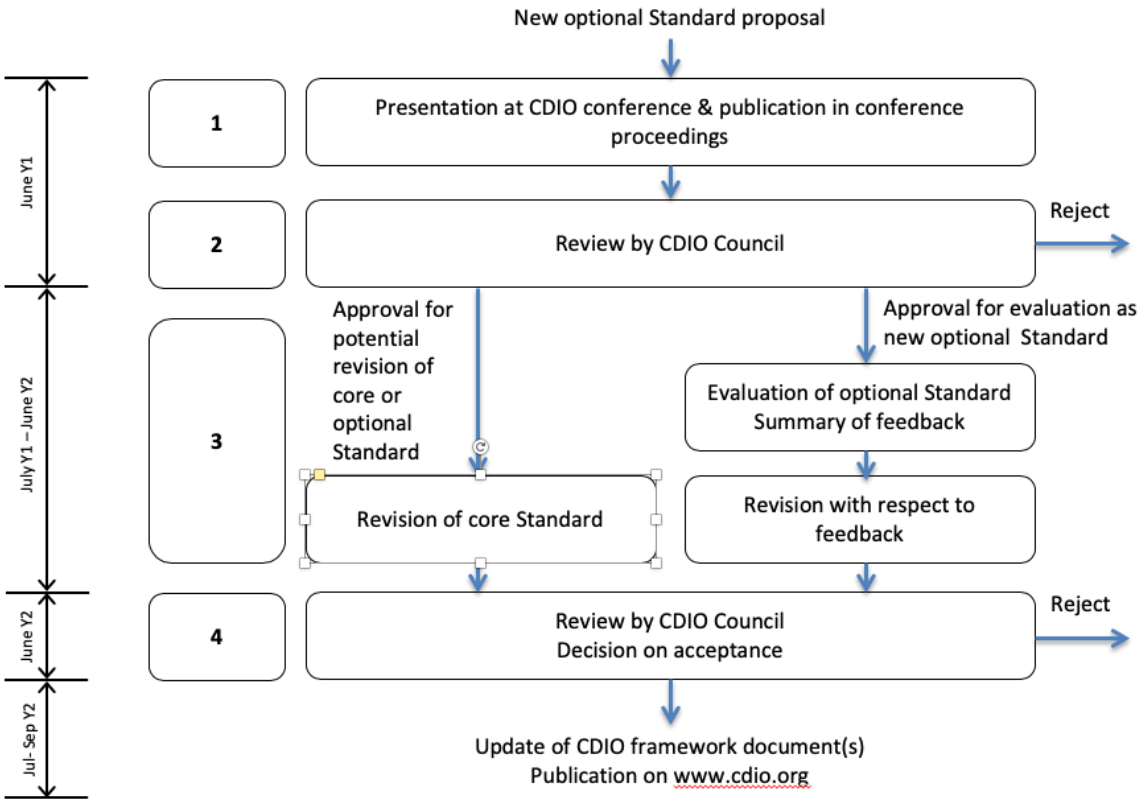

Figure 1. Optional Standards evaluation and approval process.

PROPOSALS FOR OPTIONAL STANDARDS

Malmqvist *et al*. (2019) summarized the propositions for optional Standards, 11 in total (Table 1). Three categories of proposals were identified: proposals linked to major societal trends, proposals linked to practices for outreach and collaboration, and finally proposals that suggest expansions of the scope of the standards.

During the Fall of 2019, the proposed optional standards were distributed for review in the CDIO community. The feedback was discussed during the 2019 CDIO International Working meeting in Singapore. With consideration of the feedback, the CDIO Council chose four proposals for optional standards to be further refined and complemented (for example with dedicated rubrics), and to be put forward for a possible formal adoption by the CDIO Council at the 2020 International CDIO Conference. This preparation is the scope of this paper. The four proposals are *Sustainable development*, *Simulation-based mathematics*, *Engineering entrepreneurship* and *Internalization & mobility*, as listed in the following section.

Also, the CDIO Council recommended a deeper analysis of the proposals *Industry engagement*, *Workplace learning* and *Workplace and community integration*, considering several alternatives: Integration into the texts of the core standards, merging or separate elaboration. This is essential future work, however outside of the scope of the current paper.

Table 1: Proposed optional standards (Malmqvist *et al*., 2019).

Title		Short description	Sources
Strategic trends	Sustainable development	A program that identifies the ability to contribute to sustainable development as a key competence of its graduates. The program is rich with sustainability learning experiences, developing the knowledge, skills and attitudes required to address sustainability challenges.	Malmqvist *et al*., 2017; Enelund *et al.* 2013
	Digital learning	Engineering programs that support and enhance the quality of student learning, and teaching, through digital learning tools and environments.	Malmqvist *et al*., 2017
	Simulation-based mathematics	Engineering programs for which the mathematics curriculum is infused with programming, numerical modelling and simulation from the start.	Malmqvist *et al*., 2017; *Enelund et al., 2011*
	Engineering entrepreneurs hip	Engineering programs that actively develop their graduate's abilities too, in addition, to conceive, design, implement and operate complex products, systems and processes, to commercialize technology and to create business ventures based on new technology.	Malmqvist *et al*., 2017; *Mäkimurto-Koivumaa & Belt, 2015*
Outreach & collaboration	International-ization & mobility	Programs and organizational commitment which exposes students to foreign cultures, and promotes and enables transportability of curriculum, portability of qualifications, joint awards, transparent recognition and international mobility.	Campbell & Beck, 2010

	Research-integrated education	Engineering programs that include one or more research experiences as part of student learning.	Malmqvist *et al*., 2017
	Industry engagement	Actions that education institutions undertake to actively engage industry partners to improve its curriculum.	Cheah & Leong, 2018
	Workplace learning	A curriculum that includes students working in a real-world work environment with the aims of strengthening in-campus learning and developing their professional identity.	Cheah & Leong, 2018
	Workplace and community integration	Engineering programs that actively develop their graduates' abilities to identify and address authentic and open-ended problems, in authentic settings, interacting with stakeholders.	Malmqvist *et al*., 2017
Expanding scope/coverage	Student success	A curriculum supported in the analysis and synthesis of information allowing taking effective actions to mitigate the risk and vulnerability in the student population; with strategies focused on the prevention of drop out and that guarantee student success.	Gonzales *et al*., 2018
	Foresight – Forecast – CD(IO)	Revision of all CDIO Standards to fit frame of master and PhD programs. This implies elaborating on product (etc.) lifecycle stages before Conceiving, referred to as Foresighting and Forecasting.	Chuchalin, 2018

THE FOUR FIRST CDIO OPTIONAL STANDARDS

This section lists the full definitions of the first optional CDIO standards, including descriptions, rationale and rubrics.

Sustainable development

A program that identifies the ability to contribute to a sustainable development as a key competence of its graduates. The program is rich with sustainability learning experiences, developing the knowledge, skills and attitudes required to address sustainability challenges.

Description

The program emphasizes environmental, social and economic sustainability in the adoption of the CDIO principles as the context for engineering education (Standard 1). Sustainability related knowledge, skills and attitudes, are explicitly addressed in program goals and learning outcomes (Standard 2). Aspects of sustainable development are integrated into several mutually supporting disciplinary courses and projects, possibly in combination with specific sustainability courses (Standard 3). Concepts of sustainability, potentials and limitations of science and technology and related roles and responsibilities of engineers, are established at an early stage of the education (Standard 4). Design-implement experiences provide students with opportunities to apply and contextualize sustainability knowledge, skills and attitudes, both in the development of new technology and in the reuse, redesign, recycling, retirement, etc., of existing technology (Standard 5). Physical and digital learning environments enable

interdisciplinary and transdisciplinary collaborative learning and interaction with various external stakeholders (Standard 6). Sustainability learning experiences are integrated with the learning of disciplinary knowledge, personal and interpersonal skills, and product, process, system and service building skills (Standard 7). Active experiential and transformative learning activities develop students' key competences for sustainability (Standard 8). Enhancement of faculty competencies for sustainability and related teaching competences is actively promoted (Standard 9 & 10). Approaches appropriate for assessing sustainability-related learning outcomes are implemented (Standard 11). The integration of sustainable development is evaluated by students, faculty, industry and societal stakeholders, and about relevant UN and other frameworks (Standard 12).

Rationale

To address the issues of sustainability is a key challenge for humanity. Engineers need to understand the implications of technology on social, economic and environmental sustainability factors, in order to develop appropriate technical solutions in collaboration with other actors in addressing societal issues.

Rubric for Self-Assessment

5	Sustainable development is fully integrated in accordance with the description in the optional CDIO standard for sustainable development.
4	The integration of sustainable development is pervasive, well adapted to the program context, promoting progression of knowledge, skills, and attitudes, and there is documented evidence that students have achieved the related intended learning outcomes.
3	There are explicit program goals and intended learning outcomes related to environmental, social, and economic sustainability and at least three substantial sustainable development learning experiences of increasing complexity including an introduction early in the program.
2	At least one substantial sustainable development learning experience is being implemented and there is a plan for extended integration of sustainable development.
1	Minor sustainable development learning experiences have been implemented and needs and opportunities for extended integration of sustainable development have been identified.
0	There are no sustainable development learning experiences in the program.

Simulation-based mathematics

Engineering programs for which the mathematics curriculum is infused with programming, numerical 53racticed and simulation from the start.

Description

The program emphasizes the importance of simulation-based mathematics in engineering education, research and practice. The program idea brings forward advanced simulation skills as distinctive skill of its graduates. Mathematical programming, 53racticed and simulation knowledge and skills are explicitly addressed in program and course goals and learning outcomes. Basic mathematics courses mix the learning of mathematical lemmas and methods

with direct practice of numerical program solving, aided by mathematical software. Mathematics courses teach programming of algorithms for equation solving. Common, mutually-supporting, simulation-based assignments connect mathematics and engineering science courses. Planned learning sequences for advancing mathematical 54racticed and simulation skills throughout the curriculum. Design-implement experiences are designed to, also, to develop hands-on prototyping skills, reinforce and enhance mathematical 54racticed and simulation concepts and competencies.

Rationale

The mathematics courses will include more authentic and complex problems. Realistic decision-making situations can be simulated. The connection to science and engineering courses can be reinforced. A better understanding of what advanced mathematics can be used for and how that is carried out strengthens student motivation.

Rubric for self-assessment

5	The course/module and program learning outcomes for mathematical programming, modelling and simulation are regularly evaluated and revised, based on feedback from students, instructors, and other stakeholders.
4	There is documented evidence that students have achieved the intended learning outcomes for mathematical programming, modelling and simulation.
3	Course and/or program learning outcomes for mathematical programming, modelling and simulation are validated with key program stakeholders, including faculty, students, alumni, and industry representatives and levels of proficiency are set for each outcome.
2	A plan to incorporate explicit statements of learning outcomes at course/module level as well as program outcomes for mathematical programming, modelling and simulation is accepted by program leaders, engineering faculty, and other stakeholders.
1	The need to create or modify learning outcomes at course/module level and program outcomes for mathematical programming, modelling and simulation are recognized and such a process has been initiated.
0	There are no explicit program learning outcomes at course/module level nor program outcomes that cover mathematical programming, modelling and simulation.

Engineering entrepreneurship

Engineering programs that actively prepare graduates for creating technology-based business ventures, to produce economic and other values for society.

Description

A curriculum that is permeated with entrepreneurial learning experiences, tailored to the relevant learning goals as defined in Standard 2. Entrepreneurial competence is developed *through* entrepreneurship learning activities (e.g. by students performing value creation projects in the community), by learning *about* entrepreneurship (e.g., marketing, intellectual property rights), by learning *in* entrepreneurial settings (e.g., student incubators or student-run companies) and learning *for* entrepreneurship (e.g. business model creation tools). The learning experiences are supported by appropriate learning environments, for example, various kinds of maker spaces, and by staff with entrepreneurial competence. Throughout the

curriculum, projects can be made increasingly authentic and realistic. They can allow students to make real-world connections and interacting with stakeholders. Some projects may involve co-creating solutions with clients or users. Valuable learning occurs not only through the hands-on activities, but also when the students *reflect* on their experiences, including their processes and methods, successes and setbacks. This is furthered by teacher-facilitated opportunities for reflection.

Rationale

The role of engineers has broadened from designing and implementing technical solutions to also forming business ventures based on technological innovations, thereby creating value for society. Startups are increasingly based on ideas developed by students during their studies, or on ideas and intellectual property owned by university researchers that students further develop and commercialize. The needed competencies include for example opportunity identification, business planning, intellectual property rights, company financing and marketing. Entrepreneurial learning activities can be designed to address not only students' abilities concerning venturing, but also, simultaneously, many learning outcomes that are broadly desired in all engineering programs, such as personal and interpersonal skills, and other engineering skills.

Rubric for Self-Assessment

5	The entrepreneurial learning experiences are regularly evaluated and revised, based on feedback from students, instructors, and other stakeholders.
4	There is documented evidence that students have achieved the intended learning outcomes of the entrepreneurial learning experiences.
3	At least two design-implement experiences of increasing complexity are being implemented.
2	There is a plan to develop entrepreneurial learning experiences at the basic and advanced level.
1	A needs analysis has been conducted to identify opportunities to include entrepreneurial experiences in the curriculum.
0	There are no entrepreneurial learning experiences in the engineering program.

Internationalization & mobility

Programs and organizational commitment which exposes students to foreign cultures, and promotes and enables transportability of curriculum, portability of qualifications, joint awards, transparent recognition and international mobility.

Description

The institution demonstrates a tangible organizational commitment to internationalization and student mobility. It enunciates the exposure, promotion, facilitation, opportunity and scholarship of an internationalized curriculum, qualifications and international mobility of students. Curricula which prepare engineers for a global environment and exposes them to a rich set of international experiences and contexts during their studies. Student learning outcomes include attributes and competencies which are recognized through international accords. Authentic cultural awareness learning experiences are embedded within the

curriculum or social activities. Opportunities are made available for students to learn second and third languages. Study abroad and other international experiences (including internships, exchanges) are encouraged and recognized, for credit. Institutional cross-credit for study abroad is transparent. The institution establishes partnerships with international universities, benchmarks programs internationally and is actively involved in international engineering education scholarly activities.

Rationale

Graduate engineers increasingly need to be international in their outlook and experience and be prepared to operate globally. Businesses progressively more compete and collaborate on a global scale and operate across national and international borders with organizational environments being increasingly complex, dynamic and with greater interdependencies. Our challenge, as educational institutions, is to aid our students to prepare for this global environment.

Rubric for Self-Assessment

5	Program Internationalization and student mobility outcomes are regularly evaluated and revised, based on feedback from students, instructors, and other stakeholders.
4	There is documented evidence that students have achieved the intended learning outcomes related to an internationalized Program.
3	The plan for internationalized learning outcomes and opportunities for meaningful student mobility embedded within the Program has been implemented.
2	A plan for internationalizing the Program and opportunities for student mobility to be embedded within the Program has been approved and a process to implement the plan has been initiated
1	The need for internationalization of the Program and opportunities for student mobility is recognized and a planning process initiated.
0	There is no aspect in the Program that provides a framework for students to develop internationalized practice or key skills, nor to engage in meaningful mobility opportunities within the curriculum.

CONCLUSIONS & FUTURE WORK

Provided that the proposed optional standards in this paper are accepted by the CDIO Council, the CDIO framework will be complemented by the concept of optional standards, and, specifically, with a first set of four adopted optional CDIO standards.

The concept of optional standards provides a pathway for the flexible extension of the CDIO framework. The associated process for review and decision secures that adopted CDIO standards are relevant, fulfil a published set of quality criteria and complementary concerning already existing CDIO standards.

The optional standards that the CDIO Council has selected as the first candidates for adoption address sustainability, simulation-based mathematics, entrepreneurship and internationalization. These additions can be argued to reflect changed perceptions of the role and context of engineers and engineering. Now and in the future, the engineering profession will need to broaden the focus from mainly taking responsibility for technical function and product performance to a responsibility for the social, economic and environmental

consequences of technology. Moreover, engineers are playing more substantive roles in social and commercial venture creation. Few engineers today work in a purely national context. International collaboration is essential all through the product lifecycle, including customer needs elicitation, product design, manufacture, use, recycling and retiring. Simulation-based mathematics is essential for exploiting the opportunities offered by digitalization and artificial intelligence. Thus, the implementation of these four standards in an engineering program will better prepare its graduates for the future.

The adoption of four optional standards should be seen as a first step. Multiple other optional standards proposals can be further developed, reviewed and possibly adopted by the CDIO Council. At the same time, it is also important to follow up the impact of the first four. In what CDIO programs have they been implemented, what are levels of fulfilment of the standard rubrics, what concrete effects can be observed? Also, what can count as evidence of the 57racticed57 of core and optional standards? As the CDIO community implements these optional Standards in CDIO programs, we urge them to document the work and share their experiences, in particular reflecting on the usefulness of the new standards for future refinement and development.

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CDIO STANDARDS 3.0 – UPDATES TO THE CORE CDIO STANDARDS

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ABSTRACT

An effort to update the CDIO Standards from version 2.1 to 3.0 was started in 2017 (Malmqvist et al., 2017) and further outlined in 2019 (Malmqvist et at., 2019). The aims were to incorporate external changes to the context of engineering education, to address the critique that had been raised against earlier versions of the standards, and to establish an extendable CDIO framework architecture. The work has resulted in that the original twelve CDIO standards, from now on named "core" CDIO standards, will be complemented by "optional" CDIO standards, that codify additional educational best practices that have been developed within the CDIO community in the same format as the original CDIO standards. This paper accounts for the changes made to the core CDIO standards. It includes the full definitions of the CDIO Standards 3.0, including descriptions, rationale and rubrics. The modifications are made to address mainly the following topics: *sustainability, digitalization, services and faculty competences*.

KEYWORDS

Sustainable development, Digitalization, Learning environments, Faculty competence, Standards 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

INTRODUCTION

The CDIO standards were initially introduced in 2005 (Brodeur & Crawley, 2005) and presented more extensively by Crawley *et al*. (2007). The Standards constitute a set of principles or best practices underlying the implementation of the CDIO syllabus in an engineering programme. The standards define the distinguishing features of a CDIO programme, serve as guidelines for educational reform, enable benchmarking with other CDIO programmes and provide a tool for self-evaluation-based continuous improvement.

Since 2007, the standards have been updated twice: CDIO standards 2.0 were adapted in 2014 (Crawley *et al.*, 2014) and the rubrics have been further modified (Bennedsen *et al.*, 2016), resulting in CDIO standards 2.1. These modifications have been relatively minor and have not changed the scope or the main contents of the standards.

Nevertheless, Malmqvist *et al*. (2017) pointed out that as engineering education best practice and the context of engineering are continuously evolving, also the CDIO standards must be updated. They further identified a need to address the critique that had been raised against earlier versions of the standards. Malmqvist et al. (2019) further developed the ideas from 2017 into a proposal for CDIO standards 3.0. In CDIO standards 3.0, the original twelve CDIO standards, are named "core" CDIO standards, and are to be complemented by "optional" CDIO standards that codify additional educational best practices that have been developed within the CDIO community in the same format as the original CDIO standards. The proposal has been discussed in workshops at the CDIO International Working meetings in 2018 and 2019. Feedback from the CDIO community was gathered in the Fall 2019.

This paper accounts for the changes made to the core CDIO standards, and includes the full texts, i.e., including descriptions, rationale and rubrics of the core CDIO standards 3.0. An accompanying paper presents the optional standards that were recommended by the CDIO Council for development into complete versions (Malmqvist *et al*., 2020).

CORE CDIO STANDARDS 3.0

The modifications consider the following topics (Malmqvist *et al*., 2019):

- **Sustainability:** Update due to changing world (and referencing adapted Syllabus). Affects many CDIO standards.
- **Digitalization:** Update due to the changing world. Affects mainly CDIO standard 6 and 8.
- **Services:** Explicitly mentioning services with products, processes and systems (because products – which we meant to include services – is often understood in a more limited sense as artifacts).
- **Faculty competences:** Widening standard 9 and 10 to address triple faculty competence: Engineering competence, Subject competence (pedagogical content knowledge, see Edström, 2017, pp 32-33), Teaching competence.

Malmqvist *et al*. (2019) further provides a full analysis of the topics and motivates the changes. Table 1 summarizes the updates to each of the standards.

Table 1. Updates to CDIO core standards in CDIO 3.0.

Std	Title	Changes
1	The Context	• Services are identified as objects for engineering development alongside with products, processed and systems *(Definition, Description, Rationale).* • Sustainability and sustainable development are mentioned *(Definition, Description, Rationale).* • Societal needs are added to customer needs *(Description).* • Recycling is included in the system lifecycle (*Description*).
2	Learning Outcomes	• Services are identified as objects for engineering development alongside with products, processes and systems *(Definition, Description, Rubric).* • Sustainable development is mentioned (*Description*).

3	Integrated Curriculum	• Services are identified as objects for engineering development alongside with products, processes and systems *(Definition, Description, Rationale, Rubric).* • Sustainable development is mentioned (*Description*, *Rationale*).
4	Introduction to Engineering	• Services are identified as objects for engineering development alongside with products, processed and systems *(Definition, Description, Rationale).* • The rationale for addressing sustainability in engineering is identified as an element in an introductory course *(Definition).*
5	Design-Implement Experiences	• Services are identified as objects for engineering development alongside with products, processed and systems *(Description, Rationale).* • The need to address sustainability and ethical aspects in development processes is pointed out *(Description, Rationale).*
6	Engineering Learning Workspaces	• Name modified to “Engineering Learning Workspaces” *(Name).* • The importance of configuring traditional physical learning spaces to support active learning experiences is stated (*Description*). • The role of digital technologies in the learning workspace is brought forward and two major text sections have been added (*Definition, Description, Rationale, Rubric*).
7	Integrated Learning Experiences*	• Services are identified as objects for engineering development alongside with products, processes and systems *(Definition, Rationale).* • Aspects of sustainable development are mentioned (*Description*, *Rationale*).
8	Active Learning	• Only linguistic modifications.
9	Enhancement of Faculty Competence*	• Faculty competence related to service development are included *(Definition, Description, Rationale).* • Faculty competence related to sustainable development is included *(Description, Rationale).* • Disciplinary knowledge and the related pedagogical content knowledge are listed as faculty competences, due to that maintaining up-to-date disciplinary knowledge may also be a concern *(Description, Rationale, Rubric).* • The concept of faculty enhancement is further elaborated to also include recruitment (*Description*, *Rubrics*).
10	Enhancement of Faculty Teaching Competence	• The concept of teaching competence and how to enhance it is further elaborated also including reference to Standards 5 and 12 (*Description*, *Rationale*, *Rubric*).
11	Learning Assessment*	• Services are identified as objects for engineering development alongside with products, processed and systems *(Definition, Rationale).* • Digital (online) assessment is mentioned alongside oral and written tests *(Description, Rationale).* • Sustainable development mentioned (Description).

12	Program Evaluation	• The need to evaluate fulfilment of optional standards, if the program has adapted any such standard, has been added *(Definition, Description).*

Standard 1: The Context*

Adoption of the principle that sustainable product, process, system, and service lifecycle development and deployment – Conceiving, Designing, Implementing and Operating – are the context for engineering education

Description

A CDIO program is based on the principle that product, process, system, and service lifecycle development and deployment are the context for engineering education. Conceiving–Designing–Implementing–Operating is a model of the entire product, process, system, and service lifecycle. The Conceive stage includes defining customer and societal needs; considering technology, enterprise strategy, and regulations; and, developing conceptual, technical, and business plans. The Design stage focuses on designing a solution to the addressed need, that is, the plans, drawings, and algorithms that describe what will be implemented. The Implement stage refers to the transformation of the design into the product, process, system, or service, including manufacturing, coding, testing and validation. The final stage, Operate, uses the implemented product, process, system or service to deliver the intended value, including maintaining, evolving, recycling and retiring. The consideration of environmental, social, and economic sustainability is an integral part throughout the lifecycle.

The product, process, system, and service lifecycle is considered the context for engineering education in that it is part of the cultural framework, or environment, in which technical knowledge and other skills are taught, 63racticed and learned. The principle is adopted by a program when there is an explicit agreement of faculty to transition to a CDIO program, and support from program leaders to maintain reform initiatives, visible for instance in a mission statement, or other documentation approved by appropriate responsible bodies.

Rationale

Beginning engineers should be able to Conceive–Design–Implement–Operate complex value-added sustainable products, processes, systems and services in modern team-based environments. They should be able to participate in engineering processes, contribute to the development of engineering solutions, and do so while working to professional standards in any organization. Engineers need to understand the implications of technology on social, economic and environmental sustainability factors, to develop appropriate technical solutions in collaboration with other actors. This is the essence of the engineering profession.

Rubric for Self-Assessment

5	Evaluation groups recognize that CDIO is the context of the engineering program and use this principle as a guide for continuous improvement.
4	There is documented evidence that the CDIO principle is the context of the engineering program and is fully implemented.
3	CDIO is implemented in one or more years of the program.

2	There is an explicit plan to transition to a CDIO context for the engineering program.
1	There is a willingness to adapt to a CDIO context for the engineering program.
0	There is no plan to adopt the principle that CDIO is the context of engineering education for the program.

Standard 2: Learning Outcomes*

Specific, detailed learning outcomes for personal and interpersonal skills, and product, process, system, and service building skills, as well as disciplinary knowledge, consistent with program goals and validated by program stakeholders

Description

The knowledge, skills, and attitudes intended as a result of engineering education, that is, the learning outcomes, are codified in the CDIO Syllabus. These learning outcomes detail what students should know and be able to do after their engineering programs. In addition to learning outcomes for technical disciplinary knowledge (Section 1), the CDIO Syllabus specifies learning outcomes as personal and interpersonal skills, and product, process, system, and service building skills, including concepts and competencies related to sustainable development. Personal learning outcomes (Section 2) focus on individual students' cognitive and affective development, for example, engineering reasoning and problem-solving, experimentation and knowledge discovery, system thinking, creative thinking, critical thinking, and professional ethics. Interpersonal learning outcomes (Section 3) focus on individual and group interactions, such as teamwork, leadership, communication, and communication in foreign languages. Product, process, system, and service building skills (Section 4) focus on conceiving, designing, implementing, and operating such solutions in enterprise, business, and societal contexts.

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. Programs are encouraged to customize the CDIO Syllabus to their respective programs. Also, stakeholders help to determine the expected level of proficiency, or standard of achievement, for each learning outcome.

Rationale

Setting specific learning outcomes helps to ensure that students acquire the appropriate foundation for their future. Professional engineering organizations and industry representatives identified key attributes of beginning engineers both in technical and professional areas. Moreover, many evaluation and accreditation bodies expect engineering programs to identify program outcomes in terms of their graduates' knowledge, skills, and attitudes.

Rubric for Self-Assessment

5	Internal and external groups regularly review and revise program learning outcomes and/or program goals based on changes in stakeholder needs.
4	Program learning outcomes are aligned with institutional vision and mission, and levels of proficiency are set for each outcome.

3	Course and/or program learning outcomes are validated with key program stakeholders, including faculty, students, alumni, and industry representatives and levels of proficiency are set for each outcome.
2	A plan to incorporate explicit statements of learning outcomes at course/module level as well as program outcomes is accepted by program leaders, engineering faculty, and other stakeholders.
1	The need to create or modify learning outcomes at course/module level and program outcomes are recognized and such a process has been initiated.
0	There are no explicit program learning outcomes at course/module level nor program outcomes that cover knowledge, personal and interpersonal skills, and product, process, system, and service building skills.

Standard 3: Integrated Curriculum*

A curriculum designed with mutually supporting disciplinary courses, with an explicit plan to integrate personal and interpersonal skills, and product, process, system, and service building skills

Description

An integrated curriculum is based on learning experiences that lead to the acquisition of personal and interpersonal skills, and product, process, system, and service building skills, including concepts and competencies related to sustainable development (Standard 2), interwoven with the learning of disciplinary knowledge and its application in professional engineering. Disciplinary courses are mutually supporting when they make explicit connections among related and supporting content and learning outcomes. An explicit plan identifies ways in which the integration of skills and multidisciplinary connections are to be made, for example, by mapping the specified learning outcomes to courses and co-curricular activities that make up the curriculum.

Rationale

The teaching of personal, interpersonal, and professional skills, and product, process, system, and service building skills, including concepts and competencies related to sustainable development, should not be considered an addition to an already full curriculum, but an integral part of it. To reach the intended learning outcomes in disciplinary knowledge and skills, the curriculum and learning experiences have to make dual use of available time. Faculty play an active role in designing the integrated curriculum by suggesting appropriate disciplinary linkages, as well as opportunities to address specific skills in their respective teaching areas.

Rubric for Self-Assessment

5	Internal and external stakeholders regularly review the integrated curriculum and make recommendations and adjustments as needed.
4	There is evidence that the students have achieved the intended learning outcomes concerning personal, interpersonal, product, process, system, and service building skills.
3	The approved integrated curriculum concerning personal, interpersonal, product, process, system, and service building skills is in use.

2	The curriculum that integrates learning outcomes of personal, interpersonal, product, process, system, and service building skills is approved and a process has been initiated to implement the curriculum.
1	The need to analyze the curriculum is recognized and initial mapping of disciplinary and skills learning outcomes is underway.
0	There is no integration of skills or mutually supporting disciplines in the program.

Standard 4: Introduction to Engineering*

An introductory course that provides the framework for engineering practice in product, process, system, and service building, and introduces essential personal and interpersonal skills and the rationale of sustainability in the context of engineering

Description

The introductory course, usually one of the first required courses in a program, provides a framework for the practice of engineering. This framework is a broad outline of the tasks and responsibilities of an engineer, and the use of disciplinary knowledge in executing those tasks. Students engage in the practice of engineering through problem-solving and simple design exercises, individually and teams. The course also includes personal and interpersonal knowledge, skills, and attitudes that are essential at the start of a program to prepare students for more advanced product, process, system, and service building experiences. For example, students can participate in small team exercises to prepare them for larger development teams.

Rationale

Introductory courses aim to stimulate students' interest in, and strengthen their motivation for, the field of engineering by focusing on the application of relevant core engineering disciplines. Students usually select engineering programs expecting to learn in hands-on creative ways, and introductory courses can capitalize on this interest. Also, introductory courses provide an early start to the development of the essential skills described in the CDIO Syllabus.

Rubric for Self-Assessment

5	The introductory course is regularly evaluated and revised, based on feedback from students, instructors, and other stakeholders.
4	There is documented evidence that students have achieved the intended learning outcomes of the introductory engineering course.
3	An introductory course that includes engineering learning experiences and introduces essential personal and interpersonal skills has been implemented.
2	A plan for an introductory engineering course introducing a framework for practice has been approved and a process to implement the plan has been initiated.
1	The need for an introductory course that provides the framework for engineering practise is recognized and a planning process initiated.
0	There is no introductory engineering course that provides a framework for practice and introduces key skills.

Standard 5:	***Design-Implement Experiences****
A curriculum that includes two or more design-implement experiences, including one at a basic level and one at an advanced level	

Description

The term design-implement experience denotes a range of engineering activities central to the process of developing products, processes, systems and services. Included are all of the activities described in Standard 1 at the Design and Implement stages, plus appropriate aspects of conceptual design from the Conceive stage. Students develop a product, process, system, and service building skills, and competences for sustainable development, in design-implement experiences integrated into the curriculum. Design-implement experiences are considered basic or advanced in terms of their scope, complexity, and sequence in the program. For example, simpler products and systems are included earlier in the program, while more complex design-implement experiences appear in later courses designed to help students integrate knowledge and skills acquired in preceding courses and learning activities. Opportunities to conceive, design, implement and operate products, processes, systems and services may also be included in required co-curricular activities, for example, undergraduate research projects and internships.

Rationale

Design-implement experiences are structured and sequenced to promote early success in engineering practice. Iteration of design-implement experiences and increasing levels of design complexity reinforce students' understanding of the product, process, system, and service development process. Design-implement experiences also provide a solid foundation upon which to build deeper conceptual understanding of disciplinary skills as well as appreciation of ethical and sustainability aspects. The emphasis on building products and implementing processes in real-world contexts gives students opportunities to make connections between the technical content they are learning, their professional and career interests, and societal needs.

Rubric for Self-Assessment

5	The design-implement experiences are regularly evaluated and revised, based on feedback from students, instructors, and other stakeholders.
4	There is documented evidence that students have achieved the intended learning outcomes of the design-implement experiences.
3	At least two design-implement experiences of increasing complexity are being implemented.
2	There is a plan to develop design-implement experiences at the basic and advanced level.
1	A needs analysis has been conducted to identify opportunities to include design-implement experiences in the curriculum.
0	There are no design-implement experiences in the engineering program.

Standard 6:	***Engineering Learning Workspaces***
A physical learning environment that includes engineering workspaces and laboratories that support and encourage hands-on learning of product, process, system, and service building, disciplinary knowledge, and social learning, combined with a digital learning environment that includes online tools and spaces that support and enhance the quality of teaching and student learning	

Description

Workspaces and laboratories support the learning of product, process, system, and service building skills concurrently with disciplinary knowledge. They emphasize hands-on learning in which students are directly engaged in their learning and provide opportunities for social learning, that is, settings where students can learn from each other and interact with several groups. The creation of new workspaces, or remodelling of existing laboratories, will vary with the size of the program and resources of the institution. The physical learning environment also includes spaces like classrooms, lecture halls and seminar rooms, configured to support active learning experiences as well as traditional teaching modes. The digital learning environment employs digital learning technology to enhance the student learning experience as well as teaching effectiveness. Course development and delivery are assisted using appropriate e-learning development infrastructure. Program and course development are assisted by staff familiar with the CDIO framework for engineering education development, as well as expertise in instructional design, multimedia content development (recording, editing, and distribution), assessment and learning analytics.

Rationale

Workspaces and other learning environments that support hands-on learning are fundamental resources for learning to conceive, design, implement, and operate products, processes, systems and services. Students who have access to modern engineering tools, software, and laboratories have opportunities to develop the knowledge, skills, and attitudes that support product, process, and system building competencies. These competencies are best developed in workspaces that are student-centred, user-friendly, accessible, and interactive. The ability to augment learning activities through digital tools and resources provides instructors, program designers, and students with increased flexibility. Digital content repositories from prerequisite courses enable the efficient reactivation of knowledge, facilitating scaffolding across the curriculum. Program designers can structure student learning in a manner that provides increased learning flexibility including student mobility and personalized learning experience.

Rubric for Self-Assessment

5	Evaluation groups regularly review the impact and effectiveness of workspaces on learning and provide recommendations for improving them.
4	Engineering learning workspaces fully support all components of digital, hands-on, knowledge, and skills learning.
3	Development plans of engineering learning workplaces are being implemented and some new or remodelled spaces are in use.
2	Workspaces, their functionality and purposefulness for teaching are being evaluated by internal groups including stakeholders.
1	The need for engineering learning workspaces to support digital, hands-on, knowledge, and skills activities is recognized and a process to address the need has been initiated.

0	Engineering learning workspaces are inadequate or inappropriate to support and encourage digital, hands-on skills, knowledge, and social learning.

Standard 7: Integrated Learning Experiences*

Integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal and interpersonal skills, and product, process, system, and service building skills

Description

Integrated learning experiences are pedagogical approaches that foster the learning of disciplinary knowledge simultaneously with personal and interpersonal skills, and product, process, system, and service building skills. They incorporate professional engineering issues in contexts where they coexist with disciplinary issues. For example, students might consider the analysis of a product, the design of the product, as well as the social, economic and environmental responsibility of the designer of the product, all in one learning experience. Industrial partners, alumni, and other key stakeholders are often helpful in providing examples of such cases.

Rationale

The curriculum design and learning outcomes, prescribed in Standards 2 and 3 respectively, can be realized only if there are corresponding pedagogical approaches that make dual use of student learning time. Furthermore, students must recognize engineering faculty as role models of professional engineers, instructing them in disciplinary knowledge, personal and interpersonal skills, product, process, and system building skills, including concepts and competencies related to sustainable development. With integrated learning experiences, faculty can be more effective in helping students apply disciplinary knowledge to engineering practise and better prepare them to meet the demands of the engineering profession.

Rubric for Self-Assessment

5	Courses are regularly evaluated and revised regarding their integration of learning experiences and the impact of these experiences.
4	There is evidence of the impact of the implementation of integrated learning experiences according to the integrated curriculum plan.
3	Integrated learning experiences are being implemented in courses across the curriculum according to the integrated curriculum plan.
2	Course plans with learning outcomes and activities that integrate personal and interpersonal skills with disciplinary knowledge has been approved.
1	Course plans have been benchmarked concerning the integrated curriculum plan.
0	There is no evidence of integrated learning of disciplines and skills.

Standard 8: Active Learning

Teaching and learning based on active and experiential learning methods

Description

Active learning methods engage students directly in thinking and problem-solving activities. There is less emphasis on the passive transmission of information, and more on engaging students manipulating, analyzing, evaluating and applying ideas. Active learning in lecture-based courses can include such methods as a 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-implement projects, simulations, and case studies.

Rationale

By engaging students in thinking about concepts, particularly new ideas, and requiring them to make an overt response, students not only learn more, they recognize for themselves what and how they learn. This process aims 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.

Rubric for Self-Assessment

5	Internal and/or external groups regularly review active learning activities on outcome-based learning across the curricula and make recommendations for continuous improvement.
4	There is documented evidence that active learning has been implemented suitably all across the curriculum.
3	Active learning methods are being implemented across the curriculum.
2	There is a plan and process to include active learning methods in courses across the curriculum.
1	There is an awareness of the benefits of active learning and it is encouraged to introduce it across the curricula.
0	There is no evidence of active experiential learning methods.

Standard 9: Enhancement of Faculty Competence*

Actions that enhance faculty competence in personal and interpersonal skills, product, process, system, and service building skills, as well as disciplinary fundamentals

Description

CDIO programs provide support for improving the collective competence of the engineering faculty with regards to *what to teach*, according to the full set of intended learning outcomes of the program as described in Standard 2. Faculty competence refers to personal and interpersonal skills, product, process, system, and service building skills, including concepts and competencies related to sustainable development. Faculty competence also refers to the ability to support students to achieve a deeper working understanding of the relevant disciplinary fundamentals. One way to strengthen the collective competence of faculty is to take these needs into account in faculty recruitment and promotion processes. Another way is to systematically support the competence development of the existing faculty members. The

nature and scope of faculty development vary with the resources and intentions of different programs and institutions. Some of these skills are best developed in contexts of professional engineering practice. Actions to enhance faculty engineering competence include: professional leave to work in the industry, partnerships with industry colleagues in research and education projects, the inclusion of engineering practice as a criterion for hiring and promotion, and appropriate professional development experiences at the university.

Rationale

If engineering faculty are expected to teach a curriculum of personal and interpersonal skills, and product, process, system, and service building skills integrated with disciplinary knowledge, as described for instance in Standards 3, 4, 5, and 7, they as a group need to be competent in those skills. 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, and its role in sustainable development. A key aspect of expertise is pedagogical content knowledge, which refers to the ability to effectively support students in learning the subject. The rapid pace of technological innovation also requires continuous updating of engineering skills. The collective faculty needs to enhance its engineering knowledge and skills so that they can provide relevant examples to students and also serve as individual role models of contemporary engineers.

Rubric for Self-Assessment

5	Faculty competence in disciplinary knowledge and personal, interpersonal, product, process, system, and service building skills are regularly evaluated and enhanced where appropriate.
4	There is evidence that the collective faculty is competent in disciplinary knowledge and personal, interpersonal, product, process, system, and service building skills.
3	The faculty participates in competence development activities, and faculty recruitment takes into account the need for faculty competence, with regards to disciplinary knowledge and personal, interpersonal, product, process, system, and service building skills.
2	There is a systematic plan for faculty enhancement in disciplinary knowledge and personal, interpersonal, product, process, system, and service building skills.
1	The need of a faculty competence development plan in disciplinary knowledge and personal, interpersonal, product, process, system, and service building skills is recognized.
0	There are no programs or practices to enhance faculty competence in disciplinary knowledge and personal, interpersonal, product, process, system, and service building skills.

Standard 10: Enhancement of Faculty Teaching Competence

Actions that enhance faculty competence in providing integrated learning experiences, in using active and experiential learning methods, and in assessing student learning

Description

CDIO programs take actions to enhance faculty teaching competence required for effectively creating, delivering and improving courses in the curriculum. The need for faculty teaching competence include for instance the ability to provide integrated learning experiences (Standard 7), including design-implement experiences (Standard 5) and other active and experiential learning (Standard 8), as well as assessing student learning (Standard 11) and evaluating and improving courses and programs (Standard 12). One way to strengthen the collective faculty teaching competence is to take these needs into account in faculty recruitment and promotion processes. Another way to address the need is to systematically support the development of the existing faculty members' teaching competence. The nature and scope of faculty development practices will vary with programs and institutions. Actions to enhance faculty teaching competence include: making requirements for teaching competence in hiring and performance reviews, support for faculty participation in university and external faculty development programs, creating forums for sharing ideas and best practices at the university, national and international level.

Rationale

If faculty members are expected to teach and assess in new ways, as described in the CDIO Standards, they need opportunities to develop and improve these competencies. Many universities have faculty development programs and services that might be eager to collaborate with faculty in CDIO programs. Besides, if CDIO programs want to emphasize the importance of teaching, learning, and assessment, they must recruit and promote faculty with these needs in mind, and they must commit adequate resources for faculty development in these areas**.**

Rubric for Self-Assessment

5	Faculty teaching competence is regularly evaluated and updated where appropriate.
4	There is evidence that the collective faculty has the teaching competence needed for effectively creating, delivering and improving courses in the curriculum.
3	Faculty members participate continuously in activities to develop their teaching competence, and faculty recruitment takes into account the need for faculty teaching competence.
2	A systematic plan for ensuring and enhancing faculty teaching competence is developed and budgeted.
1	A need for ensuring and enhancing faculty teaching competence is recognized and accepted within the team.
0	There are no programs or practices to enhance faculty teaching competence.

Standard 11: Learning Assessment*

Assessment of student learning in personal and interpersonal skills, and product, process, system, and service building skills, as well as in disciplinary knowledge

Description

Assessment of student learning is the measure of the extent to which each student achieves the intended specified learning outcomes. Instructors usually conduct this assessment within their respective courses. Effective learning assessment uses a variety of methods matched appropriately to learning outcomes that address disciplinary knowledge, as well as personal and interpersonal skills, and product, process, system, and service building skills, including concepts and competencies related to sustainable development, as described in Standard 2, 3 and 7. These methods may include written, online and oral tests, observations of student performance, rating scales, student reflections, journals, portfolios, and peer and self-assessment.

Rationale

If we value personal and interpersonal skills, and product, process, system, and service building skills, and incorporate them into curriculum and learning experiences, then we must have effective assessment processes for measuring them. Different categories of learning outcomes require different assessment methods. For example, learning outcomes related to disciplinary knowledge may be assessed with oral, online and written tests, while those related to design-implement skills may be better measured with recorded observations. Using a variety of assessment methods accommodates a broader range of learning styles, and increases the reliability and validity of the assessment data. As a result, determinations of students' achievement of the intended learning outcomes can be made with greater confidence.

Rubric for Self-Assessment

5	Internal and external groups regularly review the use of learning assessment methods and make recommendations for continuous improvement.
4	There is evidence of aligned learning assessment methods.
3	Learning assessment methods are aligned with the learning goals across the curriculum.
2	There is a plan to align learning assessment methods with the curriculum.
1	The need for the improvement of learning assessment methods is recognized.
0	Learning assessment methods are inadequate, inappropriate or not aligned.

Standard 12: Program Evaluation

A system that evaluates programs against these twelve standards and any optional standards adopted, and provides feedback to students, faculty, and other stakeholders for continuous improvement

Description

Program evaluation is a judgment of the overall value of a program based on evidence of a program's progress toward attaining its goals. A CDIO program should be evaluated relative to these 12 CDIO Standards and any optional standards that it has adopted. Evidence of overall program value can be collected with course evaluations, instructor reflections, entry and exit interviews, reports of external reviewers, and follow-up studies with graduates and employers. The evidence should be regularly reported back to instructors, students, program

administrators, alumni, and other key stakeholders. This feedback forms the basis of decisions about the program and its plans for continuous improvement.

Rationale

A key function of program evaluation is to determine the program's effectiveness and efficiency in reaching its intended goals. Evidence collected during the program evaluation process also serves as the basis of continuous program improvement. For example, if in an exit interview, a majority of students reported that they were not able to meet some specific learning outcome, a plan could be initiated to identify root causes and implement changes. Moreover, many external evaluators and accreditation bodies require regular and consistent program evaluation.

Rubric for Self-Assessment

5	There is documented evidence that systematic and continuous improvement is based on continuous program evaluation results.
4	There is documented evidence that program evaluation methods are being used with key stakeholders including students, faculty, program leaders, alumni and working life representatives.
3	Program evaluation methods are being implemented across the program to gather data from the majority of including the stakeholders (such as students, faculty, program leaders, alumni, working life representatives).
2	A continuous program evaluation plan exists.
1	The need for program evaluation is recognized and benchmarking of evaluation methods is in process.
0	Program evaluation is non-existing.

CONCLUSION

The CDIO standards, originally presented in 2005 (Brodeur & Crawley, 2005), need to be continually updated to reflect societal needs and developments, current engineering professional practices, to capture pedagogical innovations, and to address the critique of the CDIO standards.

This paper presented updates of the CDIO core standards to version 3.0, with regards to sustainable development, services, digitalization and faculty competence. These updated CDIO core standards are intended to address more clearly today's most important engineering challenge (sustainability) and technology opportunity (digitalization). The updates further bring forward the need for "triple-competent" faculty, i.e., faculty with pedagogic, subject-matter and engineering professional competence. Future work will be needed to field-test these new standards, in program development and self-evaluation. We would like to encourage the CDIO community to document and share their experiences to support future development.

A parallel paper presents a set of optional CDIO Standards to augment the CDIO framework (Malmqvist *et al*., 2020). The other major document defining the CDIO framework is the CDIO syllabus. The next step is to focus on updating the syllabus, based on the analysis presented by Rosén *et al*. (2019).

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ALIGNMENT AND MAPPING BETWEEN CDIO STANDARDS AND AUN-QA CRITERIA

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ABSTRACT

The ASEAN University Network-Quality Assurance (AUN-QA) Network, which was initiated since 1998, aims to develop a holistic quality assurance system to raise academic standards and enhance education, research and service among its member universities through the use of its policy and criteria. In rising to the challenges of the ASEAN Community, the AUN-QA Network has to be looking forward to advocating a harmonized framework for quality assurance in higher education within and outside ASEAN. There are 11 criteria which have been developed in the 3rd version of the AUN-QA model for programme level covering three dimensions on quality of input, quality of process and quality of output. This paper will present research and practice on alignment and mapping from CDIO standards as quality toolkits to meet the AUN-QA criteria in the view of outcome-based education (OBE) approach. First, the study outlines an in-depth literature review on the comparison between the AUN-QA criteria and the CDIO standards. Next, the mapping details of the AUN-QA criteria and the CDIO standards according to their alignment are presented. Third, the paper presents the CDIO implementation by The University of Danang - University of Science and Technology (UD-DUT) to fulfil aligned requirements of the AUN-QA assessment at the program level. It is concluded that the implementation of the CDIO framework has demonstrated a positive accelerating OBE implementation and, thus, to meet the AUN-QA expectation. Exploitation of CDIO standards implementation has reformed the UD-DUT educational system to leverage remarkably multi-dimensional quality of the university quality assurance system and study programs. A selected set of good practices on CDIO implementation are recommended for further discussion and possibly usage by the AUN-QA community for AUN-QA assessment effectiveness.

KEYWORDS

Outcome-based education, AUN-QA, Quality Assurance, Quality Assessment, Standards 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

INTRODUCTION

As previously reported by European Higher Education Area, the key challenges of opening up higher education, improving teaching and learning quality, and reforming assessment and recognition have remained the same for all countries in the last 20 years. In concerning the Sustainable Development Goals (SDGs) laid forth by the United Nations (UN, 2015), several aspects and targets of the SDG 4 have been addressed with an emphasis on the shifting of focus from content-based education to outcome-based education, and the utilization of learning outcomes to enhance academic quality. The Regional Report of Asia and the Pacific (UNESCO, 2003) has defined quality assurance (QA) in higher education as "systematic management and assessment procedures to monitor the performance of higher education institutions". Higher education quality is a multi-dimensional concept that embodies not only QA procedures, but also accessibility, employability, academic freedom, public responsibility, and higher education mobility. QA processes serve multiple purposes: enhance learning and teaching, build trust among stakeholders throughout the higher education system, and increase regional and international harmonization and comparability (Pham, 2019).

AUN-QA Quality Assurance and Open Issues

ASEAN University Network is a network of universities in ASEAN countries, established to promote higher education cooperation in the ASEAN community. To promote quality assurance within the region's universities, AUN has launched an initiative - AUN Quality Assurance (AUN-QA) sub-network - to assess the quality of higher education according to the ASEAN regional quality assurance framework. The AUN-QA models for higher education comprise strategically QA, systematically QA and functionally QA, and are subjected to both internal and external QA assessments (AUN, 2016). The AUN-QA Framework is redesigned as a transnational quality assurance framework to support the ASEAN Economic Community (ASEAN, 2015) and to promote cross-border mobility for students and faculty members and internationalisation of higher education (AUN, 2017). It is, therefore, developed to be aligned with the ASEAN Quality Assurance Framework (ASEAN, 2013) - a common reference framework, functions as a device to enable comparisons of qualifications across ASEAN member states, Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG 2015 – Part 1) (EURASHE, 2015) and Baldrige Performance Excellence Framework (Education) (NIST, 2015). This is the way that the AUN raises mutual trust in the quality of training among regional universities as well as with partner universities around the world, step by step contributing to promote recognized academic achievement and develop regional and international cooperation to benefit the ASEAN community.

Outcomes-based education (OBE) and the AUN-QA framework at programme level are principles-based quality assurance frameworks. The AUN-QA criteria at programme level do not focus on any specific disciplinary but focus on assessing the conditions to ensure the quality of a study programme. The obtained AUN-QA assessment results at programme level have shown the most critical issues which may be varied over different programmes in ASEAN countries:

- Programme learning outcomes (PLOs) do not fully reflect the needs of stakeholders (including students, alumni, employers, government, national and international experts, …). These learning outcomes are not specifically designed to be measurable for personal, interpersonal and professional skills of the learners.
- The curriculum has not been designed and developed in constructive alignment with the defined programme learning outcomes.

- The teaching and learning activities are not properly developed to support student in obtaining learning outcomes, and assessed regularly, objectively during programme execution.
- Less effectively assessment methods and specific rubrics have been established to assess student progress and learning outcomes achievement.
- The professional development programs for academic staff and supporting staff are not standardized to improve and develop the faculty in terms of quantity and quality.
- The lack of policies at institutional and national level to develop an internal quality assurance system leads to challenges in assuring and continuously improving quality of education at programme level.

It is, therefore, important to have quality assurance tools to provide study programmes and higher institutions with a design, implementation, analysis and assessment that identifies strengths and shortcomings to improve quality as well as increase the accountability and commitment of the study programme and higher institution for quality.

CDIO Initiative as Quality Assurance Framework

One of the very first papers presented by Malmqvist (2009) addresses a comparison between CDIO Standards and EUR-ACE standards (ENAEE, 2015). The paper delivered several conclusions in 4 compared areas consisting of CDIO syllabus with EUR-ACE's, CDIO standards and EUR-ACE accreditation requirements, the proficiency levels of the CDIO and EUR-ACE, CDIO rating scale and EUR-ACE threshold value scale. Another research by Crawley (2011) has shown that the 12 CDIO standards meet standards and criteria set by accreditation bodies such as ABET. The adoption of the CDIO Initiative at the School of Engineering which contributed to the recent ABET accreditation of the Diploma in Aerospace and Aeronautical Engineering has been studied in (Wah, 2015). The authors share their experiences in using the 12 CDIO standards as guidelines for course evaluation and a framework for continuous improvement.

In the similar but wider approach, a report by Gray (2011) addresses how the CDIO Council promulgate quality assurance processes to assure internal and external stakeholders that member institutions and programs are adhering to the 12 CDIO standards. The five QA processes which have been developed by the CDIO Council begin with the application to become a CDIO Collaborator and include self-evaluation based on the CDIO Standards. The Diploma in Chemical Engineering program (Cheah, 2013) has shared the successful approach of "aligning its CDIO implementation and self-evaluation process to the institution's quality management systems and holistic education framework, as well as the requirement spelt out by the Institution of Chemical Engineers, UK. The CDIO initiative have been asking institutions and programmes to do a self-evaluation to support the continued improvement of the CDIO implementation at the institution/programme. The way forward selected was to make a self-evaluation concept, where an institution or a study programme could self-evaluate how well it was doing on a six-point scale (Bennedsen, 2014). Malmqvist (2015) has also conducted surveys of CDIO implementation and effects on educational quality. This projects aim to evaluate the effects on outcomes, the perceived benefits, the limitations, any barriers to implementation, and ascertain future development needs.

In the research by Aburatani (2019), NIT's Model Core Curriculum (MCC) is compared to the CDIO standard and syllabus to clarify the similarity and difference between NIT's KOSEN education and the CDIO initiative: "It is shown that the MCC well covers and matches with most of the items in CDIO standard and syllabus". Recently, the CDIO framework is integrated

as an important part of the new quality assurance system within the Faculty of Science and Engineering at Linköping University (Gunnarsson et al., 2019). As presented, the course matrices and program matrices are built upon an adapted and extended version of the CDIO Syllabus. Besides, the CDIO standards are used in the quality reports.

This paper will present a research and practice on alignment from CDIO standards as quality tools to meet the AUN-QA criteria in the view of outcome-based education (OBE) approach.

COMPARISON OF THE CDIO STANDARDS AND THE AUN-QA CRITERIA

AUN-QA Model at Programme Level

The quality assessment evaluates the operation of the institution or programme to determine whether it meets the agreed-upon or predetermined standards. Quality assessment has two main purposes: (i) To assess a study programme or institution to determine if it meets quality standards and (ii) To support and promote study programmes and institutions for continuous improvement of quality. The 3rd version of the AUN-QA model at programme level (Figure 1) is structured with different groups of QA factors named as input QA, process QA and output QA which follow a closed cycle of Plan-Do-Check-Act (PDCA) to continuously improve and gradually improve the quality of training.

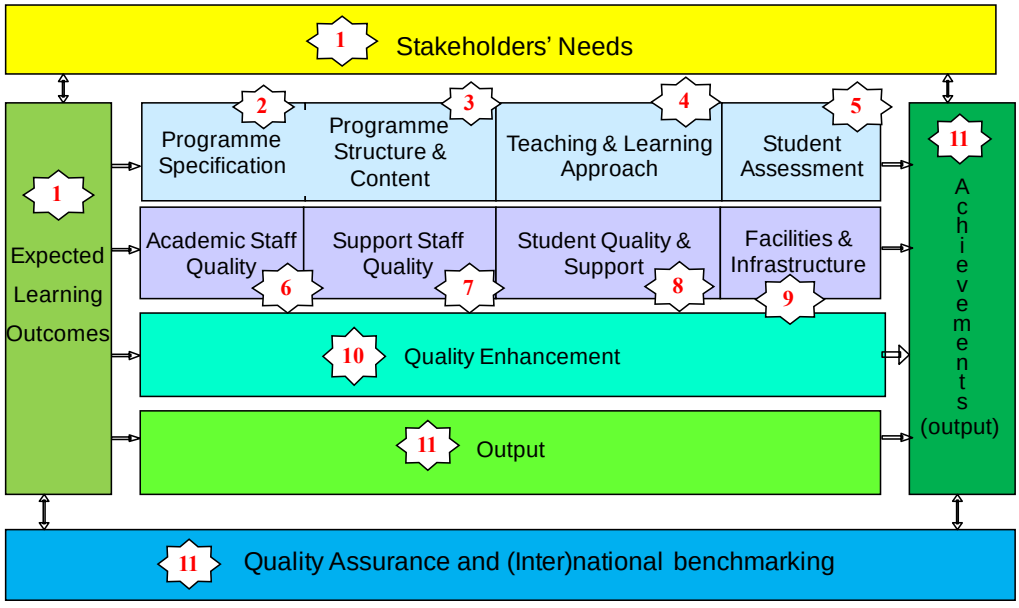

Figure 1. The AUN-QA criteria with 11 criteria and 50 sub-criteria

Mapping between AUN-QA criteria and CDIO standards

Throughout the world, CDIO Initiative collaborators have adopted CDIO as the framework of their curricular design and outcome-based assessment. In general, this framework overlaps with the AUN-QA framework as they both reply on outcome-based education principle. This section presents a comparison of the AUN-QA criteria and CDIO standards in terms of quality assurance system framework. The below study results show a strong correlation between the CDIO standards and the AUN-QA criteria.

The CDIO Standards vs. AUN-QA Criteria

The AUN-QA model (AUN, 2015) starts with the input QA process consisting of expected learning outcomes (criterion 1), programme specification (criterion 2) and programme structure and content (criterion 3) which closely match to the CDIO syllabus (standard 2) and integrated curriculum (standard 3). Teaching and learning approach (criterion 4) and student assessment (criterion 5) are reflected in the integrated learning experiences (standard 7), active learning (standard 8) and learning assessment (standard 11). Correlation between the standards and the criteria is visually depicted in Table 1.

Table 1. Correlation between CDIO Standards 2.0 and AUN-QA Criteria 3.0

	AUN-QA Criteria 3.0										
CDIO Standards 2.0	1	2	3	4	5	6	7	8	9	10	11
1. The Context*	1.3			4.1							
2. Learning Outcomes*	1	2.2								10.1	
3. Integrated Curriculum*		2.1 2.2	3							10.2	
4. Introduction to Engineering	1.3	2.2	3.3								
5. Design-Implement Experiences*			3.2					8.4			
6. Engineering Workspaces									9		
7. Integrated Learning Experiences*	1.2		3.2 3.3	4.2							
8. Active Learning				4				8.5			
9. Enhancement of Faculty Competences*						6.4 6.5					
10. Enhancement of Faculty Teaching Competences						6.4 6.5	7.3 7.4				
11. Learning Assessment*		2.2			5						
12. Program Evaluation								8.3		10	11
Shading Explanation		*Correlation with one or several sub-criteria*					*Correlation with whole criterion*				
AUN-QA Criteria 3.0	1. Expected Learning Outcomes; 2. Programme Specification; 3. Programme Structure and Content; 4. Teaching and Learning Approach; 5. Student Assessment; 6. Academic Staff Quality; 7. Support Staff Quality; 8. Student Quality and Support; 9. Facilities and Infrastructure; 10. Quality Enhancement; 11. Outputs										

A focused mapping within the input QA process will be analyzed in the next CDIO syllabus and constructive alignment sub-section. Besides, it is noticed that the sub-criterion 3.3 which requires the logical, ordered curriculum structure shows the need delivering the "introduction to engineering" course that provides the framework for engineering practice in product, process, and system building, and introduces essential personal and interpersonal skills (standard 4). The sub-criterion 3.2 which emphasizes on "the contribution made by each course to achieve the expected learning outcomes" requests a sequenced and integrated Design and Build projects over semesters should be designed to support a student in obtaining these specific expected learning outcomes (standard 5).

The setting of the education, the skills we teach, and the attitudes we convey should all indicate that conceiving-designing-implementing-operating is the authentic role of engineers in their service to society (standard 1). This context is considered as a specific educational philosophy for engineering school which should be well-articulated and communicated to all stakeholders in sub-criterion 4.1. The engineering workspace is specifically required through five sub-criteria

of the criterion 9 which matches to the standard 6. The provision of facilities, infrastructure, learning resources should be in line with the objectives of the programme to support education and research. Facilities are also connected to the teaching and learning approach (criteria 4).

The sub-criteria 6.4 and 6.5 emphasize on the quality of the academic staff which encompasses qualification, subject matter expertise, experience, teaching skills and professional ethics. Competences of support staff which are articulated in the sub-criteria 7.3 and 7.4 are identified and evaluated to ensure that their competencies remain relevant and the services provided by them satisfy the stakeholders' needs. The CDIO standards 9 and 10 provide support for the collective engineering faculty to improve its competence in the personal and interpersonal skills, and product, process, and system building skills. Besides, there is a strong need of providing support for faculty to improve their competences in integrated, active and experiential learning experiences, and student learning assessment.

A key function of program evaluation (standard 12) is to determine the program's effectiveness and efficiency in reaching its intended goals. Evidence collected during the program evaluation process also serves as the basis of continuous program improvement. Similarly, the criterion 10 requires the continuous search for improvement and best practices including all aspects of the AUN-QA criteria from 1 to 9. Criterion 11 focuses on evaluating the quality of output and its graduates. There should be a system to collect evidences and measure stakeholders' satisfaction. The information collected should be analyzed and benchmarked for making improvements to the programme, quality practices and quality assurance system.

The CDIO Syllabus vs. AUN-QA Requirements on Expected Learning Outcomes

The CDIO Syllabus (standard 2) has played a key role in the design of curriculum, teaching, and assessment in engineering education. In the curriculum and instructional design process, the CDIO Syllabus was adapted to diverse engineering programs to ensure that expected learning outcomes (ELOs) were aligned with institutional mission and vision, program objectives (Crawley et al., 2011). The CDIO Syllabus is therefore well aligned with the criterion 1 requiring the ELOs are formulated from the needs of stakeholders, engineering professional bodies, form the starting point of the programme design. The ELOs formulation must take into account and reflects the vision and mission of the institution, the goals, objectives of the programme (sub-criterion 10.1). Also, the current CDO syllabus support the ELOs structure required in the sub-criterion 1.2. The ELOs should cover both subject-specific outcomes that relate to the knowledge and hard skills of the subject discipline; and generic outcomes that relate to transferable skills which may cover personal skills, interpersonal skills, and product, process, and system building skills in enterprise, business, and societal contexts. In the instructional design process at the course level, the ELOs are used as a starting point for defining learning outcomes at the course level. This coincides with requirement on sub-criterion 1.1 which each course and lesson should be designed to achieve its expected learning outcomes which should be aligned to the programme ELOs.

Constructive Alignment in the CDIO Standards and AUN-QA Criteria

The integrated curriculum is critically required by the criterion 3 where the curriculum, teaching and learning methods and student assessment are constructively aligned to achieve the ELOs. As defined by the AUN-QA, "constructive" refers to the concept that students construct meaning through relevant learning activities; and "alignment" refers to the situation when teaching and learning activities and student assessment are aligned to achieve the expected learning outcomes. The sub-criteria 2.1 and 2.2 mention about a programme specification that

helps students to understand the teaching and learning methods that enable the outcome to be achieved; the assessment methods that enable achievement to be demonstrated; and the relationship of the programme and its study elements. The curriculum design and development process that ensures the above constructive alignment must be established and periodically reviewed, evaluated as requested in the sub-criterion 10.2. All of these AUN-QA standards could be fulfilled by applying the standard 3 requiring exactly that disciplinary courses are mutually supporting when they make explicit connections among related and supporting content and ELOs. An explicit plan identifies ways in which the integration of skills and multidisciplinary connections are to be made.

Active learning (standard 8) is a key matching to the criterion 4. Quality learning is understood as involving the active construction of meaning by the student, and not just something that is imparted by the teacher. This process helps to increase students' motivation to achieve program ELOs and form lifelong learning skills which is also defined clearly in the sub-criterion 4.3. The sub-criterion 8.5 also promotes an establishment of constructive learning environments to support the achievement of quality student learning covering a physical, social and psychological environment that is conducive for education and research as well as personal well-being. Besides, integrated learning experiences (standard 7) are pedagogical approaches that meet the sub-criteria 1.2, 3.2, 3.3 and 4.2. The AUN-QA framework requires an appropriate curriculum design embedding all learning outcomes and corresponding pedagogical approaches that make dual use of student learning time that helps students to apply disciplinary knowledge to engineering practise and better prepare them to meet the demands of the engineering profession.

Assessment of student learning (standard 11) is the measure of the extent to which each student achieves specified learning outcomes. In the same manner, criterion 5 strongly articulates assessment types at admission, course study and exit test before graduation. It is therefore important that assessment is carried out professionally at all times and provides valuable information for institutions about the efficiency of teaching and learner support. In fostering constructive alignment, a variety of assessment methods should be adopted and be congruent with the expected learning outcomes. They should measure the achievement of all the expected learning outcomes of the programme and its courses.

The CDIO Self-Evaluation Model vs. AUN-QA Quality Assessment Process

The CDIO initiative provides a self-evaluation model to analyze the CDIO adoption level concerning 12 standards. This quality self-evaluation process could be organized around a Plan-Do-Check-Act (PDCA) cycle with the CDIO components in relevant phases as demonstrated in Enelund, (2008) and repeated in Malmqvist (2009). 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 six-level scale, which is used to rate the progress towards the planning, implementation and adoption of each CDIO standard. The rubrics of the six-level scale are stated in Table 2.

Table 2. CDIO standards self-evaluation general rating scale

Scale	Criteria
5	Evidence related to the standard is regularly reviewed and used to make improvements.
4	There is documented evidence of the full implementation and impact of the standard across program components and constituents.
3	Implementation of the plan to address the standard is underway across the program components and constituents.
2	There is a plan in place to address the standard.
1	There is an awareness of need to adopt the standard and a process is in place to address it.
0	There is no documented plan or activity related to the standard.

The AUN-QA quality assessment aims to determine if the institution, system or programme meets generally accepted quality standards. The AUN-QA self-assessment serves as preparation for a site visit by external experts and the self-assessment report (SAR) provides the external experts with the basic information about the institution, programme and quality assurance system (AUN, 2015). It also provides an opportunity for the institution and its staff to discover the quality of its quality assurance system. The approach for preparing SAR which encompasses the Plan-Do-Check-Act (PDCA) cycle. The PDCA is also adopted for quality assessment at the programme level, as well as for both the institutional level and IQA system.

All programmes are evaluated against the one set of 11 criteria. The results of an evaluation fall upon a scale between one and seven. As being shown in Table 3, the rating for each criterion ranged from Level 1 - not meeting the criterion to Level 7 - excellent performance, the typical model of the world. Overall scores above a four allow recognition as completing the AUN-QA program assessment.

Table 3. The 7-point rating scale of the AUN-QA standards

Rating	Description
1	Absolutely Inadequate
2	Inadequate and Improvement is Necessary
3	Inadequate but Minor Improvement Will Make It Adequate
4	Adequate as Expected
5	Better Than Adequate
6	Example of Best Practices
7	Excellent (Example of World-class or Leading Practices)

CDIO STANDARDS IMPLEMENTATION AT UD-DUT

The Certified AUN-QA – CDIO Programmes

UD-DUT has continuously implemented the CDIO approach to improve its education quality and adapt social needs as well as international integration by the following strategic actions:

- Systemic change: Regulations for updating expected learning outcomes and re-designing curriculum in accordance to CDIO Standards has been issued in 2016 and applied to all engineering and technology programmes since 2017.
- Implementation tools: Detailed procedures, templates and rubrics have been developed subjecting to programme self-assessment and development following

outcome-based curriculum, outcome-based teaching and learning, outcome-based assessment, and outcome-based program evaluation.

- Quality culture establishment: CDIO context has been gradually built up based on the strong leadership commitment, professional attitude and skills of managers and volunteering efforts by academic staff in transforming all study programmes.
- There were a total of 9 study programmes certified with the AUN-QA quality standard as a consequence. There are 8 more programmes completed the self-assessment process. The university is now preparing for the AUN-QA Institutional quality assessment.

Good Practices on CDIO Implementation

Enhancement of Faculty Competences and Teaching Competences

A CDIO framework project had been launched between UD-DUT and Singapore Polytechnic in 2016 (DUT, 2016). This 3-year project aims to share the CDIO Framework to educate the students to become effective modern engineers as well as skilled workforces in various areas. The programme outputs and outcomes have been met as follows (Lee, 2017):

- Increased capability and capacity: There are 160 participants from 6 state university members of UD trained with new knowledge in the context of CDIO real-world systems and products. Some 70 of them have been further trained to form the specialists' team to incorporate the skills of conceiving, designing, implementing innovative user-centred solutions in engineering curricular. Some 20 of these specialists, had been carefully selected to undergo deeply training to become Master Trainers who can design and develop customized training programme.

Experiential Learning

Integrated learning experiences standard has been fully implemented at UD-DUT through the Learning Express (LeX) programme in collaborating with SPI. This is a multi-national, multi-cultural and multi-disciplinary program addressing local complex problems in complex settings (SPI, 2015). Students are required to apply cognitive and physical skills, use Design Thinking into solving a given issue. The programme outcomes have been met as follows:

- Implemented LeX: There are 5 LeX cohorts organized at UD-DUT since 2016 up to now. Many students from UD-DUT and SP had visited different villages in the countryside in Central region of Vietnam, interacted with local citizens to define problems.
- Impacts: The program helps students themselves to build their mindset in nurturing a sense of purpose and social innovation to sustainable development of society in ASEAN countries AUN-QA Program Assessment benefits

The Green Challenge

Design and build standard has been applied successfully at UD-DUT through “The Green Challenge” project launched by Bosch Vietnam together with some universities. The students were asked to develop a system to manage and operate a fleet of electrically powered and connected two-wheelers. The system had to be environmentally friendly and meet the technical requirements set by Bosch. The programme outcomes have been met as follows:

- Project product: Students from various majors had worked in a team at UD-DUT, and together with other teams at other universities did a research to propose a shared usage model which best fit in the technical, environmental and economical outcomes.
- Social and technology outcomes: Students did learn and experience of doing research and business development which help enhance the competitiveness, build up a knowledge economy, and offer a smart and eco-friendly alternative to the community.

KEY LEARNING POINTS AND RECOMMENDATIONS

This part shares key learning points on the adaptation of CDIO Standards in building quality assurance framework and preparing for AUN-QA quality assessment at programme level.

One common experience shared by all CDIO programmes is that the programme's quality is continuously enhanced subjecting to the AUN-QA quality criteria. The CDIO self-evaluation process with the six-level rating scale support well the AUN-QA self-assessment report and the external quality assurance assessment using the 7-point rating scale. The C-D-I-O cycle pairs with the P-D-C-A cycle of the AUN-QA quality assurance framework which is useful for continuous quality improvement goal.

In the learning outcome development process, the CDIO syllabus provides a powerful framework for benchmarking outcomes covering personal skills, interpersonal skills, and product, process, and system building skills in enterprise, business, and societal contexts. However, there must be a clear procedure of re-designing learning outcomes to adopt properly stakeholder's needs in disciplinary knowledge, to omit a few of the personal, interpersonal, and CDIO skills found in the CDIO syllabus, or to add a few to emphasize specific demands of employers, requirements of national standards, national and regional qualification framework, and values of its institution.

In the curriculum and instructional development process, the curriculum is designed to meet the ELOs where the contribution made by each course in achieving the programme's ELOs is clear. Specifically, there is a critical need for designing a mapping matrix of the specified learning outcomes to courses and co-curricular activities that make up the curriculum.

Integrated learning experiences are pedagogical approaches that foster the learning of disciplinary knowledge simultaneously with personal and interpersonal skills, and product, process, and system building skills. It is important not only to have an appropriate curriculum design embedding all learning outcomes and corresponding pedagogical approaches but also the constructive learning assessment methods with relevant rubrics to measure achievement of the expected learning outcomes at the programme and courses level.

The quality assurance and enhancement of the programmes and institution won't be effectively achieved without well-trained faculties. The challenges faced by most faculties at an institution is to first understand the CDIO framework and how to implement the framework. It is, thus, so important to maximize resources for staff professional training on education quality assurance; strengthen the capacity of administrative staff in terms of quality assurance; promulgate mechanisms to recognize quality achievement by staff, programmes and units inside and outside higher institution.

An important learning point is that, due to the lack of policies on quality assurance and quality assessment, implementation of CDIO standards normally will not be carried out synchronously

by different administrative departments and faculties. There must be a need of establishing a concrete model of CDIO-based quality assurance framework subjecting to enhancement of internal quality assurance system and its effective operation. Also, CDIO context should be carried out as a commitment of leaders, administrative staff and faculty managers. It is a key point of successful CDIO implementation and transformation.

CONCLUSIONS

The twelve CDIO standards serve as a useful framework for quality assurance and quality assessment at the programme/ institutional level. The CDIO standards show very good alignment with other outcomes-based higher education frameworks developed by regional and international quality assessment and accreditation bodies. It is systematically recognized that there is a strong alignment between CDIO Standards and AUN-QA Criteria. It was found to be more comprehensive and more detailed for engineering and technology education.

Exploitation of the CDIO standards and their tools to design, implement, monitor and evaluate programmes and courses subjecting to the AUN-QA criteria requirements has been proven to be an effective approach. It helps to collect different types of information needed for continuous quality improvement and external quality assessment purposes.

While CDIO framework plays a key role in meeting the AUN-QA criteria, the success of the external AUN-QA quality assessment should be mainly reserved to the strategic effort of consistently adopting the CDIO standards into institution quality assurance framework. Moving forward, institutional quality development and assessment using the CDIO standards as self-evaluation tools will further strengthen the internal quality assurance system for building a quality culture of the university.

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BIOGRAPHICAL INFORMATION

Tuan Van Pham had been designated to Vice-Chair of Electronic and Telecommunication Engineering Faculty, DUT in 2010-2014; Deputy Director, Center of Excellence, DUT in 2011 - 2018. He has been appointed to Director of Educational Testing & Quality Assurance Department, DUT since 2014. Tuan has been certified as Vietnam Educational Quality Assessor since 2016 and then AUN-QA Assessor since 2017. Tuan was DUT Project Manager of HEEAP Program (Higher Engineering Education Alliance) in 2010 – 2018, VULII Program (Vocational and University Leadership and Innovation Institute) in 2012 – 2016, BUILD-IT Program (Building University-Industry Learning and Development through Innovation and Technology) in 2016 – 2020; UD-DUT Project Leader for CDIO framework project at UD-DUT in 2016-2019.

Anh Thu Thi Nguyen got her doctoral degree at The Catholic University of America, USA in 201. She is currently the Vice-dean of the Faculty of Advanced Science and Technology at DUT, UD, where CDIO-based innovation projects are actively applied. Anh Thu is also a vice-director of the Danang International Institute of Technology, UD conducting studies in IoT, AI engineering solutions for smart city, health care, etc. Loving creativity and high quality of education, from 2016 she has also joined Fablab Danang (one of 600 Fablabs over the world established by MIT) as a Senior vice-president and focusing on academic leading of innovation projects in STEAM (STEM+Art) for K-12 students and community and has founded L.Y.D.I.N.C Ltd. company with LYD3D brand for 3D printing development and LYDEdu brand for consultancy in Quality Assurance on STEAM Education.

Hong Hai Nguyen received Dr Technical Degree in Civil Engineering from the University of Nantes (France) in 2012. During the thesis, he was granted with a Temporary Lecturer and Research Assistant position at University Institut of Technology of Saint-Nazaire – The University of Nantes in 2011 - 2012. Hai has been promoted to Associate Professor at UD-DUT since 2017. He has been designated to Dean of Road & Bridge Engineering Faculty, DUT in 2013-2018 and appointed to Director of Academic Affairs Department, DUT since 2018. He is a member of the Scientific and Training Council, DUT in 2017-2022. From 2018, Hai was one of the DUT leading members for CDIO Outcomes-based Curriculum Training and Development project.

Minh Duc Phan finished his PhD degree in Mechanical Engineering at Chulalongkorn University, Thailand in 2007. Before being the Director of Academic Affairs Department in March 2010, he had taken Senior Lecturer at Transportation Mechanical Engineering Faculty of DUT. Dr Duc has actively participated in many HEEAP, VULII and BUILD-IT activities, particularly in teaching and learning, quality assurance, and leadership. Since 2018, Duc has been promoted to Vice-Rector in charge of Education and Quality Assurance at UD-DUT

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UNIVERSITY-INDUSTRY COLLABORATION THEMES IN STEM HIGHER EDUCATION: A EURO-ASEAN PERSPECTIVE

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ABSTRACT

This paper analyses University-Industry collaboration models in Science, Technology, Engineering and Mathematics education. First, a review of published CDIO optional standards for University-Industry collaboration is presented. With strong industrial link requirements, the French related standards for engineering accreditation are then scrutinized and echoed with European requirements. To broaden the perspective, the Swedish and Thai quality criteria for industry links are also reviewed. As a result, five identified University-Industry collaboration themes and criteria of requirements are mapped in a table. Three new emergent themes are also identified based on questionnaires and interviews operated during fall 2019 in the context of a Euro-ASEAN capacity-building project. By identifying themes of collaboration with industry and business, the analysis of this paper lay the foundation of a structured relationship model for STEM universities, to be fueled later by shared good practices among countries. The eight proposed University-Industry themes could indicate directions of development to the CDIO framework for specific optional standard definition, at a relatively high level. This paper may also contribute to advancing 4.0 STEM-educational frameworks for curriculum guidelines aligned with skills for industry.

KEYWORDS

Relationship between Academia and Industry, Work Integrated Learning, Continuous Improvement of Education, STEM, CDIO optional Standards, Standards 1

CONTEXT: NOT PRESCRIPTIVE STEM-EDUCATIONAL FRAMEWORKS

New skills are required in the era of the Fourth Industrial Revolution, now also for the post-COVID-19 era (or with-). As stated by Skills Development Scotland & Centre for Work-based Learning (2018), skills 'serve as the bridge between knowledge and performance. (…) This

bridge is every learner's path to success'. From the perspective of STEM universities (Science, Technology, Engineering, and Maths) and engineering educational institutions, it is crucial to meet new industry expectations in curricula. Institutions are to offer education focused on students' needs but also labour market needs. For proactive alignment of STEM training models with industrial requirements, University-Business-Industry Collaboration (UBIC) is a top concern within educational frameworks.

UBIC Models in CDIO Optional Standards 3.0 Since 2017

In 2017, Rouvrais, Remaud, and Saveuze suggested a potential CDIO new standard to sustain Industry-University partnerships, in addition to a dedicated rubric as a maturity scale for assessment. In engineering education, the CDIO international framework relies on twelve non-prescriptive standards for curricular planning and outcome-based assessment. In this suggestion, partnerships with various types of companies (regional, national, and international) are 'to be in place in the institution and within the formal integrated curriculum. Adequate models of WBL (European Commission, 2016) are to support student competency development of the product, process, system building, knowledge, personal and interpersonal skills, so as of company social contexts and related professional responsibilities.' As a rationale, the curriculum and learning outcomes are designed with authentic pedagogical approaches, in and out of the formal curriculum. Students recognise STEM professionals and especially engineers as role models. With WBL experiences for their students (Rampersad, 2015), faculties are more effective in contextualising their lessons and can better prepare their students to meet the demands of the engineering profession and to become lifelong learners.

In 2018, Cheah and Leong proposed then to extend the CDIO standards in connection with the new manufacturing landscape. After analysing the relevance of each of the twelve CDIO standards to Industry 4.0, the authors recommended two additional standards, along with dedicated rubrics for assessment. The first one industry engagement is defined as 'Actions that the education institution undertakes to actively engage industry partners to improve its curriculum (…) to make explicit the necessity of actively seeking industry feedback not just in designing curriculum, but also in delivering them'. The second is on Workplace Learning and defined as 'A curriculum that includes students working in a real-world work environment with the aims of strengthening campus learning and developing their professional identity. (…) In the workplace, the acquisition of knowledge or skills can occur via both formal and informal means.'

UBIC Models in Suggestive European Frameworks

In 2015, the European QAEMP collaborative project (Bennedsen et al., 2018) introduced in its evaluation handbook three criteria related to University-Industry collaboration, among 27 for cross-evaluation of science and engineering programmes. The first was on stakeholder input, with as rationale 'programme development takes place in a way that engages a range of internal and external stakeholders e.g. Industry Advisory Board and Benchmark Statements. This ensures that the programme is 'fit-for-purpose''. A second criterion was on 'opportunities should be provided at points in the programme to allow students to engage in work-based activities'. A third was on links to employability, with as rationale 'a frequent contextualisation of the learning experiences with respect to future employment possibilities is taking place, (…) to ensure students have the opportunity to develop their ideas about possible careers'.

In 2020, a European initiative suggested the Curriculum Guidelines 4.0 (PwC, 2020) to promote better cooperation between industry and education and training organisations. The

focus is on the alignment of Advanced Manufacturing Technologies education and training with the needs of the New Industrial Age. Eight dimensions are considered, one is in collaboration to 'promote practices that move beyond the typical institutional collaboration patterns, by engaging individuals and communities'. The conceptual principles derived include the following: further increasing university-industry collaboration in terms of both volume and diversity of collaboration forms (e.g. internships/apprenticeships, mentoring, project banks, think tank competitions, summer schools, etc.); acknowledging the role of industry partners as educational, research and employment partners, and ensuring their engagement in the full student's learning experience, including strategy development; creating effective learning ecosystems that engage all key stakeholder groups, including education & training providers, industry, policy-makers, supporting structures and the broader community.

UBIC MODELS IN SOME EU AND THAI ACCREDITATION REFERENCES

Aside indicative educational frameworks for internal quality enhancement, more prescriptive accreditation systems include standards and criteria for external evaluation and labelling.

French Engineering Education Themes

As a Quality Assurance (QA) organisation, the *Commission des Titres d'Ingénieur* (CTI) was established under French law in 1934, with strong industrial link requirements. CTI's board membership comprises 50% of employers and professional engineers' representatives. In France, an engineering graduate school must establish partnerships with counterpart institutions and its stakeholders, particularly employers, industries and communities. The CTI references and guidelines serve for periodic assessment and accreditation, as authorisation to grant the Award of *ingénieur diplômé*. The latest English version (CTI, 2017) is used hereafter to identify the formal UBIC requirements, with verbatim text in quotation marks:

- A formal UBIC requirement to integrate industrial partners in programme design and operation: in the standard B on external links and partnerships, CTI strongly recommends that 'the engineering programmes have established lasting and mutually beneficial relationships with industry. Active professionals are involved in the school's bodies as well as in the design and implementation of programmes' (CTI, 2017). In the standard C on design and follow-up of the training project, CTI also recommends that 'the school has advisory committees comprising professional representatives and alumni; students may participate. For each programme, the committees provide advice for follow-up and update the curriculum' (C2), and 'there is a clear formal process for the design and approval of new engineering programmes. The programmes are regularly reviewed and updated to assess their relevance (C2.3)' (CTI, 2017). 'Significant training time is provided by professionals from the corporate world (e.g. guest lectures) in the University workspaces for theory/practice balance' (C5.2), with a quantitative minimum percentage required. Active professionals are involved in the implementation of programmes (CTI, 2017), a quantitative threshold is fixed;
- A formal UBIC requirement to facilitate Work Placement of students during the curriculum: in the standard C on industry and research internships, CTI requests that 'curriculum include learning experiences which enable the development of practical skills to enhance graduate employability and strengthen the links with industry, […] programmes […] should comprise a significant amount of industrial experience throughout the curriculum, mainly in the form of internships in the industry' (CTI, 2017). Learning experiences that contribute to practical training are to include:

- Internships in the industry: a compulsory integrated internship period for all programmes and students of 28 weeks minimum, with ECTS credits;
- Learning activities that reproduce real-life experiences (projects with industrial partners directly involved, simulations and industry games);
- Industry visits, and seminars organised by industry representatives (CTI, 2017);

- A formal UBIC requirement to analyse graduate employment & employability: in the standard E on graduate employment, CTI strongly recommends that 'the school has an organised approach to surveying and analysing the development of the job market and the employment of engineers' (CTI, 2017). For employment and employability analysis at programme level, 'Surveys are periodically conducted to collect and analyse information on the employment and careers of engineers in general, and more specifically on the employability of degree programme graduates (time to the first job, level of wages, area of activity, etc.)' (CTI, 2017);
- A formal UBIC requirement to prepare students for employment & careers: in the standard E2, CTI recalls that 'the school promotes career guidance and job preparation for future graduates. It values the creation of professional businesses by the engineering students and supports them' (CTI, 2017). In Criteria C5.2, individual orientation activities and coaching is provided by professionals.

European Level Themes for Accreditation

From 2012 to 2015, the European Ministers of the European Higher Education Area gave as a priority for working to improve employability, learning throughout life, the ability to problem-solving, entrepreneurial skills, through enhanced cooperation with employers, especially for the development of training programmes. This formal recommendation applies to all Higher Educational Institutions (HEI) and fields and it has a special resonance for the training of STEM learners in universities. To contribute to the common understanding of QA for learning and teaching across European borders, the Standards and Guidelines for QA of the European Higher Education Area (ESG) were set in 2012. Accordingly, as an instance, the French *Haut Conseil de l'évaluation de la recherche et de l'enseignement supérieur* (Hcéres) set criteria for research-led universities, including their educational programmes and research labs. But the ESG criteria are less complete than for accredited engineering programmes much more industry-oriented, as with CTI in France. In another European country, the Swedish QA system is not strictly aligned with the ESG. The Swedish Higher Education Authority (UKÄ, 2020) proposed an assessment area on Working Life and Collaboration, but with one criterion only, at programme level for engineering. The area is more a recommendation than indicated formal requirements, as written in the assessment procedure: 'The HEI has well-functioning collaborations with the labour market and with the surrounding society that help improve the courses and programmes. Working life and collaboration are systematically factored in as part of the HEI's quality system and quality work. Using information produced within the quality system, the HEI identifies needs for the development of working life and collaboration elements in its education. The HEI implements measures and improves the programmes to ensure they are useful, and continuously develops students' preparedness to face working life. The HEI has systematic procedures and processes for ensuring that planned measures or implemented measures are appropriately communicated to relevant stakeholders, both internal and external' (UKÄ 2020).

On a pan-European level, the European Network for Accreditation of Engineering Education (ENAEE) aims at building a framework, to enhance the quality of engineering graduates and to facilitate the mobility of professional engineers in Europe. ENAEE evaluates the policies and

procedures implemented by accreditation and QA agencies that have applied for authorisation to award the EUR-ACE® label to the engineering degree programmes which these agencies accredit (e.g. CTI). In collaboration with industry, accreditation agencies should confirm to ENAEE that their HEIs (verbatim):

- Achieve the programme aims, which must reflect the needs of employers and other stakeholders (ENAEE, 2015, sec. 2.4.1). The aims should take into account employment opportunities for graduates and the needs of employers. For such, are the relevant industry and labour market organisations and other stakeholders consulted? Is the methodology and schedule of consultation adequate to identify educational needs? Have the stakeholders' educational needs identified in a way which facilitates the definition of the programme aims and programme outcomes? Are these aims and outcomes described in terms of professional competence profiles and functions/roles/activities expected?
- Provide a teaching and learning process that enables students to demonstrate achievement of Programme Outcomes; if the programme includes time spent in the industry, it should be assessed in the context of its contribution to the achievement of the Programme Outcomes (ENAEE, 2015, sec. 2.4.2). Thus, are the partnerships with public and/or private bodies for training periods outside the university adequate, quantitatively and qualitatively, to the achievement of the programme outcomes?
- Comply with internal QA procedures. Processes of engineering graduate placement monitoring are in place. Thus, do the results of the monitoring of the engineering graduates' job placement and the employed graduates' and employers' opinions on the graduates' education provide evidence of the qualification's value, of the appropriateness of the programme aims and the programme outcomes to the educational needs of the labour market? (ENAEE, 2015, non-prescriptive Appendices sec. 5.5);
- Provide adequate resources. Assistance with external placements should be readily accessible by students (ENAEE, 2015, sec. 2.4.3). Thus, does the programme provide student support services (career advice, tutoring and assistance) relevant to the learning process and enable students' learning and progression easier?

UBIC Thai Criteria

The Thai government provides funding for the public universities to develop degree and non-degree programmes that can produce the graduates equipped with professional competency i.e. STEM skills as well as 21st-century skills. This is to prepare a high-quality workforce that can serve industrial needs for Thailand 4.0 policies. The regulation is ensured by Thailand's Office of the Higher Education Commission (OHEC, 2014) and the Office for National Education Standards and Quality Assessment (ONESQA, 2018). ONESQA has a broad scope and does not provide strategic plans for the industry linkage, being at the institution level, it does not provide UBIC details at the programme level. For work-integrated learning is the policy at the Ministry and university levels.

In Thailand, there is a UBIC linkage in terms of curriculum development, credited and uncredited internships, and learning activities. The industry provides feedback as stakeholders and evaluates the university graduates whether they are well equipped with both hard and soft skills for the jobs in their sectors. The Thai government has launched many programs to involve the industry aiming for enhancing students' learning experience. For instance, the Thailand Science Research & Innovation has launched the Industrial & Research Projects for Undergraduate Students programme, which provides funds for undergraduates to work and help solve industry-based problems in Thai factories/industries. The learning activities echoing UBIC mostly involve project-based learning in the fourth year of undergraduates to complete

science and engineering degree requirements. Furthermore, a ‘Talent mobility’ program was established to assist both undergraduates, and postgraduates to research on industry-based and problem-based learning by providing financial support and also matching demands and interests between university researchers and the industry.

In Thailand, some industries and university alumni also participate to host undergraduates during their third year of the degree programme to work as apprentices for 2–3 months. The internships can also be credited to some degree programmes, according to each curriculum regulation and requirement fixed by the university. Furthermore, some programmes offer cooperative education, where students can be trained in the industries as staff for at least one semester. Each student is supervised by both a mentor from the company and a teacher at home university.

UBIC MAPPING

In suggestive frameworks for STEM education (e.g. CDIO optional standard suggestions and Curriculum Guidelines 4.0), UBIC common themes are thus including Partnerships and Industry Engagement in designing and operating curricula, Workplace and Work-based learning. The QAEMP project added Links to Employability. For prescriptive accreditation standards and criteria (e.g. French CTI, ESG, UKÄ, ENAEE), UBIC themes differ, and sometimes also include employment analysis (e.g. tracer study) and career preparation courses. UBIC recommendations or formal requirements are at different levels. They could be partially required (P), largely required (L), fully required (F), or even not required (N) when no elements are explicitly provided (cf. NPLF scale of ISO33020). A mapping of themes to structure and exemplify UBIC models for Continuous Improvement of STEM Higher Education and Engineering Education, by columns of reference sources, is proposed in the next Table, with its NPLF subjectivity as written requirements in the literature are sometimes ambiguous and interpretative and may not reflect reality. It consists of the following selected themes, bylines, resulting from the previous section analysis:

- UBIC-1: Industrial and Business partner’s implication in STEM programme design, review & revision;
- UBIC-2: Industrial and Business partner’s participation in STEM programme teaching & learning activities;
- UBIC-3: Professional work activities integrated in STEM curricula;
- UBIC-4: Graduate Employment & Employability Analysis at STEM Schools;
- UBIC-5: Students Preparation for Employment & Careers in STEM programme.

Table 1. Tentative Mapping of UBIC Themes in some Frameworks Applicable to STEM Education, NPLF requirements according to ISO33020 scale.

NPLF req. scale	CDIO (Rouvrais & al 2017)	CDIO (Cheah & Leong 2018)	QAEMP (Bennedsen & al 2018)	Guidelines 4.0 (PwC 2020)	France (CTI 2017)	Sweden (UKÄ 2020)	EU (ENAEE 2015)	Thailand (ONESQA 2011)
UBIC-1	L	L	L	N	F	P	F	L
UBIC-2	L	N	N	L	F	N	N	P
UBIC-3	L	L	L	L	F	N	L	L
UBIC-4	N	N	N	N	F	P	F	L
UBIC-5	N	N	L	N	L	N	L	N

As a discussion, for some UBIC criteria, indicators and thresholds for achieving the so-called excellence are different. Even if incorporating involvement of academic staff, students, and other stakeholders is classical in periodic STEM programme design & revision in most universities, the profound implication of industrial partners can be rather partial (P), quantitatively in the process and decision committees for UBIC-1. For example, Thai QA has reflected industrial and business partners' implications in programme design & revision for curriculum development that has to be done every five years with comments and feedback from industries as one of the stakeholders. To report annually if most Thai public institutions send questionnaires to industries which are employers of some of their graduates to meet ONESQA Criterion 2 (indicators on employability in one year after graduation and employer satisfaction), the formal requirements remain rather partial (P) or empty (N) on other UBIC themes, quantitatively and quantitatively. The quality of research is the main concern. In Thailand, universities also provide cooperative learning which is a collaboration between academic and industry partners (UBIC-3), most curricula accredit vocational training of third-year students. The industry partners take part in mentoring on special projects for fourth-year students. As another example, the formal level of requirements for work placements by French CTI during the curriculum is high (F), with a minimum of 28 weeks (internship compulsory and ECTS credited for all students), including mature processes in place at the institution level.

A EURO-ASEAN COLLABORATION TO SHARE UBIC GOOD PRACTICES

In light of the global fourth industrial revolution era, high quality STEM education is seen as a critical success factor for ASEAN countries' economic growth. In that context, the EASTEM (Euro-Asia Collaboration for Enhancing STEM Education 2019-22) capacity-building project, aims at improving the employability of STEM graduates from ten partner universities by ensuring students acquire skills needed in the workplace. With the knowledge exchanged through the EASTEM partnership, each partner's expertise and experience synergistically enrich each other, and will in turn subsequently benefit all partners. This includes developing strategies for enhancing their STEM education system, to establish a platform for networking on STEM education, and to safeguard the pitfalls of education in rapid changes in science and technology.

The project consortium includes three universities in Europe and ten universities in Thailand, Indonesia, and Vietnam. In EASTEM, most of the STEM programmes under focus are at BSc levels, in 4 years. In that context, methods and tools are already developed for fostering competence integration in STEM programmes and for establishing STEM centres at partner universities. Overall, 17,399 students enrolled are in the scope of EASTEM impacts in ASEAN partners in the short term.

Most universities in Thailand are members of the Council of University Presidents of Thailand (CUPT), and they tend to apply CUPT for quality assurance. CUPT QA at programme level adopted the ASEAN University Network-Quality Assurance, as in Vietnam and Indonesia. The eleven criteria developed in the third version of the AUN-QA model for programme level (Pham et al. 2020) will be studied further in the EASTEM project, as it was done with ENAEE standards for regional levels. As an example, AUN-QA criterion 2 recommends that programme learning outcomes are formulated based on stakeholders' needs. The industry and business partners are the main stakeholders. Out of the scope of this paper, two other national ASEAN Higher Education Quality Standards which include some UBIC assessment areas are under review as well (i.e. Vietnamese Bộ Giáo dục và Đào tạo criteria and Indonesian BAN-PT with its recent flexibility to learn outside the study programme called Kampus Merdeka).

Additional UBIC Themes Also Fitted to ASEAN Local Needs

EASTEM partner universities have enthusiasm to establish or reinforce UBIC themes in their STEM education to better serve the industry and community needs. Nevertheless, the integrated approach and its ecosystem for local impacts have yet to be created and promoted among students, faculty staff, and communities. To broaden the perspective of the UBIC mapping, a qualitative analysis had been run with university partners from two different European (France and Sweden) and the three ASEAN countries. In the first phase, partners were asked what the new missions for their STEM Faculty/Schools or the ones could be to be reinforced within the 3–5 years. The five UBIC themes presented earlier were recognised as missions to be reinforced in priority by most of the partners. Based on questionnaires operated in the fall 2019 and ongoing semi-structured interviews, additional themes and good practices of UBIC models were then identified. Thirty-eight new missions were collected and used to identify new themes or subthemes. Around 50 strengths and 40 weaknesses were collected on the UBIC themes. The philosophical stance is interpretive, to prevent personal bias from influencing, as we emphasise the meanings University STEM programme leaders and deans confer upon their institutional contexts. Three additional UBIC themes were put to the light by partners with the following potential missions:

- UBIC-6: Financial aspects with Industry (strategic QA): public funds are under pressure and external sources will permit to better prepare a high quality workforce to serve industrial needs for ASEAN 4.0 policies: to collect external financial support & resources, to obtain financial support from industrial partners for STEM activities, to foster scholarship from industrial sectors, and to receive support for STEM teaching tools from companies and alumni are keys;
- UBIC-7: Innovation and R&D with Industry (functional QA): a few years ago, some analysis of research development & technology (based on paper publications and patents) in Thailand and south-east Asia (except Singapore) reflected that the research does not strongly contribute to industry development in the country: to develop a research platform for university-industry, to attract the companies setting up R&D centres in University, to integrate industrial environment and startup ecosystem into the campus, and bring students into the incubation, and to collaborate with the industrial partners on human resource capacity building and innovative startup development are keys;
- UBIC-8: Workspaces with Industry (echoing CDIO standard 6): to increase/enrich learning infrastructure and facilities, to obtain support for improving education facilities, to create a real-life learning environment from companies for students, and to receive support from companies that experiential and creative learning spaces for students are keys.

The qualitative analysis opens up new prospects, e.g. the need to investigate further on guiding partners on how to integrate competence development for students into STEM education programmes and university strategies by engaging with deans, vice-rectors and rectors, echoing CDIO standard 1. With the knowledge to be exchanged and capitalised in the next phase via focus groups and workshops with high-level University representatives, ASEAN partner institutions may acquire the capacity to develop their processes for continuous integration of competence development aspects into their educational programmes and university strategies and policies, including the 5 + 3 UBIC themes identified.

DISCUSSION AND INSIGHTS

Requirement and maturity levels in UBIC models differ greatly between the countries and institutions (e.g. prescriptive with quantitative minimums, quality assured formal processes to be in place) and are part of the international diversity, culture, educational and industry history, and national economic growth. In the EASTEM project, good practices are already identified and categorised according to UBIC themes, with collaborative support from the university management of the EASTEM partners. One objective is that STEM programmes will be more sustainable and partner institutions better equipped to interact with corporate partners in the development of their STEM-university education.

The results of this paper could echo strategic plans and policies on higher education in two communities. First, with eight UBIC themes categorised and mapped, this paper may contribute input to advance the CDIO framework's optional standards with UBIC. Recently, the CDIO council recommended a 'deeper analysis of the proposals industry engagement, workplace learning and workplace and community integration, considering several alternatives: Integration into the texts of core standards, merging or separate elaboration. This is essential future work' (Malmqvist et al., 2020). Secondly, within the EASTEM international partnership in the ASEAN 4.0 contexts (WEF, 2017), to sustain the change in the ten ASEAN partners on a strategic level, updated university strategies on UBIC will be stimulated, echoing CDIO standard 1. University and industry competency alignment for the new Industrial Age is now a consideration, but strategies, priorities, regulations, culture of change, and problem facing differ. But for enhanced UBIC, Industry and Academia values and actions need, however, to be shared, and collaboration reinforced. Resistance factors remain as stated by Morell (2014): 'Industry and academia have different cultures, different values, different needs and different expectations. (…) The biggest barrier that may exist is the failure to recognise that each sector has different needs.' In EASTEM partnership, by engaging with deans, vice-rectors and rectors in each institution, hopefully, UBIC models and guidelines are to be shared for proposing a reference model on governance including UBIC strategies and missions (strategic QA rather than functional QA only). For partners to effectively start or reinforce their competence integration process in their selected STEM programmes and STEM centres, aligned with industrial needs, reaching collaborative conclusions on how to adapt programmes with UBIC in the EASTEM framework is now a prospect.

Worth to be noted, the COVID-19 pandemic will change the future of work and students' employability and careers. As recently argued by Fernandes (2020), 'a global recession now seems inevitable. But how deep and long the downturn will be (…) also depends upon how companies react and prepare for the restart of economic activities.' How do STEM higher education systems cope with and will recover from the crisis? UBIC themes in STEM education in the post-COVID-19 are to be further explored.

ACKNOWLEDGMENTS

The authors would like to acknowledge all their colleagues from the EASTEM project, co-funded by the Erasmus+ Programme of the European Union (www.eastemproject.eu, reference 598915-EPP-1-2018-1-SE-EPPKA2-CBHE-JP). More specifically on these University-Industry collaboration themes, for their inputs are thanked in Vietnam Duong Van Hieu from HUS, Le Tan Cuong from HCMUTE, Tran The Van from UTEHY, in Indonesia Arlinta Barus from IT Dell, I Made Supartha Utama from UNUD, Irwan Endrayanto from UGM, Muhammad Zuhri Catur Candra from ITB, in Thailand Somkid Amornsamankul, Tipaluck

Krityakierne & Wasakorn Laesanklang from Mahidol University, Yupawadee Somboonkul, Tanate Panrat & Jarutas Andritsch from Prince of Songkla University, and Miriam Tardell at Uppsala University. The European Commission's support for the production of this publication does not constitute an endorsement of the contents which reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

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CDIO Implementation

CDIO IMPLEMENTATION FOR MECHANICAL COURSES AT PHAROS UNIVERSITY IN ALEXANDRIA

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ABSTRACT

Effective and sustainable education of engineering fundamentals is the main objective for any accreditation body such as ABET, in particular the criteria of "Design, Conduct Experiment and Analyze the results." From this perspective, the Mechanical Engineering Department at Pharos University in Alexandria, Egypt, adopted the concept of CDIO (Conceive-Design-Implement-Operate), aiming to stress these criteria over the past three years starting in the academic year 2017/2018. Six courses in mechanical power engineering were selected, and their course specification modified to stress their educational fulfillment in the context of CDIO and enhance the real-world systems approach using prototypes designed and built by students. The presented work intends to summarize the adaptation and implementation of CDIO-based learning through the Engineering Fluid Mechanics course by replacing most of the laboratory instructional experiments with hands-on learning using the CDIO approach where the professional practice is in focus. The CDIO implementation in spring 2018 pursued the four stages (conceive-design-implement-operate), which are described and outlined in this manuscript. Furthermore, based on the students' feedback, satisfaction assessment, and semester grades, the CDIO method proved its capability to enhance student learning and gave a chance for close encounters with the course instructor as well as the mechanical design professor. This is reflected in the overall students' learning, as well as their achievements in comparison to previous semesters. Although the semester work grade still follows the normal curve shape, its standard deviation became smaller, which meant that most students benefited from the CDIO approach in teaching and learning.

KEYWORDS

CDIO implementation, engineering education, enhanced learning, CDIO projects, Standards 8

INTRODUCTION

There are no doubts that educators strive to achieve the highest standards of education practices. Through the past years of strategic cooperation between the Faculty of Engineering at Pharos University in Alexandria (PUA) and the KTH in Sweden, the concept of integrating CDIO within the undergraduate education of mechanical engineering program has received considerable attention.

June 2011 was the first graduation of students from the Faculty of Engineering – Pharos University in Alexandria. Since establishing the faculty in 2006, the university administration and faculty were keen on providing an outstanding learning environment with distinct and developed methods of teaching and learning. The educational and scientific partnership agreement with the Royal Institute of Technology in Sweden KTH marks the efforts of the faculty in the field of international cooperation in order to apply high academic standards concerning the syllabus and follow up. Based on this cooperation, programme at the faculty of engineering at Pharos University adopt the CDIO methodology as the centre for their curriculum. The expected learning outcomes of the courses are structured in four sections; disciplinary knowledge, professional skills, interpersonal skills, and general skills, which include; conceiving, designing, implementing, and operating systems in the enterprise, societal and environmental context.

CDIO Standards consists of twelve properties that characterize an education program that follows the CDIO framework. The CDIO Standards are useful tools in the development of an education program, and it can also be used for self-evaluation.

CDIO recommendations are adopted as best practices aiming to improve the curriculum and to enhance students' learning. The Faculty of Engineering at Pharos University in Alexandria is committed to regular curricula reviews and reform. The implementation of CDIO for the Mechanical Engineering program is a result of such an initiative.

The present manuscript presents the initiatives carried out at the Department and gives highlight to the corresponding outcomes. The different stages of the implementations are described, and related experiments and projects are discussed.

OVERVIEW OF THE IMPLEMENTATION INITIATIVE OF CDIO

Effective education of engineering fundamentals is the main objective for any accreditation body such as ABET, in particular, the criteria of "Design, Conduct experiment and Analyze the results." From this perspective, the Mechanical Engineering Department of Pharos University in Alexandria, Egypt, adopted the concept of CDIO (Conceive-Design-Implement-Operate) to stress these criteria three years ago in the academic year 2017/2018. Practical work and experimentation are of indispensable importance in undergraduate engineering education. Six courses in mechanical power engineering were selected, and their course specification modified to stress their educational fulfillment in the context of CDIO and enhance the real-world systems approach using prototypes designed and built by students.

The CDIO concept has found noticeable attention in engineering curricula worldwide (Poblete, P. et al. 2007). It has been introduced (Yang Yong et al., 2016), the idea of establishing a new application pattern of LAB-CDIO（LABORATORY-CDIO). The LAB-CDIO is the new pattern that runs the CDIO scheme and process in the laboratory-like environment. It combines the assembly of the experimental equipment and the simulation process with the idea, the design, the implementation, and the operation (CDIO). Furthermore, it has been indicated (Karl-Frederik Berggren, et al., 2003) that CDIO is an open architecture endeavor. It is specifically designed for and offered to all university engineering programs to adapt to their specific needs. It is an ongoing developmental effort. Several educators (Cheah Sin Moh et al., 2013) reported that their effort, during the last five years, to integrate the various CDIO skills appeared to be

successful, as validated by the feedback received from students on their learning experience in CDIO-enabled modules; as well as from graduates who responded to their surveys.

In order to overcome the gap between real-world applications and curricular standards, it has been reported that CDIO is an effective approach to achieve such an aim (Crawley, E. et al., 2007). In a comprehensive paper (F. Edward, 2009) the idea of 'Re-understanding of Engineering Education -International CDIO training mode and method' has been raised and indicated that the CDIO engineering education pattern is the latest achievement of international engineering education reform in recent years where students take the active and practical way which has a link between classes and project. It is worth mentioning that it has been emphasized (Edward F. Crawley, et al., 2008) that the proper context for engineering education is in engineering practice, that is, lifecycle development and deployment of products, processes, and systems. They adopted the Conceive-Design-Implement-Operate approach to engineering education and indicated that there are other models that describe engineering practice, which can be used effectively for teaching and to learn engineering.

In a recent paper (Lahtinen, T. and Kuusela, J, 2016) it is reported on why, what, and how they ran this project, and they pointed out that the trigger for this project was the feedback from the students: "we want hands-on projects." Also, they indicate that with proper motivation, the students can form a strong link between theoretical and practical knowledge and skills.
In a recent paper (Cosgrove, T. and O'Reilly, J., 2019), it has been outlined how the reflective dimension has been embedded in the Civil Engineering undergraduate program at the University of Limerick. This paper summarizes the adaptation and implementation of CDIO-based learning of some courses over the past three years by replacing most of the laboratory instructional experiments with hands-on learning using the CDIO approach where the professional practice is focused.

The cited work by (Liang, Z. et al., 2012) pointed out that the use of the CDIO teaching practice in the Hydraulic Driving Technology proves that a positive and effective result can be obtained by the pedagogical method based on practice capability and teamwork collaboration. The reasonable adoption and arrangement of the teaching case of the control valves in the hydraulic molding machine promotes the cultivation of a student's comprehensive ability.

CASE STUDY AND LESSONS GAINED

In this section, a case study related to the implementation of CDIO is presented. Results and outcomes are discussed. The CDIO method is implemented each academic year in 6 senior courses extended through 6-semesters: namely:

A. Three Courses During Fall Semester:
   1. EM 211 Mechanics of Material
   2. EM 214 Mechanical Vibrations
   3. EM 220 Measurements and Sensors
B. Three Courses During Spring Semester:
   1. EM 212 Mechanics of Machinery
   2. EM 252 Engineering Fluid Mechanics
   3. EM 333 Renewable Energy

To illustrate CDIO implementation, EM 252 “Engineering Fluid Mechanics” 3 Credits (2,1,2) is selected in spring 2018. EM 252 has the following catalog data “Similarity and model testing; Flow through pipes; Pipes networks; Pumps.” In this course, piping and pumping are stressed by implementing CDIO in the course contents, as shown in Table (1). As indicated in Table (1) the CDIO implementation pursues the following stages:

In the third week, Stage # 1: Conceive: ideas and creative thinking related to piping & pumping are proposed and discussed with students. They form a group of 5 students with one as a leader to carry out a specific piping system and specific pumps arrangement (4 different systems x 3 pump arrangement x 5 students cover the 60 students enrolled in this course)

In the sixth week, Stage # 2: Design: a specific system associated with piping losses and pumping for each group to be designed. Along with the instructor, a design professor is appointed. A weekly meeting is held for the remaining weeks to help each group in their system design and material selection as well as the practicality of components of the prototype before purchasing any items

In the twelfth and thirteenth week, Stage # 3: Implement: purchasing, fabricating, and assembling the parts into a working piping system, including two pumps and different piping systems. Each system is connected to a pumping system on the hydraulic bench, which has been designed and fabricated by all students through their leaders. The lectures during these weeks concentrate on obtaining the operating point for each group and the associated theoretical analysis for piping losses and pumping different arrangements (single, 2-pumps in parallel and in series). Plate (1) shows the designed and built hydraulic bench including two pumps & four piping systems

In the fourteenth and fifteenth week; Stage # 4: Operate: measurements & analysis and reporting the results obtained by measuring the flow rate using lab rotameter. Also, a pressure gauge is used to measure friction and fitting losses. The number of experiments = 3 pumping arrangement X 5 piping systems = 15 experiments. The analysis involved uncertainty analysis and comparison with the Euler equation of Turbomachinery. A technical report is required from each group and discussed with the instructing professor, to be resubmitted two days later.

Table (1) implementation of CDIO in the course contents

Course Outline	Week
Dimensional Analysis & Flow Similarity and Model studies.	1 & 2
Energy Equation and Basic of Pipelines CDIO: Conceive	3
Pipe Flow Problems & Pipeline application Pipes in parallel and in series	4 & 5
Pipe Network; CDIO: Design	6
Introduction to Turbomachinery	7
Mid-Term Exam	8
Moment of Momentum & Euler Eq.	9
Pump Analysis & Velocity Triangles	10
Performance of Pumps & System Curve Pumps in Parallel and in Series	11
CDIO: Implement, Operate & Test and Results	12,13&14
CDIO: Results analysis and reporting & presentation	15

Based on the students' semester grades, this CDIO method proved its capability to enhance student learning and gave a chance for a close encounter with the course instructor as well as the mechanical design professor. This is reflected in the semester work grades in comparison to grades of previous spring terms. Although the semester work grade still follows the normal curve shape, its standard deviation became smaller, which means that most students benefited from the CDIO way of teaching.

Before CDIO implementation, the course had seven instructional experiments for a large number of students (20 to 25 students per lab), with limited effectiveness of achieving course objectives and a lack of planning and practical hands-on experience. Also, not all students were involved in executing each experiment from a to z. The concern of each student was just completing the data in given tables as per the instruction sheet hand-out. In fact, students without CDIO implementation were studying to pass the exam, after which the subjects were quickly forgotten.

The new course specification retains only two selected basic instructional experiments for piping losses and operating point with one single pump only. The remaining 5 experiments are replaced with the context of CDIO, which stimulates thought and gives time for the students to think and ask questions and get answers during their close encounter with the instructor and design professor. Students became part of the deep learning process involving design and built a prototype to work on the course objectives, which will be retained even after graduation. Also, students have the chance to use pump manufactured data and compare it with theoretical analysis for different pump arrangements.

CDIO was implemented through design, and an apparatus was built to determine water head losses due to fluid friction and minor losses through 4 different piping systems. The operating point for each group was obtained by the intersection of the characteristic curves for pumps purchased from the market. In their report, each group requested to write a user manual for their system, the problems encountered, the cost involved, and also the usefulness of the prototype for future experiments.

Figure 1. Plate (1) Designed and Built Hydraulic Bench including Pumps & Piping Systems
1-Water tank 2-Two identical pumps arrangements (can be operated as single, in series or in parallel) 3-Pressure gauge 4-Rotameter for flow measurements 5-Helical pipe 6-Tube banks 7-Gate valve and Globe valve

In Spring 2019 another set of CDIO prototypes related to the course objectives were designed, implemented, and tested, namely:

Firefighting Experimental Model

The objective of this CDIO project is to design and implement an automatic fire sprinkler system used to save buildings and people according to NFPA 13. The theory involved in the CDIO project is to calculate the pressure losses up until the remotest location in the building from which the pump head and flow rate are calculated.

Three Water Reservoirs Model

The aim of this CDIO project is to identify the change in the flow rate as a result of changing the elevation levels. Three pipelines connect three reservoirs at a common junction. The three reservoirs have different elevations, and water flows from the highest to the lowest reservoir. The main question is: will water flow to or from the middle reservoir? The classic problem concerns the calculation of the steady flow rates and hydraulic grade lines in the system. Three different tanks were used with one designed to be movable by using a motorized mechanism.

Piping Network Model

The objective of this CDIO project is to implement and operate the design and piping network, which consists of 2 pipe loops and 8 -junctions with one supply pipe and one discharge pipe. The theory is based on the Hardy Cross method by assuming the flow rate and iterate to calculate the flow rate and its direction for each pipe (At each junction ∑Flow rate = 0.0 & Pressure for each loop = 0.0)

Venturi Pump Model

The objective of this CDIO project is to implement the design of Venturi, which operates as a pump in a system of piping, tanks, and circulating pump.

CONCLUSION

In conclusion, it can be reported that adopting CDIO-based learning in some engineering courses motivates students and increases the effectiveness of learning objectives which is reflected not only on the deep understanding of piping and pumping systems but also on acquiring the ability to work in a team and enhancing their professional and practical skills. Moreover, student-faculty interaction is greatly improved through continuous supervision throughout the semester and answering questions that were never asked before implementing CDIO.

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SUPPORTING CROSS-CULTURAL UNIVERSITY EDUCATION

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ABSTRACT

Current and future students will work in a rapidly changing world that differs significantly from the present situation. We do not know exactly which new learning outcomes will be needed, but population growth combined with globalisation and digitalisation makes it clear that a global mindset and the ability to effectively operate in a multicultural environment will be crucial. Student immersion into different cultures within a university might facilitate the development of intercultural competence within "the international classroom"; however, the competencies and support of teaching staff are also essential for optimising this process. This paper shows the approach of Wageningen University towards the international classroom, including its student population, policies, informational resources, and support activities. The teachers are relatively experienced with the international classroom, but additional training was requested and developed. The first six training sessions provided, received positive evaluations, showing that even in a situation with experienced teachers and clear policies and support for the international classroom, additional training is still valuable. The overview of policy, activities, support, and training might help other universities to reflect on their approach towards cross-cultural university education.

KEYWORDS

Diversity, 21st-century skills, Cross-cultural, Teacher training, Standards 2, 3, 7, 8, 9, 10

INTRODUCTION

The global population has increased from under one billion 200 years ago to over 7.7 billion today (Roser & Ortiz-Ospina, 2019; World Population Review, 2020). The growth rate has declined to 1.12% in 2018, but the population is still expected to climb to more than 9 billion by 2040 (World Population Review, 2020). Combined with increasing urbanisation, the effects of this enormous growth in a short time span are quickly reshaping our world.

In addition, the human population is innovating society ever more quickly, which, according to Kamp (2016), is the result of three major forces:

1. globalisation and digitalisation,
2. the horizontalization of the socio-economic world,
3. the blending of technical, economic, and societal cultures.

These forces, combined with population growth and urbanisation, have a strong impact on technology, business, and organisational and social systems. Current and future students will, therefore, work in a rapidly changing world that differs significantly from the present situation. We do not know exactly which new learning outcomes will be needed, but population growth combined with the first force (globalisation and digitalisation) makes it clear that a global mindset and the ability to effectively operate in a multicultural environment will be even more crucial in the future.

In addition, global challenges such as clean energy and climate action, as formulated by the United Nations (2015), will require effective intercultural cooperation (Hofstede, Hofstede & Minkov, 2010). Tomorrow's workforce will need to undergo a shift in cultural perspective and a bridging of behaviour across cultural differences. This requires students to learn to shift from a mono-cultural mindset of denial and polarisation to the intercultural mindset of acceptance and adaptation, as described by Hammer (2012).

Wageningen University & Research (Wageningen University) expects its graduates to be able to work on global challenges, compete for jobs in an international environment, and function well in a multicultural setting. It considers an international classroom, in which the experiences of students from different countries can be shared, to be one of the best settings for learning intercultural skills (Wageningen University, 2017). Immersion into different cultures might not be sufficient to facilitate the development of intercultural competence, however, as shown by Hammer (2012) for a largely English-speaking country (although this might be more effective for universities in small non-English-speaking countries). The efficient utilisation of international groups for intercultural learning ("the international classroom") requires the competencies and support of teaching staff to facilitate this process.

Wageningen University has a long tradition of supporting the international classroom through its policies, informational resources, and activities. An inquiry among Programme Directors led to requests for additional international classroom training for teaching staff. This paper provides an overview of the existing policies and support for the international classroom and presents the results of the training programme developed in response to the requests of the Programme Directors.

The entire overview of policy, activities, support, and training might help other universities to reflect on their approach towards cross-cultural university education.

THE APPROACH OF WAGENINGEN UNIVERSITY

Intercultural Classroom Composition: PhD Students

Wageningen University has 2121 PhD students from 109 countries (Wageningen University, 2020). Only 33% of them are Dutch, while 37 nationalities are each represented by 10 or more PhD students. The top 12 most frequent countries of origin are distributed across four continents, as shown in Table 1.

Table 1. Top 12 most frequent countries of origin for PhD candidates at Wageningen University, and the number of PhD candidates from each of them (January 2020)

The Netherlands	711	Italy	53	Kenya	39
China	305	Ethiopia	48	Spain	36
Germany	82	Mexico	45	Greece	34
Indonesia	74	India	45	Brazil	28

Intercultural Classroom Composition: MSc Students

Since 2002, all Master's programmes at Wageningen University are taught in English, resulting in a large enrolment of students from outside the Netherlands. In 2019, 62% of the first-year MSc students were Dutch, while the rest came from all over the world. (Table 2).

Table 2. First-year MSc enrolment by nationality (October 2019)

All first-year MSc students			2,498
		Chinese	202
Dutch	1,559	Indonesian	46
		Indian	43
Italian	98	American	18
German	88	Mexican	14
Greek	63	Ghanaian	14
Spanish	54	Colombian	13
French	32	Turkish	12
Belgian	16	South Korean	8
Portuguese	15	Kenyan	7
British	11	Thai	6
		Taiwanese	4
		Tanzanian	4
Total other European	444	Total non-European	495

Intercultural Classroom Composition: BSc Students

Until 2018, the first-year BSc courses were taught partially in Dutch, resulting in a low BSc participation rate for non-Dutch students (most of whom came from Belgium and Germany). From September 2018 onwards, six of the 19 BSc programmes are offered entirely in English, which has resulted in 7.7% of first-year BSc students coming from outside the Netherlands in September 2019. This percentage is expected to increase over the next ten years.

International Classroom Policy

The strategic plan of Wageningen University states that "*We prepare all our students for work and life in an international, intercultural and multi-stakeholder environment."*

The policy regarding intercultural competence and the international classroom is described in more detail in the Wageningen University Vision for Education (Wageningen University, 2017):

"We expect all our students to be open-minded, eager to develop multicultural skills, and to have a good level of proficiency in English. In the international classroom, lecturers are encouraged to use the experience and background of the (international) students in their courses. We strive for a balance in the international classroom, monitoring the composition of classes in terms of incoming students, and adapting our recruitment strategies when necessary. Almost all our students go abroad or work in an international company or organisation during their time at Wageningen University. We maintain an extensive network of international partners to facilitate student exchange and offer the possibility of double and joint degrees. On-campus, we provide a welcoming atmosphere for people from all over the world by using English in all our communications, organising international events, and by providing essential administrative and practical support."

Tackling More Differences in Engagement Caused by Increased Diversity.

Biggs and Tang (2011) analysed changes in the nature of higher education and reported that they result in higher levels of diversity among students. The consequences of this are that universities must deal with larger differences in engagement between students. Wageningen University is experiencing this phenomenon and tackles it by implementing flexible learning paths and smart combinations of teacher and learning activities (van Puffelen, 2017), particularly with the use of balanced combinations of online and face-to-face teaching and learning activities (van Puffelen, van Berkum & Diederen, 2018).

Information and Support Activities

Wageningen University is constantly improving its information and support activities for the international classroom. In 2019, the centrally organised activities and informational resources consisted of:

- Guidelines on working with multicultural settings
- One World Week: a week of many activities celebrating diversity
- An extensive website for international students and staff, covering many topics such as healthcare, housing, and international communities on Facebook.

There are also information and support activities specifically produced for international staff, including:

- A buddy system for new international staff
- A monthly partner programme with social activities for staff and their families
- Workshops providing an introduction to the Netherlands (6x per year)
  Partners can also attend
- A language policy: all staff must have a certain level of English language
- International staff groups organising social events with an international scope
- Intercultural Competences training within the didactic programme for teachers
- Centre for Immigration procedures and support for incoming international staff
- Career support for partners
- Information for international staff regarding tax and salary/scholarship regulations
- Employee survey questions on satisfaction about international orientation
- A travel policy and Erasmus mobility for staff members to learn at another university

ADDITIONAL SUPPORT

Questionnaire

Policy implementation and the provision of information and support are ongoing activities that can be extended with additional actions if required. In December 2017, a small-scale questionnaire with options for additional support was offered to the Directors of the study programmes. The Directors of 11 study programmes responded, for a total of eight people (some are directors of multiple programmes). The results are shown in Table 3.

Table 3. Total number of requests for each support option

Support requested	Total number
A toolbox with materials, good practices and literature on Internationalisation	8
Training of staff	8
Pre-, during and post-course training for students	1
Intensive tutor training	2
Materials for student workshops on intercultural communication	8
Exchange with others (such as Programme Directors) working on Internationalisation	7
Support from an expert in this field on …	2
Training for teachers on how to teach students from other cultures and backgrounds	2
Training for international teachers on how to work and learn with colleagues or students from other cultures and backgrounds	4

Of course, this was a very limited survey. Nevertheless, there seemed to be a clear request from the Programme Directors for additional support. The toolbox and materials requested were developed by the EQUiiP programme (EQUiiP, 2020). This is supplemented by a toolbox developed within 4TU.CEE (4TU.CEE, 2020b). The additional training programs requested were developed by Wageningen University. They are described below.

The Additional Training Programme

The development of the training programme started at the beginning of 2018, and the first six training sessions were offered between May 2018 and March 2019, as shown in Table 4. The training programme continues for the next three years, with upcoming training sessions displayed on the 4TU.CEE event webpage (4TU.CEE, 2020a). The sessions are available for staff at all four universities within 4TU.CEE, occasionally also for other universities and organisations, and offered on any requested location.

Table 4. The first six training sessions offered

Training session	Date
Supporting international students: how to turn fear of failure into competency	9-5-2018
How to beat procrastination	15-6-2018
Inclusiveness for better study results	18-9-2018
From emotional to cultural intelligence	21-9-2018
Culturally appropriate and effective feedback	14-12-2018
Teaching in the international classroom	21-3-2019

All training sessions were evaluated using the online university course evaluation system to ensure an objective and anonymous evaluation. There were 13 questions about the usefulness and quality of the course and its constituent parts. They were scored using a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree), with 3 representing a neutral score. There were two additional questions on the course as a whole, which were marked on a score of 1 (very bad) to 10 (excellent). The response rates for the sessions ranged from 33% to 74%, which is normal for anonymous online evaluation. The results are shown in Table 5.

Table 5. Evaluation results of the training sessions (average of all participants)

	International students: from fear of failure to competency	How to beat procrastination	Inclusiveness for better study results	From emotional to cultural intelligence	Culturally appropriate and effective feedback	Teaching in the international classroom
The learning outcomes were clear to me	4.4	3.9	3.6	4.3	4.2	4.5
The course activities fit well with the learning outcomes	3.8	3.9	3.6	4.5	3.4	4.3
The achievement of the learning outcomes contributed to a better performance in my teaching/guiding	4.3	4.1	3.5	4.0	4.4	4.3
The course subjects were relevant to the learning outcomes	4.2	4.1	3.8	4.0	3.6	4.2
The order of subjects discussed in the course was good	4.4	4.3	3.8	4.3	3.4	4.4
The format of the course stimulated to participate actively	4.6	4.4	4.3	4.8	4.6	4.6
The course format stimulated me to reflect critically on my experiences and learning process	4.3	4.3	4.1	4.0	4.0	4.6
The reference material is useful and relevant to the learning outcomes	4.1	3.8	3.4	4.0	4.2	4.2
The training methods helped me to achieve the course learning outcomes	3.9	3.7	3.6	4.5	3.3	4.0
There were sufficient opportunities to exchange ideas with, and learn from, fellow course members	4.4	4.2	3.8	4.5	5.0	4.3
The feedback and interventions by the trainer(s) helped me to achieve the course learning outcomes	4.0	4.3	3.8	4.8	3.8	4.0
The course content fits my knowledge, experience and personal goals	3.9	4.1	3.8	4.8	3.4	4.5
What I learned in the course can be directly used in my teaching practice	4.1	4.0	3.4	4.3	3.6	4.0
Mark between 1 (very bad) and 10 (excellent) for your own contribution to the course	7.2	7.6	7.3	8.3	7.4	7.2
Mark between 1 and 10 for the course as a whole	8.1	8.1	7.3	8.5	6.6	8.2

For all training sessions and questions with answers on the five-point Likert scale, the average score was above neutral, ranging from 3.3 to 5.0 (with an SD between 0.4 and 1.5). These relatively positive results were also seen on the ten-point scale evaluation of the course as a whole. Four of the average course scores were above 8 (very good), one was 7.3 (good), and one was acceptable but with room for improvement (6.6). The first five of the six training sessions were newly developed, and their relatively well-received first versions are a good start. Of course, the evaluation results also contained text remarks and suggestions, which will be used to further improve the next versions of the training sessions.

DISCUSSION AND CONCLUSION

The MSc and PhD students of Wageningen University come from all over the world. Their course groups are truly multicultural, albeit with relatively large numbers of students from the Netherlands and Asia. Most Wageningen University teachers have experience with this environment, and some international classroom training is included in the teacher training programme for the University Teachers Qualification (in use from 2009 onwards). Wageningen University supports the effective use of the international classroom through its policies, informational resources, and actions; however, additional requests for further support, including training, were made by Programme Directors.

The evaluation of the first six additional training sessions showed that such training is useful, even in an environment with experienced intercultural teachers. Of course, it will take a few years to train sufficiently large numbers of teachers to detect the effects of these courses on a university scale, but the positive evaluations of these training sessions suggest that they improve the ability of teachers to utilise the intercultural classroom for the development of intercultural competence. For many students, international classroom training is supplemented with intercultural learning during internships and research performed in other countries and cultures. These experiences might also benefit from teachers provided with additional support training, which will help teachers in their role as long-distance mentors.

FUTURE WORK

The training programme is continuously improved using (post) session communication with participants and the information about the online course evaluation system. This has also resulted in more focus on the dynamic of intercultural, interdisciplinary group work from 2020 onwards. There is a high demand for the sessions at the four universities, and the sessions are continuously scheduled a year ahead (4TU.CEE, 2020a). This is supplemented with dedicated sessions on request. Wageningen University started six international BSc programmes in 2018, resulting in an increase in the enrolment of international undergraduate students. From 2020 onwards, a research programme explores the effects of that shift in more detail.

ACKNOWLEDGEMENTS

We would like to thank our partners within 4TU.CEE, especially at the University of Twente, for their contribution to the discussions and text of the Programme Directors questionnaire. We would also like to thank colleagues in the Quality and Strategic Information Section of Wageningen University for their help with the provision of enrolment data and the evaluation of the training sessions.

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CASE STUDY ON SELF-DIRECTED LEARNING IN YEAR 1 CHEMICAL ENGINEERING

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ABSTRACT

This paper provides a case study on how the Diploma in Chemical Engineering (DCHE) integrates self-directed learning (SDL) into its 3-year curriculum using the CDIO Framework. The paper first provides a brief overview of the DCHE spiral curriculum and our SDL model; and how we aim to progressively develop this competency in our students by explicitly teaching of SDL skills. The paper then presents details of how we integrate SDL into core modules, starting with answering with the questions: (a) The full set of knowledge, skills, and attitudes that engineering students should possess as they leave the university, and the required level of proficiency, and (b) The way that we can do to ensure better that students learn these skills. The paper thereafter shares how we define the desired learning outcomes and proficiency level for SDL. For the former, we refer to the SP-customized CDIO syllabus for the underpinning knowledge of what constitutes SDL in general, as well as the Technical Skills and Competencies of the Energy and Chemicals Skills Framework (E&C SF) of the Singapore SkillsFuture Initiative to provide the technical knowledge and context of SDL in the practice of chemical engineering. For the latter, we refer to the Generic Skills and Competencies of the E&C SF. The paper then shares the design of learning tasks in the Year 1 Semester 2 module *Laboratory and Process Skills 2*, with examples of real-world job roles and the responsibility of a chemical process technician or technologist in the chemical processing industries. The paper also shares our efforts of providing scaffolds and online guidance questions to help students in their learning, and use of reflection journal to evaluate if they had developed the required competencies. Lastly, the paper shares results of our survey of the students' learning experiences in their SDL journey and possible areas of improvement. (304 words)

KEYWORDS

Chemical Engineering, Spiral Curriculum, Self-Directed Learning, CDIO, Standards 1, 2, 3, 6, 7, 11

NOTE: Singapore Polytechnic uses the word "courses" to describe its education "programs." A "course" in the Diploma in Chemical Engineering consists of many subjects that are termed "modules,"; which in the university contexts are often called "courses." A teaching academic is known as a "lecturer," which is commonly referred to as "faculty" in the universities.

INTRODUCTION

In an earlier paper, Cheah et al. (2019) shared the general approach taken by the Diploma in Chemical Engineering (DCHE) to integrate self-directed learning (SDL) into its 3-year course which is structured around a spiral curriculum (Cheah & Yang, 2018) as shown in Figure 1. The earlier paper shared how SDL was introduced into the Year 1, Semester 2 core module entitled *Laboratory and Process Skills 2*. This paper shared specific activities in the module to illustrate how CDIO is used and provide an update to the experience gained from the module redesign process.

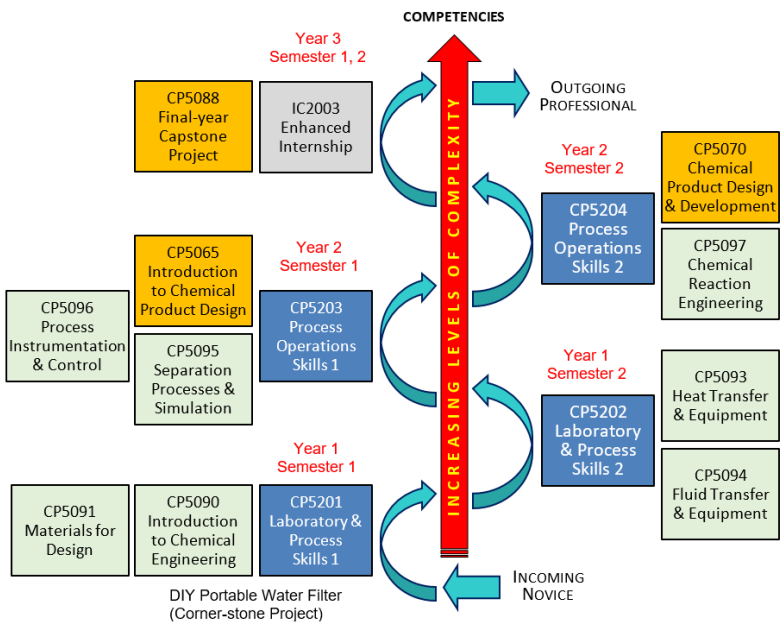

Figure 1. Integrating SDL into DCHE Spiral Curriculum

The inclusion of SDL into the integrated curriculum (CDIO Standard 3) involves the explicit teaching of key steps in becoming a self-directed learner using the model, as shown in Figure 2, which also includes the teaching of good thinking heuristics (Cheah et al., 2019).

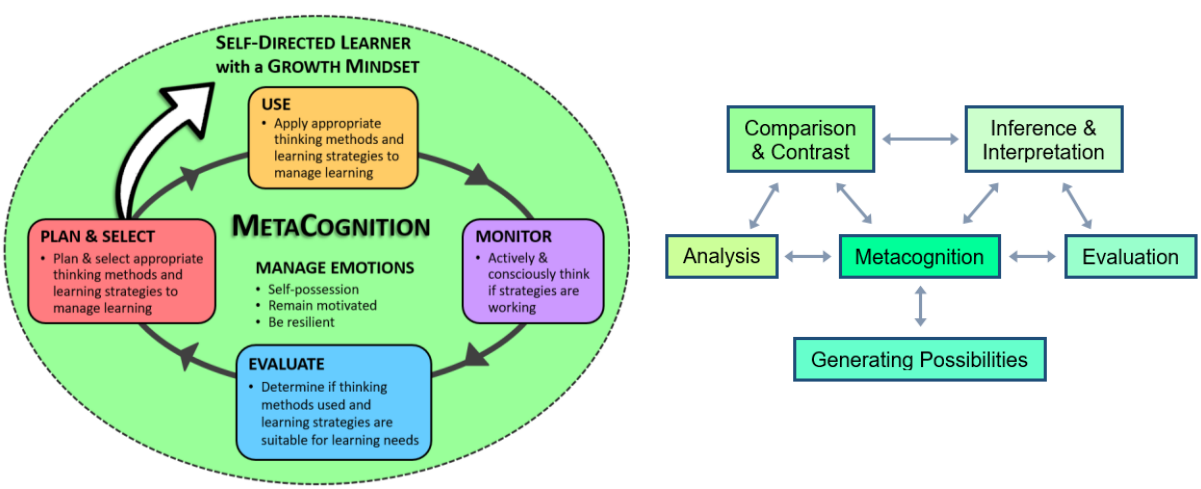

Figure 2. DCHE SDL Model (left) supported by Sale's Model of Thinking (right)

THE CDIO DESIGN APPROACH TO INTEGRATE SDL SKILLS IN CURRICULUM

Using the CDIO approach, we seek to answer the following questions posed by Crawley et al. (2007):

- 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?
- How can we do better at ensuring that students learn these skills?

We first unpacked the notion of SDL by taking reference from the SP-customized CDIO syllabus, in particular, section 2.4.6 which showed the underpinning knowledge for what constitutes SDL:

Engage in Lifelong Learning (Self-directed Learning)

Identify key aspects of the learning process

Explain how emotions and beliefs affect learning

Explain the motivation for lifelong learning, e.g., curiosity, professional development, etc

Appraise one's own learning needs

Identify strategies and skills for lifelong learning

Use a range of learning strategies and skills (e.g., goal setting, learning plans, managing information, receiving feedback, etc.)

Evaluate competence attainment in terms of goal(s) set and strategies employed

In terms of proficiency level in SDL, we find it more convenient to refer to the Generic Skills and Competencies (GSC) spelled out in the Singapore SkillsFuture Initiative (Cheah, 2018), which is valid for all industry sectors in the country. There are altogether 18 GSCs, and each contains 3 levels of proficiency, namely Basic, Intermediate and Advanced. The specific GSC for lifelong learning, which is defined as: "*Seek out opportunities to enhance one's knowledge and skills. Access and acquire new knowledge and skills actively for continual learning*." Its 3 levels are as shown below:

- Basic: Organise and manage their learning by setting learning targets. Identify learning approaches to achieve work or career goals.
- Intermediate: Engage in collaborative learning by discussing one's learning with others and soliciting feedback to improve oneself continually.
- Advanced: Conduct self-reflective practices to review one's learning to facilitate continual growth in one's career or profession.

For our students, we aim to develop our students' SDL competency up to the Advanced level, in line with the aspiration of the SkillsFuture Initiative as well as the institution's new educational model currently under development. The acquisition of SDL competency is to take place simultaneously with the application of technical know-how (CDIO Standard 3) from the Energy & Chemicals Skills Framework. This will be elaborated later. The module *Laboratory and Process Skills 2* is a 45-hr module, taught over 1 semester, i.e., 15 weeks. The schedule is shown in Figure 3. In Week 1, we provide a recap of what they had learned in an earlier module, *Laboratory and Process Skills 1* in the previous semester, and the explicit teaching of the SDL model and the model of thinking (Figure 2). The first 3 activities (on Weeks 2 to 4) is a continuation of laboratory skills from another module, where students are required to use SDL in the 3 activities. This is followed by debriefing on Week 5 on what had been covered up to that point. The debrief also marked the conclusion of laboratory skills for students, where they

will subsequently move on to develop capability in process skills – skills used by chemical engineers, technologists, and technicians in the operation of chemical plants.

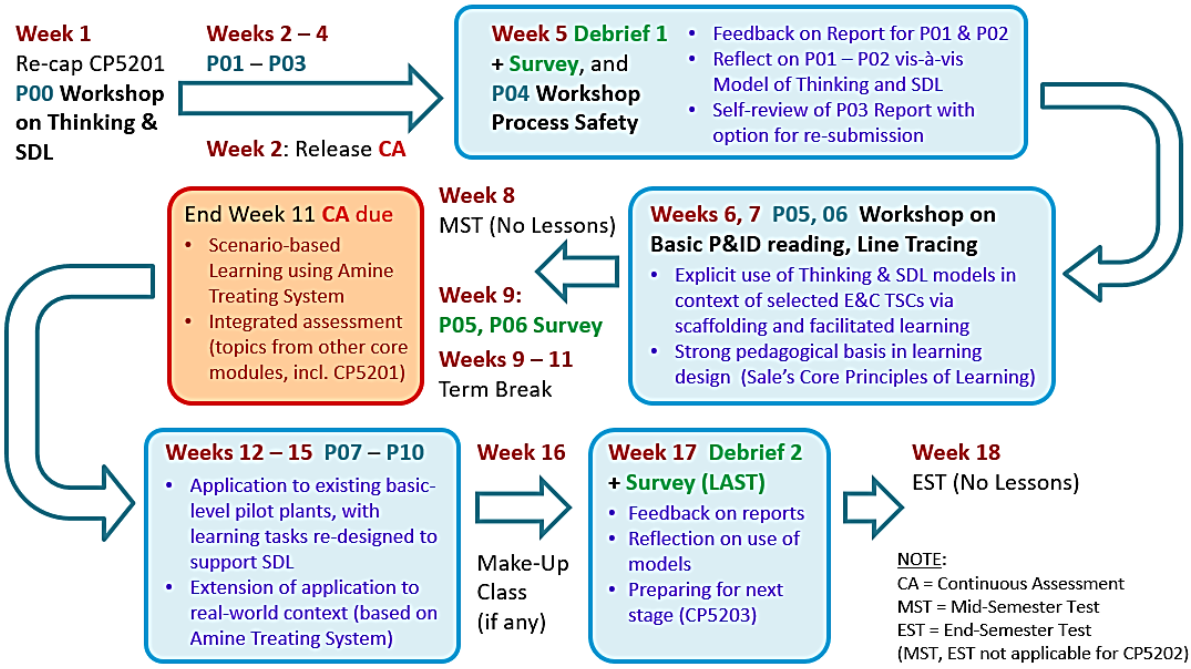

Figure 3. Development of SDL Competency in *Laboratory & Process Skills 2*

DESIGN OF LEARNING TASKS TO SUPPORT SDL COMPETENCY DEVELOPMENT

The specific learning tasks described here took place on Weeks 6 and 7, where students learned about job roles and key tasks required of Process Technicians and Senior Process Technicians in the chemical processing industry through two "workshops" with integrated learning experiences (CDIO Standard 7). These "workshops" (shown as P05 and P06 in Figure 3) are aimed at helping students to acquire key competencies in reading piping and instrumentation diagrams (P&IDs) and carry out line tracing for the pilot plants that they will later operate on in Weeks 12 to 15. A set of P&IDs are essentially the blueprint of a chemical plant, and one can "walk the plant" using a technique called line tracing. The technical aspects of P&ID reading and line tracing are aligned to the Skills Framework for the Energy and Chemicals Sector (or E&C SF in short). More specifically, we take reference from the Technical Skills & Competencies (TSCs) for the track "Production and Process Engineering," which best meets the career pathway for our graduates, i.e., starting with Process Technician. There are many TSCs within this track, as shown in Table 1, and many are amenable to be used in the teaching of SDL. As our intention is to teach SDL from Year 1, we choose the TSC for "Engineering Drawing Interpretation and Management" to provide the context of learning (CDIO Standard 1) and learning outcomes to be achieved (CDIO Standard 2). Also noteworthy is TSC proficiency level, which ranges from 1 to 6 that matches the job role (for details see Appendix 1). For our students, we select the TSC "Engineering Drawing Interpretation and Management" and pegged the proficiency at level 2 for Process Technician, and up to level 3 for Senior Process Technician as they progressed under the spiral curriculum course design.

(a) Interpret piping and instrumentation diagram (P&ID) of a given process.
- Able to apply prior knowledge in Block Flow Diagram (BFD) and Process Flow Diagram (PFD), to explain the operation of a chemical plant using its Process Description
- Able to explain simple Process Control Loops shown in a PFD and the relationship between process variables
- Able to understand symbols shown in a Piping & Instrumentation Diagram (P&ID) in terms of the item (equipment, instrument, valves, and other piping elements) that the symbol represents and how it is connected to other items
- Able to explain information (size, class, material, etc.) contained in a line number as explained in the P&ID's Lead Sheet

(b) Perform line tracing of pilot plants.
- Able to trace a given line (process or utility), locate and identify all items (equipment, instrument, valves, and other piping elements) contained in the given line using the P&ID
- Produce a PI&D sketch (including lead sheets) of a given pilot plant
- Able to obtain additional details about an Item from various sources, e.g., nameplate attached to the item, information stamped on the item, tags, or labels secured to the item, as well as data sheets and vendor catalogs.

Table 1. Skill Map for E&C SF for the Track "Production and Process Engineering"

Skill Map for E&C SF for the Track "Production and Process Engineering"				
Technical Skills & Competencies for the Category "Process Operations Management"	Job Role and Proficiency Level (1 to 6)			
	Process Technician	Senior Process Technician	Production Supervisor	Superintendent
Control Room Operations Management		3	4	
Engineering Drawing Interpretation and Management	2	3	3	4
Feedstock and Product Transfer Operation Management	2	3	4	5
Operations Reporting Protocol Application	2	3	4	5
Process Equipment Preparation for Mechanical Work	2	3	4	4
Process Operations Troubleshooting	2	3	4	5
Process Plant and Equipment Integrity Management				3
Process Units and Utilities Operations Management	2	3	4	5
Standard Operating Procedures (SOPs) Development and Implementation	2	3	4	5

Students were taken through the nuances of P&ID reading in an interactive manner, starting with pictures of various equipment, valves, pipes, and piping components and instruments. Then selected symbols that represent these items, letters representing their functions, and labels that indicate their relative positions are introduced. The students are required to prepare a document called the Lead Sheets that summarizes all this information, which is usually made available in the front part of the set of P&IDs. More specifically, they were taught P&ID symbols for valves, pipes and piping components, and instruments. They need to complete their Lead Sheets for the remainder of the items, namely equipment, which comprises various pressure vessels, columns, towers, heat transfer equipment, and fluid moving equipment. The challenges they faced are real: even though international standards exist for P&ID symbols, there are a plethora of symbols being used, from a chemical company's in-house engineering division; a vendor who markets valves and instruments, a contractor who offers EPC

(engineering, procurement, and construction) services, and P&ID software vendors. Students are required to look for different symbols (from different sources) for the same item, as well as resolving any conflicting symbols (same symbols used for different items) or correcting symbols that were miscategorized. They were then given sets of P&ID drawings for the pilot plants in our workshop (CDIO Standard 6). These pilot plants were supplied by different contractors and suffered from the shortcomings mentioned above. In addition, the part of these drawings also did not reflect actual set-up as the pilot plant were relocated from older laboratories and some re-piping need to be done. The students' task is to use these drawings to do line tracing and sketch new, corrected drawings using the Lead Sheets that they prepared. As part of the deliverables (CDIO Standard 11), they need to submit these drawings for markings, and also to complete short assignments on how they managed their learning and reflections on the use of the self-directed learning model.

FINDINGS FROM STUDENTS' LEARNING EXPERIENCE

This part reports on the finding for the second run of the learning task, with several improvements made based on results of the first run, which was reported earlier by Cheah et al. (2019). More specifically, the following are the changes made to the teaching of SDL, and the support provided for P&ID reading and line tracing:

(1) Teach SDL explicitly on Week 1 – by comparison, SDL was only taught to students for the first run during Week 5.
(2) Provide guidance questions for different stages of SDL in the context of P&ID reading and line tracing as shown in Table 2
(3) Provide samples of poor P&ID Lead Sheets and reflection journals from the first run
(4) Provide facilitation guide on P&ID reading and line tracing to the teaching team

Table 2. Guidance Questions for SDL in P&ID Reading and Line-tracing

Stages of SDL	Guiding Questions
Plan & Select	Draft a PLAN and strategy to achieve your GOAL, e.g., should you do research in the library or use the Internet? Do you know which section in the library to go to, which category to look for, textbook or journals, etc.; If you use the Internet, possible questions include: Which web sites should I search – academic, government, companies, or vendors? How do I learn best? Make my notes, highlighting important paragraphs, or use Post-It notes? How do I cross-check my understanding?
Apply & Use	Are you consciously referring to the learning objectives? Is the information found comprehensive enough? Are you getting the right information? Are these particular Wikipedia entries reliable? Should I Google with something general, e.g., "P&ID," or should I use more specific keywords? How to select among the more than 1,000,000 hits? Are you also consciously tracking your learning strategy – did you ended up deviating, such as resorting to merely memorize things?
Monitor	How are you doing with the selected approach? How comprehensive is one source? What if you found out that different sources show different results for the same item (e.g., plate heat exchanger shown with 2 different symbols from 2 different web sites)? Will you gave up on this source and looked elsewhere? But where? What about the strategy you used – do you think it is working, e.g., did highlighting work for you? Are you overwhelmed by too many highlights? Was looking at academic writings adequate?
Evaluate	How satisfied are you with what you had found? Is there any nagging feeling that you may have missed something? Did you share this with your team members? What is the response? Are there any areas that you would have done differently? What is stopping you from trying out a different approach? Are you inhibited by negative emotion, fear of being rejected? From what you had obtained, are there any new areas or related topics that you discovered that you think you should explore? Why or why not? Should you use the same strategies?

Meta-cognition	Does your previous strategy (where you searched for P&ID symbols for valves as part of Pre-Class Preparation for today) work? If not, why not? Any part of the strategy that worked? Or not work, and why did it not work? How can you adapt/modify it? How about your learning approach, did that worked? Are there any 'interferences' that got in the way, e.g., Your belief ("What is published must be right"), the pressure to conform to group norm – align your view with members? Others?
Manage Emotion	How are you feeling, especially you could not quite get what you are looking for, after visiting several websites? Were there disagreements among members over strategy used? What measures did you take to keep your unhappiness in check –grab a cold drink? Paused and listen to music for several minutes? Others? What do you do to bring yourself back to the search again, e.g., self-vocalization? Look at the inspirational poster on the room wall? Others?

For the second run, we collected information regarding students' learning experience from various sources: survey questionnaire, work done and focus group discussions. The last item was administered by an independent third party without the presence of the author. The main findings are shown in Figure 4 and Figure 5.

Figure 4 is based on the written response in a survey questionnaire where students reported on how the P&ID Reading and Line Tracing Activity can be of use to them when they start their first job as a junior process technician in the chemical processing industry. A comparison is made between students in the two runs. The number of respondents is comparable: 82 valid responses for the second run and 74 valid responses for the first run. The results clearly showed an increase in the number of students who found the 2 "workshops" useful.

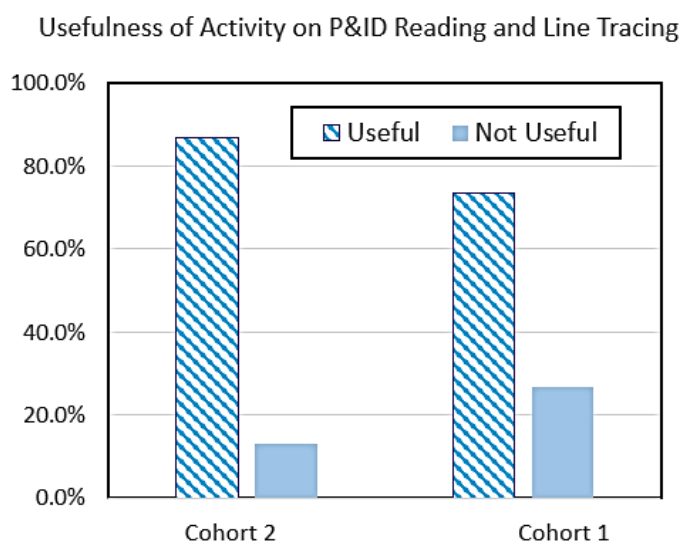

Figure 4. The usefulness of P&ID Reading and Line Tracing Activity

Figure 5 makes a comparison in responses between students in the current second run and those in the first run on how likely are they going to make use of the skill learned in subsequent activities in weeks 12 to 15, as shown in Figure 3. There are again more students who expressed enthusiasm in using the SDL model and competency gained in subsequent activities.

The results showed that there is an improvement in student learning in carrying out P&ID reading and line tracing. This showed that the various interventions introduced into the second run are working, as we also see improvements in the works students submitted. They were able to explain their experience with the SDL model better, and articulated clearly the

importance of P&ID reading and line tracing for the following activities that they will embark on, as well as in the context of their future job role as junior process technicians. Sample entry from a student noted that: "*From P05 and P06, we learned many important ways to do line-tracing and how to read P&ID. These skills will be very important for future practicals. For example, when we are doing line-tracing, we must know where to start. For example, the shell-and-tube heat exchanger, we can start from the liquid in the storage tank and slowly trace the whole system from the start to the end. This will give us a clearer picture of the whole system and understand how to identify the different pipes, valves, and different components in the heat exchanger, and we will also learn how to draw and identify the different parts of any P&ID in the near future. Hence, P05 and P06 are useful, educational, and beneficial*."

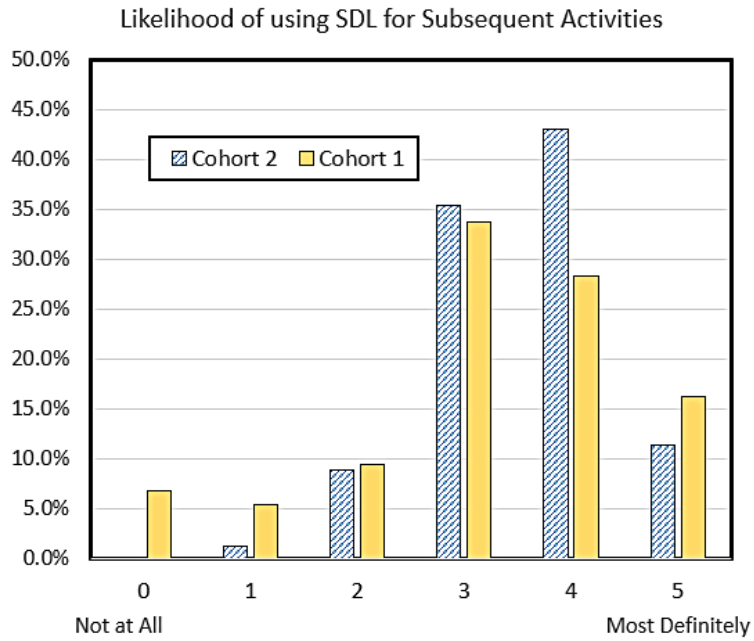

Figure 5. Likelihood of SDL for Subsequent Activities

However, there are also a number of students who disliked the approach taken to bring out their awareness on the importance of SDL, especially in the earlier activities on laboratory skills where they need to suggest their procedures. Some expressed frustration when the team intentionally let them make mistakes in the learning activities. For example, one student commented that it was: "*Unfair to all as everyone wastes time making mistakes. I feel that it would be better to teach students the solution to the problem, then let students have the freedom to expand their knowledge by intentionally making mistakes to learn from that. That way, each person's learning can be quantified by their passion/interest in their course.*" Some of these students felt they are not yet ready for SDL, or simply preferred to be lectured in the traditional way.

On the other hand, there are also students who appeared more positive and did not find the approach frustrating for them, saying: "*I feel that it is quite effective as it allows students to be proactive and learn by themselves before the class starts. It also allows students to be more self-disciplined and not always rely on the lecturers*". One student suggested that the correct procedures be given after they were told of the mistakes, instead of making them rewrite the procedures. Another student was able to see beyond the immediate situation, and commented: "*I understand that it's an important skill that can be useful in the future since there's no one whose going to handhold is and teaching us everything in the future when we go to work.*"

MOVING FORWARD

Such findings are perhaps not surprising, given that we have a total of 145 students of varying academic abilities and motivations towards study, especially when there is a sizeable number where chemical engineering is not even their top 3 choice of courses.

We had also gained important insight into students' perceptions of SDL. While the majority of respondents agreed that SDL is an important competency to acquire, there remained a handful who felt that they could manage their own learning by using their own approaches. When asked the question, "*How do you see the usefulness of the Self-Directed Learning Model in relation to you in learning new things*? Select one option,"; a significant number of students chose the response: "*No, as I feel my own way of learning is still better*." This finding is consistent from the 2 runs: 7.23% out of 83 valid responses for the second run, compared to 6.25% out of 80 valid responses for the first run. A future survey may need to unearth via open-ended question what are the students' current approaches are. The concern here is that some may still rely on rote learning 'honed' through years of secondary school education, which may still work to a limited extend in year 1 of study.We will also review again the learning tasks for the module, not only for P05 and P06 but, more importantly, for the 3 earlier learning tasks, which focus on laboratory skills. In particular, we will completely redesign the first learning task (P01, in week 2) to demonstrate how the steps in the SDL model can be modeled. In the present approach, we simply assumed that students are already comfortable with laboratory skills, having acquitted them from the previous semester (Stage 1A). Hence, we just "bolted on" the SDL model (as covered in week 1) and expect students to use it for laboratory skills; and focus on further developing SDL skills in process skills.

Lastly, the approach to date in supporting the development of SDL skills is still the typical "one size fits all" design. Given the constraints of available resources (equipment, laboratory space, etc.), we are not able to offer individualized coaching that matches the different levels of SDL abilities. In any case, all the workshops and activities are group-based, and students will invariably "parceled-out" the work to be done among themselves, often with an unequal amount of responsibilities. With the availability of affordable Web 2.0 Tools, we may be able to provide more differentiated support mechanisms for students with different learning challenges. An area of improvement is making the guidance questions (Table 2) available "on-demand" via the school intranet, instead of in table form in the appendix of the manual. More importantly, in line with the spirit of self-directed learning, we need to engage students more in taking responsibility for their learning, in the form of self-assessment (Boud, 1995). We intend to supplement the sample reports with the use of evaluation rubrics so that students can better understand the assessment criteria and be able to monitor and evaluate their work. We will need to review the scheduling of the activities (Figure 3) to provide more opportunities for giving students feedback on their work.

CONCLUSION

This paper shares the design of learning tasks to integrate SDL into an engineering curriculum using the CDIO Framework. Although the specific example used pertains to chemical engineering, the approach applies to any discipline. Important learning points include the need to better understand the students' readiness for SDL, especially when dealing with a cohort with diverse academic backgrounds. There are still many rooms for improvement, and we are learning as we travel along this journey. Future works will make greater use of technology to

provide more customized assistance to students with different learning needs to develop their SDL competency.

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Appendix 1. Generic Descriptors for TSC Levels in Skills Framework

Level	Responsibility (Degree of supervision and accountability)	Autonomy (Degree of decision-making)	Complexity (Degree of difficulty of situations and tasks)	Knowledge and Abilities (Required to support work as described under Responsibility, Autonomy, and Complexity)
6	Accountable for a significant area of work, strategy or overall direction	Empower to chart direction and practices within and outside of work (including professional field/community), to achieve/ exceed work results	Complex	• Synthesise knowledge issues in a field of work and the interface between different fields, and create new forms of knowledge • Employ advanced skills, to solve critical problems and formulate new structures, and/or to redefine existing knowledge or professional practice • Demonstrate exemplary ability to innovate, and formulate ideas and structures
5	Accountable for achieving assigned objectives, decisions made by self and others	Provide leadership to achieve desired work results; Manage resources, set milestones and drive work	Complex	• Evaluate factual and advanced conceptual knowledge within a field of work, involving a critical understanding of theories and principles • Select and apply an advanced range of cognitive and technical skills, demonstrating mastery and innovation, to devise solutions to solve complex and unpredictable problems in a specialised field of work • Manage and drive complex work activities
4	Work under broad direction Hold accountability for the performance of self and others	Exercise judgment; Adapt and influence to achieve work performance	Less routine	• Evaluate and develop factual and conceptual knowledge within a field of work • Select and apply a range of cognitive and technical skills to solve non-routine/abstract problems • Manage work activities which may be unpredictable • Facilitate the implementation of innovation
3	Work under broad direction May hold some accountability for the performance of others, in addition to self	Use discretion in identifying and responding to issues, work with others and contribute to work performance	Less routine	• Apply relevant procedural and conceptual knowledge, and skills to perform differentiated work activities and manage changes • Able to collaborate with others to identify value-adding opportunities
2	Work with some supervision Accountable for a broader set of tasks assigned	Use limited discretion in resolving issues or inquiries. Work without frequently looking to others for guidance	Routine	• Understand and apply factual and procedural knowledge in a field of work • Apply basic cognitive and technical skills to carry out defined tasks and to solve routine problems using simple procedures and tools • Present ideas and improve work
1	Work under the direct supervision Accountable for tasks assigned	Minimal discretion required. Expected to seek guidance	Routine	• Recall factual and procedural knowledge • Apply basic skills to carry out defined tasks • Identify opportunities for minor adjustments to work tasks

INCULCATING SAFETY MINDSET IN CHEMICAL ENGINEERING STUDENTS USING AR / VR

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ABSTRACT

This paper shares the experience of the Diploma in Chemical Engineering (DCHE) of Singapore Polytechnic (SP) in using suitable information communication technology (ICT) tools to develop a safety mindset in chemical engineering students through its skill-based modules. In particular, it focuses on the usage of virtual reality to provide a meaningful learning experience. The paper first introduces the four skill-based modules in the DCHE curriculum, where the spiral curriculum model was adopted to provide a systematic structure to build up student competencies spanning across 5 semesters. The spiral curriculum introduces simple concepts first, which are then revisited and re-construed in a more in-depth and elaborated manner through the instructional process over time. The competencies are built on basic key concepts at the beginning of the course, and complex concepts are developed more elaborately over time through various learning activities. The knowledge and skill competencies are leveled up from one semester to another, which allow students to progress from basic know-how to application of principles in various context. The paper then provides a brief explanation of the use of augmented reality / virtual reality (AR/VR) in safety training. It presents our approach to progressively developing safety competency consisting of the spiral curriculum course structure, culminating in the attainment of the desired safety mindset. The first attempt aims to develop workplace safety awareness so that students become aware of safety practices. In subsequent efforts, students learn to identify workplace hazards, evaluate risks posed by various hazards, and eventually demonstrate a safety mindset in a suitable work environment, which signifies the advances in student learning to inculcate a safety mindset. A simple quantitative survey was carried out to evaluate the effectiveness of the training package in terms of engagement of learning and knowledge retention. The preliminary findings indicate that the training package has a positive impact on student learning. The last section of the paper outlines the broad areas where we can continue to improve the development of the safety mindset in chemical engineering students.

KEYWORDS

Chemical Engineering, Spiral Curriculum, Safety Mindset, Augmented Reality / Virtual Reality (AR/VR), Standards 1, 2, 3, 5, 6, 7, 8, 11

NOTE: Singapore Polytechnic uses the word "courses" to describe its education "programs." A "course" in the Diploma in Chemical Engineering consists of many subjects that are termed "modules,"; which in the university contexts are often called “courses.” A teaching academic is known as a "lecturer," which is commonly referred to as "faculty" in the universities.

INTRODUCTION

The Diploma in Chemical Engineering (DCHE) produces graduates to meet the manpower needs of the chemical processing industries. Safety is of paramount importance to all personnel working in the chemical plants. In DCHE, we strive to instill in students a safety mindset right from the beginning when they start their study in Semester 1, Year 1. We have the opportunity to improve on our safety training when we changed our course structure based on spiral curriculum design. Details of the work done had been covered previously by Cheah & Yang (2018). For this paper, it is sufficient to note that one aspect of the DCHE curriculum needs to be enhanced is the use of Augmented Reality / Virtual Reality (AR/VR) in safety management. With the roll-out of the DCHE spiral curriculum course structure, the teaching of process plant safety will be progressively enhanced via 4 skills-based modules, as shown in Figure 1 (Cheah, Wong & Yang, 2019).

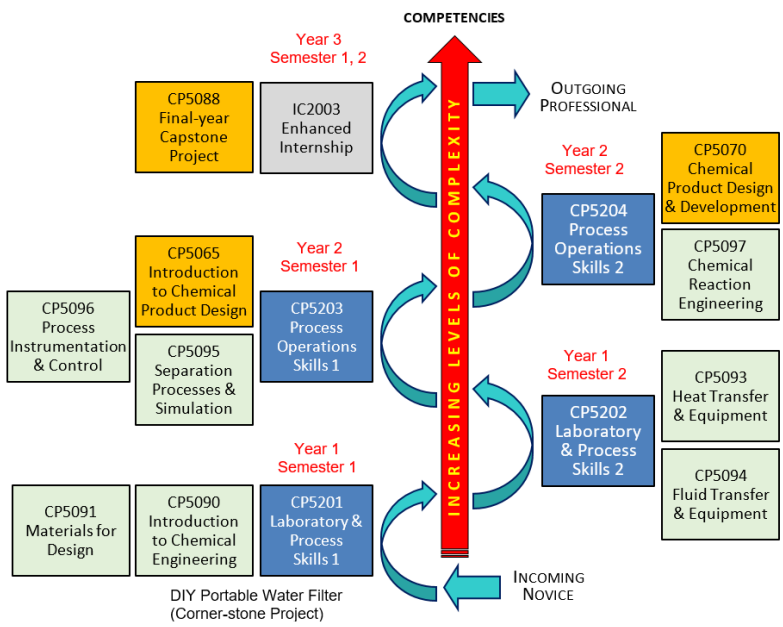

Figure 1. Progressive Learning via Spiral Curriculum

Furthermore, a study by Cheah & Leong (2018) on the relevance of CDIO Framework in the advent of Industry 4.0 suggested that one can expand on the interpretation of the existing 12 CDIO Standards to continue guiding curricular redesign. For example, engineering workspaces (Standard 6) can be "enlarged" to include virtual workspaces as well as shop floor in companies. The ways students are engaged actively and experientially (Standard 8) can be enhanced by the use of 3-D visualization afforded by AR/VR in an immersive learning environment (Standard 7). In this paper, we share our approach of using CDIO standards to guide us in the design of a progressive learning pathway from Year 1 to Year 3 to develop in students the necessary safety mindset that is absolutely essential while working (often alone) in the chemical plant to ensure not only personal safety but also process and equipment safety in terms of hazards associated with chemical processing using various dedicated equipment.

BRIEF OVERVIEW OF AR/VR IN SAFETY TRAINING

The use of VR for education in science, technology, and engineering was covered by an excellent review by Potkonjak et al. (2016). In the engineering domain, AR/VR had been widely used in safety training in construction, aviation, naval, mining, and rail operations. Comparatively, its use is not so prevalent in the chemical processing industries. This could be due to the more diverse nature of chemical plant operations in terms of the large numbers of different types of chemical reactions involved, producing a variety of products, which requires the use of several specialized types of equipment; and henceforth the operation and control of the processes and equipment over a range of temperatures and pressures. Training of engineers, technologists, and technicians had traditionally relied on on-the-job training that reinforces the knowledge gained in institutes of higher education. Some companies also use the dynamic simulation for its employees' training; however, this is more oriented towards developing competency in plant operations instead of process safety. It is only recently that AR/VR found increasing use in the chemical processing industries in safety training.

In terms of training effectiveness, Koskela et al. (2005) reported on the results of their work on the effect of the virtual learning environment (VLE) on student learning that showed VLE students outperforming lecture-based students. They concluded that, based on these results and previous case studies, the VLE is suitable for higher education. In the area of chemical process safety, Konstantinos (2002) investigated the use of VR in hazard spotting and several typical chemical plant operations, including a virtual boiler plant. They concluded that VR training could improve the safety awareness of the participants. However, as reported by Kassem et al. (2017), the evidence of the effectiveness of VLE as an intervention for safety learning across the entirety of the risk management process is still limited. The authors further noted that the most investigated phase in safety training is hazard identification, which is the initial stage of the overall risk management process. In other words, VLE applications in different risk management phases such as hazard evaluation, risk assessment, risk control, etc., receive minimal attention thus far. We would add that VLE applications can further advance one's safety competency beyond risk management, and that is towards developing a safety mindset.

OUR APPROACH TO INCULCATING SAFETY MINDSET USING CDIO APPROACH

Various learning tasks are designed to integrate safety concepts while performing works that mimic real-world jobs in the chemical processing plant (Standard 1 – The Context). More specifically, the learning tasks require students to exercise safety awareness and precautions at all times when performing a simulated job role, while at the same time making use of the relevant technical know-how (Standard 3 – Integrated Curriculum) to assess the hazards posed by the job at hand. These tasks take place in our newly renovated training center, equipped with state-of-the-art instrumentation and control systems (Standard 6 – Engineering Workspaces). For example, a chemical engineering technician often needs to collect gas and/or liquid samples from the chemical plant for laboratory analysis. The technician needs to understand not just the chemical properties of the said sample, but also the conditions under which it is being produced, that is he/she needs to also understand how the equipment works, its operating temperature, and pressure, besides just following a set of pre-determined steps of sample collection. A distillation column presents different hazards compared to a reciprocating compressor, so one must be mindful when collecting samples from these two pieces of equipment. The technician must also remain in contact with the central control room (via walkie-talkie) on his/her whereabouts in the chemical plant (Standard 7 – Integrated

Learning Experiences). The learning tasks are designed with an increasing level of complexity, and their learning outcomes are clearly communicated to students (Standard 2 – Learning Outcomes). The lecturer-in-charge gives demonstrations to students on the proper behavior expected while working in the chemical plant, often reinforced via "negative demonstration," obviously without compromising his/her own safety. Students are then given time to practice before proceeding to apply the safety practices in later activities, under the observation of the lecturer-in-charge. As such, the learning experiences that students go through are active and experiential in nature (Standard 8 – Active Learning). Students are given real-time feedback on their safety practices while carrying out a given job, e.g., collecting a liquid sample (Standard 11 – Learning Assessment).
Table 1 shows how we have planned to progressively develop a safety mindset among our students for the first four semesters of study using the spiral curriculum model.

Table 1. The progressive development of safety mindset

Year of study	Module	Learning Outcome
Year 1 Semester 1	CP5201 *Laboratory & Process Skills 1*	• Understand the meaning of hazards in the workplace and appreciate the importance of identifying them at the workplace • Understand the fundamental principles of structured job hazards identification and key steps involved in the process of identification • Apply the key steps to identify potential job hazards
Year 1 Semester 2	CP5202 *Laboratory & Process Skills 2*	• Identify potential hazards when operating a chemical process plant according to a given set of operating procedures • Apply Job Safety Analysis (JSA) in the identification of potential job hazards
Year 2 Semester 1	CP5203 *Process Operation Skills 1*	• Understand the hierarchy of safety control measures • Understand the importance of using appropriate safety control measures to mitigate potential workplace hazards
Year 2 Semester 2	CP5204 *Process Operation Skills 2*	• Understand and know how to do a Risk Evaluation & implement Risk Control • Understand how to perform Risk Assessment
Year 3	IC2003 *Internship Program*	• Understand safety practices in a working environment • Practice workplace safety in accordance with safety requirements • Understand Risk Management in a company

Note that students start learning laboratory safety skills, in the module *Laboratory & Process Skills 1*, in Year 1 Semester 1, which is mainly done in a laboratory setting, although many students would have some familiarity with the handling of chemicals when they were in secondary schools. In Year 1 Semester 2, through the module *Laboratory & Process Skills 2,* students learn to apply the key steps to identify potential job hazards when operating a chemical process plant, which is a shift from laboratory safety skills to process operation safety skills. Job Safety Analysis is used to lay the foundation where students identify the procedures for operating a pilot plant, determine what is to be performed and the tools or materials required,

visualize how the procedure is performed together with the tools or materials, envisage potential hazards based on the manner each step is performed and finally identify safety measures for each step performed to prevent potential injury. Here, students use pilot plants that are relatively simple in construction to identify job hazards related to the pilot plants, such as the shell-and-tube heat exchanger, pump rig, and others. At this point, the major challenge for students is the visualisation of how the procedure is performed with tools or materials and the associated potential hazards. This is mainly due to their lack of knowledge and experience in handling the tools or materials and plant operations. In addition, the majority of the students, if not all, have not operated a pilot plant before. Hence, this affirms that it is even more crucial for us to facilitate this learning process with them as early as possible in the three-year course and gradually develop the safety mindset in them over several semesters.

Progressively from Year 1 to Year 2, the safety skills foundation is laid and continuously applied in Year 2 when they go on to take *Process Operation Skills 1* and *Process Operation Skills 2* modules. After knowing how to identify potential hazards, students learn the hierarchy of safety control measures and understand the importance of using appropriate safety control measures to mitigate potential workplace hazards. This is then followed by learning how to perform a risk assessment for the work activities in the chemical engineering laboratories, which includes perform risk evaluation and implement necessary risk control to mitigate risk.

With the progressive learning of safety practices in the laboratory setting, the students are expected to apply these safety practices learned in the working environment, appreciate and practice workplace safety requirements when they are placed on a 22-weeks internship program in a company.

Pedagogical Basis for Design of Learning Progression

Before these progressive learning can take place in each semester, all students must undergo a safety orientation. The safety orientation consists of an e-learning platform for students to understand the general laboratory safety guidelines and a VR learning application for students to acquire the necessary safety knowledge before they are allowed to carry out any activities in the chemical engineering laboratories. The VR learning application is likely to be the first encounter for the students to be exposed to workplace safety, although students may have worked in a laboratory setting in secondary schools. However, safety awareness then may not be thorough.

Figure 2 shows a generic model of how information communication technology (ICT) is used in education, adapted from Anderson (2010); as an “update” of advances in ICT to reflect the use of AR/VR in education in the context of our work to inculcate safety mindset.

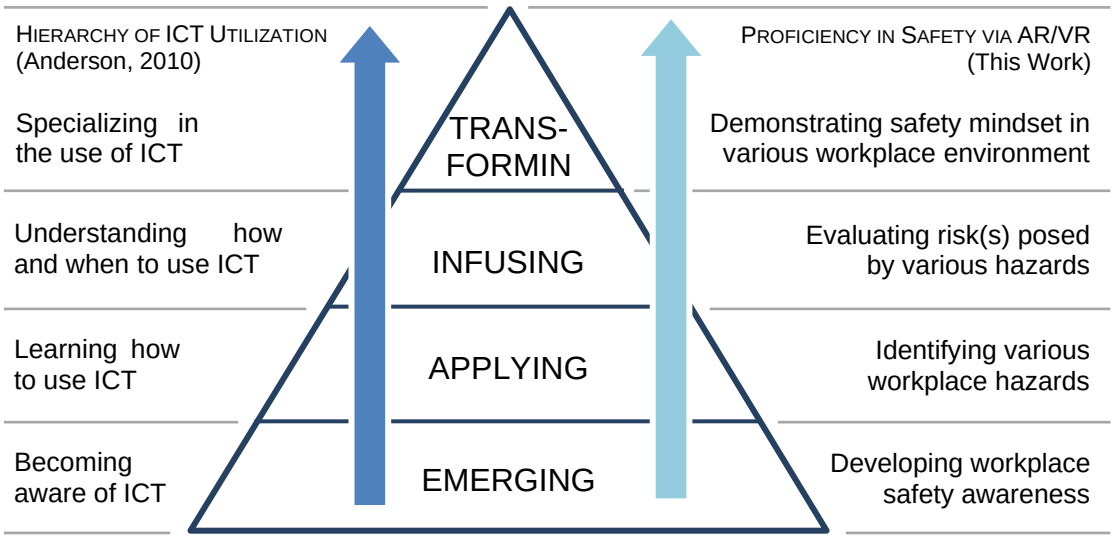

Figure 2. The progressive development of safety mindset using AR/VR

Notwithstanding the above, during the design of any learning tasks, we remind ourselves and members of our team to be cognizant of the use of ICT: i.e., "pedagogy before technology" (Watson, 2011). Another important consideration is the constructive alignment (Biggs, 2003) between the intended learning outcomes, learning tasks design, and learning assessment.

Hence, with reference to Figure 2, the use of VR learning applications in the DCHE course is currently at the EMERGING stage because it was developed to create workplace safety awareness in students. It covers the basic knowledge of safety, such as using appropriate personal protective equipment (PPE) in various situations, knowing the emergency evacuation procedure and routes in chemical engineering laboratories, how to respond to minor and major spillages in a laboratory setting as well as medical and fire emergencies. With the basic knowledge covered, students then proceed to the APPLYING stage to identify various hazards in the workplace, which will be progressively developing the safety mindset among our students through the first four semesters of study through the spiral curriculum in the DCHE course, as shown in Table 1.

DISCUSSION ON WORK DONE TO-DATE

A safety orientation package has been developed using ICT, which consists of a set of learning materials placed on an e-learning platform and a VR learning application for students to acquire basic knowledge of safety.

Previously, this was achieved by getting the students to watch a safety video in the laboratory. Then, a Technical Executive was made to ask several safety-related questions, and students randomly shout out the correct answers. This practice could not assure that all students were paying attention to the safety video nor knew the correct answers to the questions asked. Hence, the Course Management Team (CMT) initiated a revamp to design and develop a safety orientation package that is more engaging and compels all students to learn the importance and seriousness of workplace safety.

In this “newly” developed safety orientation package, every student must complete all learning activities in the learning package in order to be deemed “competent” to use the laboratory. The learning activities must be completed individually, where the time and date of their completed attempts are recorded. Several safeguards have been put in place to ensure students progressively complete all the activities in the VR learning application. For each question, the student must provide the correct answer before he/she can move on to the next section. The questions can be attempted multiple times until the student answers the questions correctly. This trial-and-error approach allows a student to learn from their mistakes in a “fail-safe” environment so that they are able to make the right decision in actual practice.

The DCHE CMT carried out a preliminary survey to evaluate the effectiveness of the safety orientation package as part of the continuous improvement effort. The Kirkpatrick Evaluation Model is used to guide the evaluation exercise as follows:

- Level 1 – Reaction. Evaluation on this level measures how those who participate in the training react to it and the extent to which trainees were satisfied with the training program.
- Level 2 – Knowledge/learning. Learning can be defined as the extent to which trainees change their attitudes, improve their knowledge, and/or increase their skills as a result of participating in the program.
- Level 3 – Behaviour. The extent to which behavioural change has occurred as a result of the training program.
- Level 4 – Results. The final results that occurred due to the training program, including increased productivity, improved quality, decreased costs, reduced frequency and/or severity of accidents, increased sales, reduced staff turnover, and higher profits.

A quantitative survey was designed to evaluate Level 1 and 2 in the Kirkpatrick Evaluation Model using the following questions on a Likert scale of 1 to 5, with 1 being strongly disagree and 5 being strongly agree:

Table 2. Survey questionnaires for evaluating student learning

No.	Statement	Likert Scale 1 being strongly disagree; 5 being strongly agree				
		1	2	3	4	5
1	The e-learning package and VR safety training engaged me to learn and remember the safety requirements and practices in the laboratory.					
2	After going through the e-learning package and VR safety training, I can remember the safety requirements and practices in the laboratory better.					

The survey was administered to 112 students from all years of studies in the DCHE course. Random classes were selected in each year of study, with at least one class being selected to complete the survey questionnaire. The survey respondents are either in Year 1, Year 2, or Year 3. Student names were not collected during the survey to keep the identity of the survey respondents anonymous and enabled the data to be analysed objectively. A non-probability sampling (Creswell, 2012) was used to obtain students' responses to the survey questionnaire. Specifically, convenience sampling was used because the students were readily available to provide responses to the survey questionnaire immediately after they have completed the

safety orientation package. Lecturers who are on-site assisted in administering the survey to the students. These students represent the characteristics of the students in the course, in terms of age group and the ratio between male and female students.

The purpose of survey question #1 is to ascertain that the "newly" developed safety orientation package engages the students to learn the safety requirements and practices in the laboratory. Survey question #2 was targeted at students who had experienced the previous safety briefing using video and verbal questioning. These students are mainly in Year 2 and 3 of their studies, and they have compared their prior experience with the newer approach to affirm that the "newly" developed safety orientation package is more effective in helping them remember the safety requirements and practices.

The survey responses are shown in Figures 3 and 4, respectively. With reference to Figure 3, more than 90% of the students agree that the safety orientation package engaged them to learn and remember the safety requirements and practices in the laboratory. This is likely due to the immersive environment created in the simulated virtual environment that increases the level of student engagement. One student commented that "this semester's use of VR was more engaging," where he compared the didactic delivery of safety briefing with the use of VR.

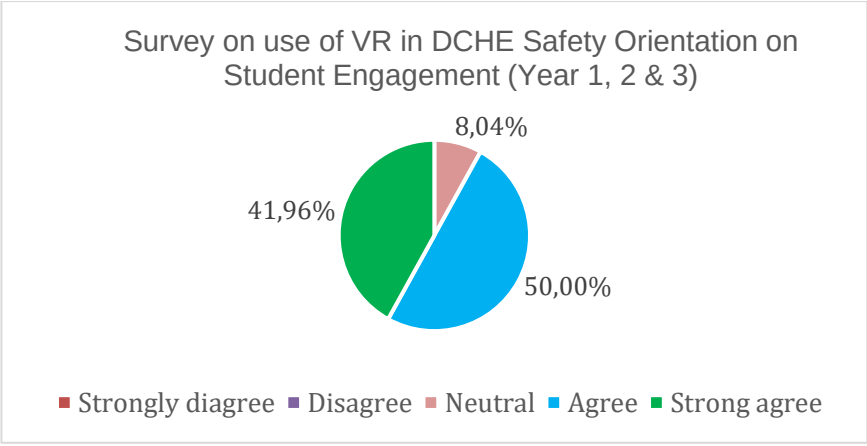

Figure 3. Survey responses from Year 1, 2 and 3 students on safety orientation package engaged them to learn and remember safety requirements and practices in the laboratory

With reference to Figure 4, more than 85% of the students agree that the safety orientation package enabled them to remember the safety requirements and practices in the laboratory better. These students have experienced the safety briefing that includes watching a safety video and answering verbal questions in the previous semester, and they are able to compare it with the newer approach of using VR as a means of delivering the knowledge. As each student must complete the learning activities individually, this improves knowledge retention. In support of this observation, one student commented that "the self-check quiz helped" to reinforce the knowledge.

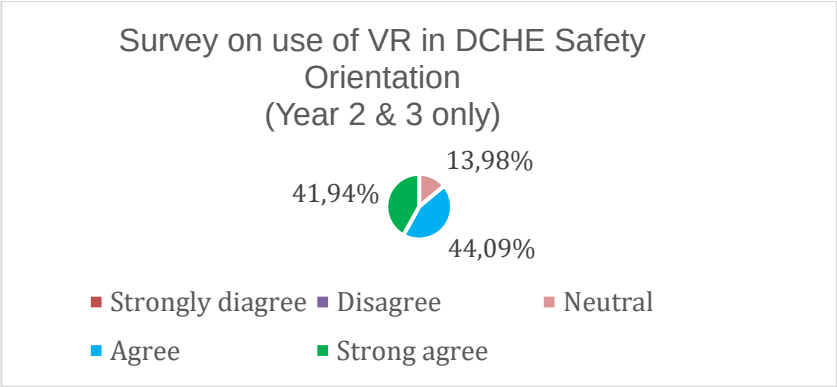

Figure 4. Survey responses from Year 2 and 3 students on safety orientation package enabled them to remember safety requirements and practices in the laboratory better

Level 3 in the Kirkpatrick Evaluation Model will require observation during lesson time to examine and monitor students' behaviour towards safety practice. According to Ekenes (2001) and Weidner et al. (1998), the effectiveness of training can be determined by a change in the behaviours of those trained. The safety orientation package was rolled out for the first time in the semester started in October 2019. We will continue the observation effort in subsequent semesters to ascertain if there is a positive development in students' safety practices.

Level 4 also requires long term observation, perhaps in a longitudinal study. If we observe students are able to execute tasks in a safe manner, with fewer reminders given on safety practices as they progress through the course, it is a positive indication that the curriculum put in place is effective and the safety mindset is progressively developed.

Through the evaluation, the DCHE CMT also aims to establish if ICT helps increase the retention of knowledge and accelerates the learning process, which is found in Lanzotti et al. (2018)'s study that technology allows workers to experience a simulated hazardous environment in a safe scenario, helps increase the concentration and speed up the learning process. In another similar study, Sacks et al. (2013) found that VR training was more effective in terms of maintaining participants' attention and concentration than traditional safety training approaches. The comments below were gathered from student feedback following from the use of the safety orientation package, and they support the studies done by Sacks et al. (2013) and Lanzotti et al. (2018):

- "I feel that the VR video helps us to remember things easier than a teacher's instruction."
- "VR safety training is made more interesting for us to remember and learn, which is definitely effective for us to visualise it."
- "I feel like this experience is more engaging and helps me to prepare for any emergencies in the future."
- "I feel privileged to have such equipment to help me remember these instructions."

PLANS FOR MOVING FORWARD

Based on the outcome of the quantitative survey, the survey questionnaire will be revised to obtain responses that better measure the effectiveness of the safety orientation package in helping students to remember the required safety practices, preference for using safety

orientation package than the previous face-to-face type of training and whether more of such technology should be used for briefings. Open-ended type questions will also be incorporated to solicit after-thoughts from students to find out why the use of technology is preferred for learning than a face-to-face type of training/briefing.

Studies have found that training not only enhances individuals' motivation to engage in safe behaviour but also increases the personal ability and desire to recognise and deal effectively with hazards (Leiter et al., 2009). Hence, with reference to Figure 2, the VR learning application can be further enhanced to provide scaffold learning in accordance with the spiral curriculum model. For example, at the EMERGING stage, students identify the PPE that is needed when they carry out different tasks in the laboratory, be aware of the location of fire extinguishers, and emergency evacuation routes; as well as know what to do when they encounter minor chemical spillages on body and benchtop. Then, at the APPLYING stage, various hazards could be purposefully inserted into different scenarios for students to use the Job Safety Analysis approach learned earlier to identify workplace hazards, choose the proper PPE to use, or the correct emergency evacuation route to take.

Leveling up to the INFUSING stage, it is possible for students to learn fire emergency procedures without first showing a fire in the virtual laboratory setting. For example, a fire could randomly appear, and the student will need to decide whether the fire is small enough to be put out by a fire extinguisher or call for help. For small fires, the student could learn how to handle the fire extinguisher and put out the fire. In the process, they can also be assessed in their ability to choose the correct type of fire extinguisher to use based on the type of fire present.

By randomly triggering a location where a hazard can appear, students are not able to regurgitate the correct answer when attempting the scenarios multiple times. This is the essence of using VR learning where scenarios can be changed using appropriate software and without the need to make a physical change to an existing setting in the laboratory. A real change in a physical setting could impose more hazards and put other students and users at risk, and also potential damage to costly equipment and downtime.

With the learning put in place at the EMERGING, APPLYING and INFUSING stages, it is hopeful that students reach the eventual TRANSFORMING stage where they demonstrate a safety mindset in the workplace environment and perform the tasks safely and conscientiously. This can be ascertained when they truly demonstrate safe practices in a real environment. This is important when dealing with serious operational problems such as major spillage caused by pipe rupture or equipment failure, where one had to deal simultaneously with multiple hazards. Also, in the TRANSFORMATION stage, we can integrate students' safety awareness with other competencies such as critical thinking, such as when proposing a modification job to implement certain design change, to take into consideration of potential hazards specific to the job at hand. In this manner, we can better prepare our students for their internship program, where they will be attached to real companies and subjected to real hazards at the workplace.

Lastly, we noted that training effectiveness and the influence of training on safety performance could be affected by a number of factors such as the method of training, delivery medium, and tutor style. This can culminates in the extent to which skills, knowledge, attitudes, and experience are developed through training. Salas et al. (1999) acknowledged that the transfer of training would be influenced by trainees' characteristics and motivation and pre-existing competence levels. And interestingly, even though a meta-analysis by Merchant et al. (2014)

showed that the use of VR is effective in attaining the learning outcomes, these studies were all based on games and virtual worlds. Clarke and Flitcroft (2013) noted that there is little research relating to the longer-term effectiveness of training as an intervention in the specific aspect of improving safety. Thus, we can go beyond inculcating safety mindset among our students, to look into the use of AR/VR to review the applicability of the training content to the delegates' day to day work activities, transference to the workplace, the reality of the work environment. All these can be possible areas of future research into factors affecting the effectiveness of safety training using AR/VR.

CONCLUSION

In conclusion, the safety orientation package developed using ICT has created better learning experiences for students as compared to the previous practice. Based on preliminary findings, the VR learning application created workplace safety awareness amongst students and formed the foundation of developing a safety mindset for chemical engineering students at Singapore Polytechnic. Nonetheless, the learning application can be further enhanced to allow students to level up their knowledge and skills as well as culminate good safety practices in accordance with the spiral curriculum model. The approach is to introduce simple concepts related to safety first; then, these are revisited and re-construed in a more in-depth and elaborate manner through the instructional process over the four skill-based modules. The competencies are built on basic key concepts on safety at the beginning, and complex concepts are developed more elaborately over time sequentially from one module to another.

The VR learning application will be enhanced for students to revisit knowledge and content at different stages of the curriculum, activate prior knowledge, and integrate knowledge and skills. The terminal objective is to provide students with a comprehensive understanding of the key concepts in safety so that they can apply these thoughtfully across a range of real-life contexts. They gradually develop a safety mindset in which they make personal meaning of the knowledge and see how it is used in the real working environment. According to Clarke & Flitcroft (2013), when safety training is integrated into a broader safety intervention program, training can have a wide range of benefits, particularly in terms of enhancing employee safety motivation and participation. Our students are potential employees of the future for the industry; hence, it is important that they possess the right safety mindset when they graduate so that they are able to induct into the new workplace with ease, without having to go through a rigorous safety training. This can potentially reduce resources that companies need to spend on training the new hires.

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COMPARING SDL IN SINGAPORE AND VIETNAM: APPROACHES AND STUDENT PERCEPTIONS

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ABSTRACT

Self-directed learning (SDL) is becoming a critical and important skill in the labor markets of today's VUCA (volatile, uncertain, complex, ambiguous) world. With significant advances in technology, we are now faced with the challenges of making sense with big data and discerning fake news from genuine ones. SDL is, therefore, a necessary skill in the world we are preparing our students for. However, the classroom culture we have created and inherited is not designed around self-direction, which tends more towards the dissemination of information characterised by large lecture classes, students practicing standard tutorial questions, and for most of the time assessed through time-sensitive examination formats in which students regurgitate information absorbed to demonstrate comprehension. There are, however, many challenges in integrating SDL into an already-packed curriculum. This paper compares the approaches between two institutions in two countries – namely Singapore Polytechnic in Singapore and Duy Tan University in Vietnam – on their respective efforts to impart SDL skills among students. The aim is to learn from each other's practices that both can advance and improve students' learning on these important skills. We are interested in how each institution handles the teaching of SDL skills, faculty preparation, issues and challenges faced, the method used (whether using the CDIO Framework or others; choice of pedagogy, assessment), the measurement used to ascertain the effectiveness of any interventions used, as well as the students' own self-efficacy and perception of SDL in helping them learn better; and lastly plans for moving ahead. This paper firstly provides a brief summary of the vast literature available on these aspects and then shares our findings in the abovementioned areas. It concludes with a discussion on possible ways the 2 institutions can collaborate to further improve each's SDL implementation.

KEYWORDS

Self-Directed Learning, Curriculum design, Standards 3, 7, 8, 11

INTRODUCTION

The world that we know of today in the context of technology adaption, business disruption, and pervasiveness in human-computer interaction is no longer similar to the one a century ago due to the rapid growth of the Internet and technological advancement in computing processing power and speed. With information being processed and exchanged across the globe at a stunning rate (from 100 GB of Internet traffic per day in 1992 to a forecast 157,000GB per second in 2022 (Cisco, 2019), one will inevitably be faced with disruptions in their workplace or a broad context, their job market area, due to the volatility and uncertainty of the environment brought forward by technology disruptions and fast information dissemination. In the current VUCA (volatile, uncertain, complex, ambiguous) world, one needs to have the right growth mindset and skills to be able to navigate the world of big data and the erosion of data integrity due to false or altered information around them. Self-directed learning thus becomes a critical and essential skill set for students to be able to adapt to the ever-changing environment continuously. Having the correct mindset will enable them to see changes as part and parcel of their daily life and be able to take on the role of positive change agents allowing them to effect positive change to the environment and people around them in moments of disruptions.

To draw the link between the industry and one's educational journey, currently, there exists an urgent need to address how we could best instill self-directed learning (SDL) in each student, enabling them to take ownership of their learning similar to the real working world. On an institutional level, we need to continually engage, share our best practices, and collaborate to tackle the challenges in the implementation of SDL, which is inherently different from the classroom culture we have inherited and find the best way ahead for our students.

The updated CDIO syllabus 2.0 captures the essential broad-based knowledge, skills, and attributes in students necessary to prepare them to be successful, young professional engineers for the future. The key areas of SDL in addressing one weakness through self-education, metacognition aspect of thinking, and knowledge integration for lifelong learning are widely summarised and highlighted in part 2.4.5 and 2.4.6 of the CDIO syllabus.

BRIEF LITERATURE REVIEW

In the pioneering work, SDL studies were conducted to gain insight into the deliberated learning effort of adults, their challenges, and the learning process, including intentional and self-planned learning (Tough, 1971). Knowles most notably defines SDL as "a process in which individuals take the initiative without the help of others in diagnosing their learning needs, formulating goals, identifying human and material resources, and evaluating learning outcomes" (Knowles, 1975). Several researches spawned thereafter, which focuses on the model for SDL implementation. Grow (1991, 1994) proposed the SSDL, which consist of 4-stage to match the learner's learning stage according to teaching style. Gibbons (2002) similarly proposed a 4-stage strategy in the context of how an educator will present and developed their course. Once the stage is determined, the curriculum will be designed based on the 3 themes of learning activity, skill to gain, and personal quality to be developed by the students. Brockett & Hiemstra (1991) proposed the Personal Responsibility Orientation (PRO) model, which based on the core of learning on individual responsibility. The learning of individuals depends largely on their learning management and assumption of accountability (ownership). Garrison (1997) proposed a theoretical model that integrates self-management, monitoring, and motivation similarly to achieve SDL. Lastly, Boyers (2014) provided a

summarised overview for SDL research over 30 years exploring the relationship of SDL with self-control, motivation, performance, and self-efficacy.

SUMMARY OF APPROACHES TAKEN BY SP AND DTU

There can be more than one way to introduce SDL into a curriculum, depending on a myriad of factors, not limited to faculty competence, program structure, student cohort size and readiness, existing infrastructure, etc. It is not possible to discuss everything in detail within the limit of this paper. The sections below provide a summary of 2 institutions: Singapore Polytechnic (SP) and Duy Tan University (DTU) in Vietnam.

Institutional Approach to Integrating SDL into Curriculum: SP

To prevent a top-down approach for this SP institutional wide initiative, the SP's SDL model shown in Figure 1 was curated through the collective effort of 88 SP staff of various levels (Academics staff and management) coming together in May 2018. The representatives from the different schools and departments worked together. They jointly provided their inputs through co-created sessions, looking at the best approach to develop our students to be self-directed learners who lead to the original creation of the SP's SDL model.

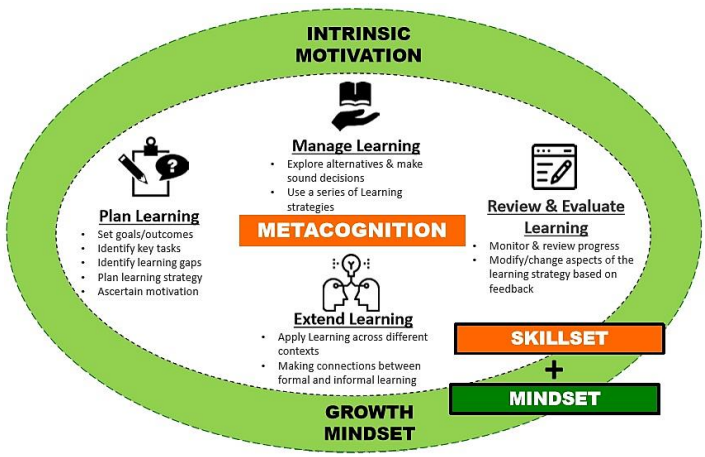

Figure 1. SP Self-Directed Learning Model

From thereon, the Department of Educational Development (EDU) took over the lead in the refinement of the model. It provided advisory for individual schools on the best practices if the schools decided to adopt the model for their curriculum.

Faculty Preparation: SP

EDU does not mandate the adoption of the model but instead uses the model to guide the individual school's diploma in planning. For faculty preparation, a timeframe was set to introduce the SP's SDL model to the respective schools in phases.

Phase 1: Generating Awareness
Phase 2: Experimentation
Phase 3: Measurement and adoption

The various schools were given the freedom to use the SP's SDL model as a fundamental framework and customised it according to their individual needs and requirement. The SP's SDL model denoted in Figure 1 served to achieve one of SP's collective aspirations to help develop our students to be self-directed and knowing how to learn. It focuses on two key abilities in (1) skillset (2) mindset of the individual learner, building the metacognition aspect of learning through the four keys stages of the SP's SDL model. It further instills a growth mindset to enable one to continuously learn, unlearn, and relearn adapting according to environment and needs.

Institutional approach to integrating SDL into the curriculum: DTU

The SDL model used in DTU is shown in Figure 2. It is the result of the process of teaching innovation (applied in the CDIO project) over the past 3 years at the Faculty of Electrical & Electronic Engineering (FEEE). This process consists of 3 basic steps: Learning Ownership, Management of Learning, and Extension of Learning. As an active learning subject, students proactively identify learning goals clearly and specifically. Based on that, students develop their study plan and determine the appropriate level of learning content. From there, they proactively organize learning activities according to the defined plan and content, under the necessary support of the lecturers, to achieve the learning goals.

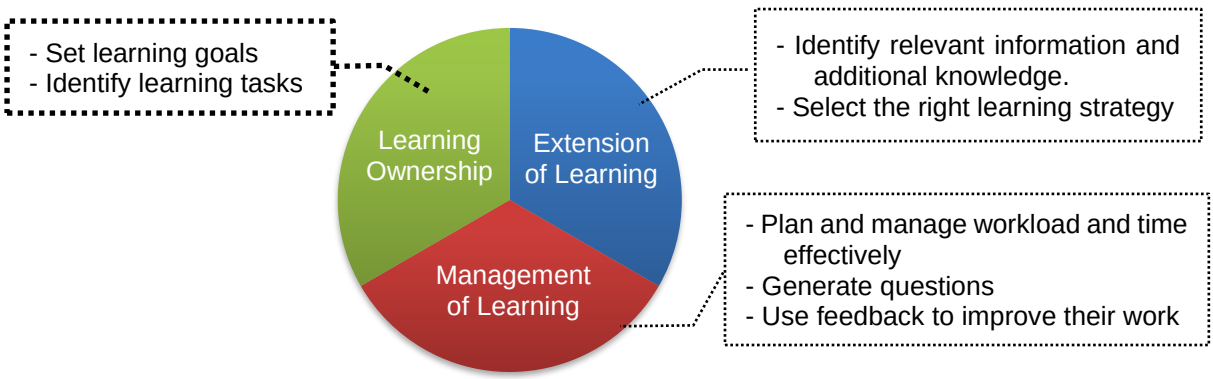

Figure 2. DTU Self-Directed Learning Model

Faculty Preparation: DTU

FEEE regularly organizes seminars to allow each member to participate in CDIO SDL classes to be aware of their mission. These seminars ensure the lecturers understand SDL and the resources needed to understand them (e.g., Learning Resource Center; Internet; Professional journals). Lecturers and students are also provided with instructional materials for using learning software (Learning Management System, Teamwork project software, Dropbox, and Google Drive). Based on the proposed SDL model, each instructor and student must be aware of their role through 5 steps, as shown in Figure 3. Students will be the main implementers. Students must understand: It is not about daily progress; it is about progress daily.

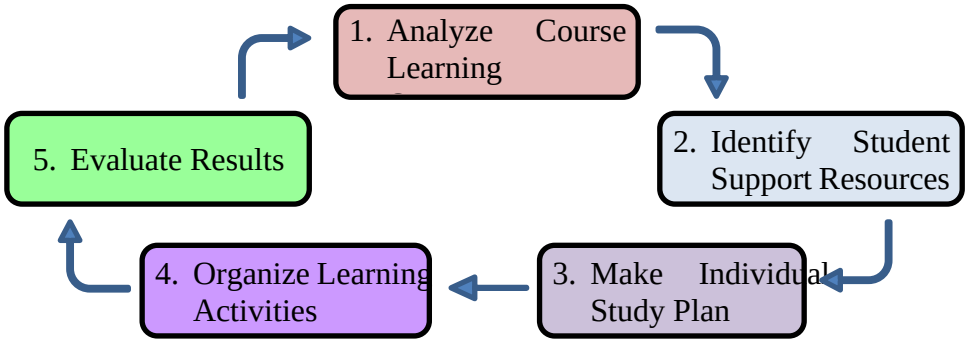

Figure 3. DTU 5-steps Approach to SDL

Issues and Challenges Faced: SP

During the inception of the SDL model, several challenges were faced by both staff and students alike due to the relative newness of the area. For staff, there were genuine concerns on the knowledge and know-how to adapt the SP's SDL model into their current modules and to decide what is the best approach to revamp their teaching approach to bring out the students' self-directed learning behaviours. From the viewpoint of students, the SDL way of learning is very different in comparison to a traditional classroom setting. There is now a need for an individual student to take up more ownership in their learning, setting their own goals, identifying their gaps, and adjusting their learning strategies along the way.

To address the anxiety of academic staff, SP ties together SDL with other supporting initiatives to help them see the connections of what they are venturing towards, is part of the larger picture of institutional-wide effort to redesign SP's education system. Some of the initiatives include:

- Introduction of Poly-wide electives
- Internships
- Education and career guidance
- Flipped Classroom

Issues and Challenges Faced: DTU

Indeed, the SDL implementation in DTU is also challenging for both instructors and students. It takes a lot of effort and time for instructors to compile lectures and video lectures for each Flipped Classroom class. Self-study lectures must be truly concise and, at the same time, ensure the attention of students. The second biggest challenge we encountered was not finding the best solution for tracking students' progress during the project. The unequal level of students' knowledge and awareness makes it difficult to implement a Flipped Classroom. Finally, the specific method we are applying in SDL is the Flipped Classroom, which does not apply to all subjects in the training program, requiring careful selection from the Faculty Advisory Board. On the student side, the biggest challenge is motivation. Self-study is much more challenging than studying under direct instruction. Students also often set learning goals that are too high for their knowledge level. Sometimes, the setting up of necessary tasks to achieve learning goals are also unreasonable because of their inexperience.

Method of Infusing SDL (e.g., CDIO Framework): SP

During the first year of experimentation for SDL, staff from various schools explored and adapted the SP's SDL model for their own curriculum needs. Some examples of the work are summarized in Table 1. EDU then coordinates various sharing sessions for the early adopters to share their learning experiences with other colleagues. Various platforms were utilized – at SP-level, there are events such as Brown Bag sessions, Pedagogy Meetings, Poster Sessions during annual Excellence in Education, and Teaching Conventions. Individual schools also held the annual Teaching & Learning Day, where SDL initiatives are shared.

Method of Infusing SDL (e.g., CDIO Framework): DTU

We started implementing SDL with Flipped Classroom, which is well described in the paper "The effects of Industry 4.0 on teaching and learning CDIO project at Duy Tan University", 2019. When implemented, we encountered several problems and are working hard to solve in the 2019-2020 academic year. We started to apply online software in monitoring the progress of the project implementation of each group student. Teamwork Project software (Teamwork.com, 2019) makes it easy for everyone to see what they are working on, who they are working with, and what comes next - whatever size a team is. Instructors and students discuss to find the most appropriate learning strategy and learning schedule. All are explicitly shown on a Gantt chart. These are the first steps in implementing a Flipped Classroom towards Blended learning. It is a type of multichannel method that incorporates tutor-led activities, images, videos, digital tasks, and face-to-face discussion. The role of the instructor in the development of SDL was also discussed very carefully (Ha et al., 2019). Finally, assessing scores is an essential step in testing students' self-study accumulation. We unified to use the evaluation form divided into many levels 1 - Not proficient, 2 - Less than desired proficiency, 3 - Marginal proficiency, 4 - Good proficiency, 5 - Superior proficiency to evaluate students' CDIO skills. For example, in FEEE CDIO Project 3, we use evaluation forms, including Teamwork Rubric, Technical Report Rubric, Oral Rubric, and Manufacturability of Work Discussion Rubric.

Table 1. Examples of SDL Integration into Curriculum (SP)

Name of School	Description of Work Done	Reference
School of Chemical & Life Sciences	3-year progressive development and transfer of SDL skills in Chemical Engineering using CDIO	Cheah, Wong, & Yang (2019)
School of Architecture & Built Environment	Use flipped learning and integrated SDL experiences for year 1 DCEB[1] students	Soo-Ng (2019)
School of Chemical & Life Sciences	Utilize the data analytics from SmartBook to teach meta-cognition in the teaching of chemistry	Tan (2019)
School of Electrical & Electronic Engineering	Use the internship program, via a journal, report, and assessment as "solution-minded interns."	Anwar (2019)

[1]DIPLOMA IN CIVIL ENGINEERING WITH BUSINESS

School of Electrical & Electronic Engineering	Synergize with IT Curriculum 2017 Framework for an ICT project-based module	Chew, Chia & Teo (2019)
Singapore Maritime Academy	Use competency-based training for his Diploma in Nautical Studies students to learn SDL skills	Savio (2019).
School of Business	Use team-based learning to impart SDL skills among his students in Diploma in Accountancy	Neo (2019)

Measurement of Effectiveness: SP

Measurement techniques are often critical in the evaluation of any pedagogical interventions used in curriculums or modules. In the first year to explore the SP SDL model, the utilisation of measurement tools is still in the infancy stages and required more studies for further refinement. At this point, for most studies (Table 1), the authors focused on understanding students' learning experience with regards to the change in teaching methods to introduce SDL. Helene, Chan & Chong (2019) presented their findings for 4000 SP students using both qualitative and quantitative studies. The objective is to monitor and review the impact of Flipped learning for students and their learning through SDL. The work performed data collection using both pre and post-tests for students, adapting 34 items questionnaire, which comprises learning strategies and Motivation Strategies for Learning Questionnaire (MSLQ) (Pintrich et al. 1991).

In another example, Cheah, Wong & Yang (2019) reported that there is still a significantly large number of Year 1 students in their study who are not receptive to the teaching of SDL. The authors also report that, even though students responded positively to SDL in the survey, the evidence collected (such as a reflective journal) or work done (such as a written report) does not appear to support their claims of being able to apply SDL. It would look while students understand the SDL model and appreciate its importance; still, they are not sure how to put them into practice in different contexts. In addition, different learning abilities among the students will also affect the learning process.

Measurement of Effectiveness: DTU

We are in the third year of applying the Flipped Classroom and the first year of applying group supervision through the Teamwork Project software in CDIO teaching. To evaluate the effectiveness of this method, we have calculated the percentage of students' Superior Proficiency, Proficiency, and Poor Proficiency (Figure 4) in ABET Outcomes 7 (ABET, 2019). The parameters were collected on 4 CDIO CR347 classes in 2018-2019, 2019-2020 academic years. The number of students per class is 20. It was found that the percentage of students who did not achieve SDL skills increased to 20% when applying online study monitoring software. However, with the advantages of using this method, we will continue to use and observe statistics in the following years to make appropriate recommendations.

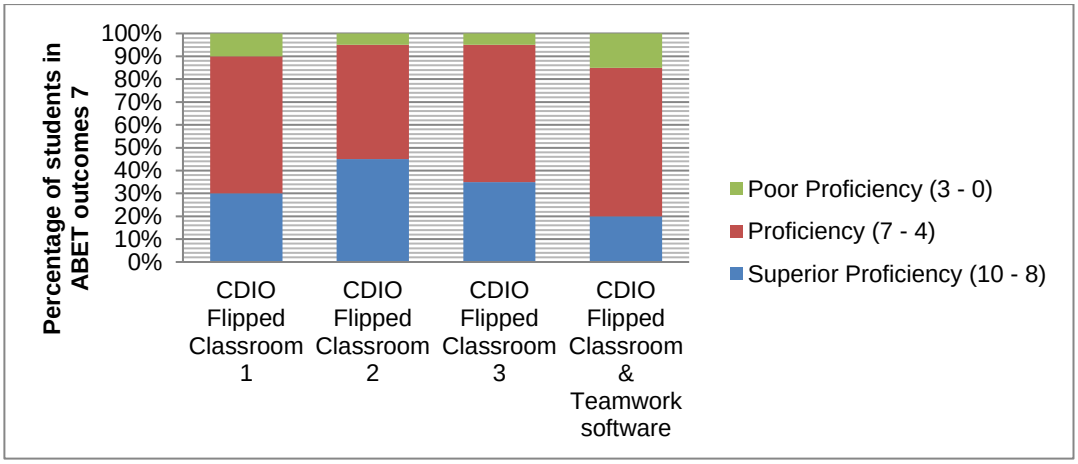

Figure 4. Percentage of students according to ABET Outcomes 7

We also conduct online surveys to determine whether students are satisfied with this learning method. Results showed that 28.7% of the total of 80 students surveyed proved unsuitable for the SDL learning method. The collected data proves that the SDL method we apply must be heavily revised in the future.

Students' Self-efficacy and Perception of SDL: SP

Students are generally receptive to SDL and think that it is useful for their future learning. However, most students find the concept of being entirely self-directed to be fairly new and different from their previous classroom setting. To address this, we need to strengthen further the students' mindset (metacognition) and intrinsic motivation (individual) to encourage them to take ownership of their development, thus growing them to be self-directed in their learning. Below are some of the comments:

"*The current SDL process allows students to reflect and track what they are doing and whether what they are doing is effective. This allows us to know whether we are actually learning or just doing and following instructions from the book blindly*. " - SP Year 2 student

"*Actually no, because I already have my way of learning, so to follow the learning format given, I would have to re-adapt and try to change the way I think*." - SP Year 1 student

"*Yes I believe that the usage of the Self-Directed Learning Model has helped our group to be more systematic in the planning before the experiment*." - SP Year 1 student

Students' Self-efficacy and Perception of SDL: DTU

We consulted 3 students in the same CDIO class to apply the SDL method. These students have very different scores, and their perception of SDL is different.

"SDL is a very interesting learning method. Thanks to it, I eliminated many hours of boring theory lessons. Instead, I took the initiative to set my learning goals and conduct learning whenever, wherever I was to reach that goal. It is challenging to make laws that govern myself, but it will be a good lesson for my future." - CDIO Year 2 student 1

"The CDIO class applies to FC very well, but it is not suitable for me. I need more time to get the theory delivered in class, as well as more exercise. It is very difficult for me to have an overview of an issue when implementing SDL. I always thought I needed an instructor like the other regular classes." - CDIO Year 2 student 2

"SDL is not suitable for many people in the class, including me. This method requires too much research time, while my study and work schedule cannot meet that. I could barely keep up with the classroom lecture and didn't understand the other lecture videos. These self-study videos are long and boring." - CDIO Year 2 student 3

PLANS FOR MOVING AHEAD: SP

Moving forward from the first year to generate awareness of SDL and experimentation of the SP's SDL model, reflections and learning points will be consolidated.

In the next phase (Adoption and Measurement) – more focus and attention is allocated on the efficient implementation of the framework, which will impact the students at diploma and cohort level. Metacognition, which dictates the reflections process of one's learning to achieve a more positive outcome in the future learning cycle, will be more deeply studied and researched.

To quantify the success of the institutional level SDL implementation, there is a need to look into the curation and development of more effective measurement tools using the wide collection of metrics available such as Self-directed learning Readiness Scale (SDL-RS), Motivated Strategies for Learning Questionnaire (MLSQ), graduate surveys, and industry feedback. This allows for self-evaluation and benchmarking to identify the strength, weaknesses, and areas for improvement in the implementations. Lastly, to move towards the collective aspiration of having holistic developments for our graduates and developing them to be self-directed learners, SP is in the process of setting up an innovative SDL ecosystem (see Figure 5), which comprises of curriculum, resources and action research to facilitate the change journey. This will also include tool kits for staff and professional development programs.

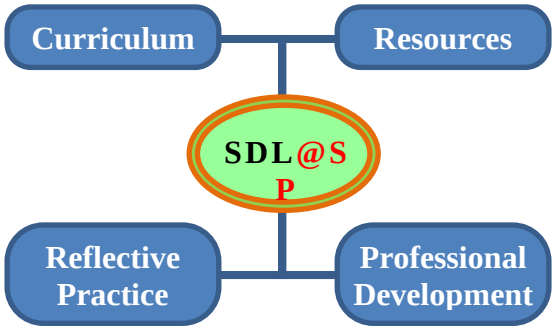

Figure 5. SP's SDL Ecosystem

PLANS FOR MOVING AHEAD: DTU

In the following academic years, we try to perfect the Flipped Classroom method in all CDIO subjects, cover all content: lectures, implementation methods, assessment methods,

supporting software. We also see a lot of problems that still exist in these classes and have proposed a number of remedies:

- Increasing the level of learning interest for students with more vivid video lectures, replacing class assignments with learning games (e.g., Kahoot software).
- For students who have a low level of knowledge and do not keep up with the SDL process (identified through the point of assessment of previous CDIO subjects), the form of "Grouping oriented" will be implemented. The best students will be grouped to support the weaker students; depending on the level of support, there will be corresponding reward points.
- Time management and work efficiency issues should also be considered and handled by the software.

Besides, in addition to the practical skills gained during the teaching process, FEEE instructors will actively participate in the Innovating Educational Methods Conference and CDIO Conferences, Workshop, etc.

DISCUSSIONS ON THE 2 INSTITUTIONS' APPROACH TO SDL

The individual journey of SDL implementations from the two institutions demonstrates the similarities in challenges both faced in curriculum design, staff/students reception towards SDL, having the required knowledge and right mindset to adopt the new domain challenge. SDL, as currently implemented, which uses the 'across-the-board" approach for all students, may pose problems for less academically-abled students. Resource limitations (especially manpower) are a real constraint in supporting the development of SDL competency for all students. Opportunities exist, primarily through the use of educational technology (various Web 2.0 tools) for faculty to offer more customized support for these students.

Granted, the work reported here will not be exhaustive, and there may exist pockets of excellence in various programs. Both institutions will continue to refine their respective approach to SDL. It would be useful for both institutions to continue to capture best practices, as well as gathering evidence of the pros and cons of each approach.

Looking ahead, both institutions show individual strength in educational innovation that could be a potential area that can be further tapped for deeper collaborations. Spawning from this joint paper, work is already underway to strengthen the collaborative efforts between the two institutes. One of the areas of cooperation includes identifying areas of action research where it best benefits the students from the two schools. Another area includes looking into potential future visitation between the two schools and crosses sparring of best practices to encourage the sharing of knowledge and experiences.

CONCLUSIONS

This paper documents the collaborative effort between Singapore Polytechnic (SP) and Duy Tan University (DTU) in Vietnam to share best practices and learn from each other experiences in the context of SDL implementation. The joint work set off with a clear and common objective to learn, share, collaborate, and improve our respective SDL framework and processes to achieve better learning outcomes of the students and experiences for our staff. The paper reported the learning journey undertaken by the two institutions on the integration of SDL to

our respective curriculums, and challenges faced, stakeholders' perception and measurement used to assess the effectiveness of the school's SDL implementation.

Many functional case studies were discussed and shared in this paper, providing a springboard for future works together between the institutes. Taking the collaboration further, potential plans for future discussion into areas including (1) Cross-institutional action research in SDL (2) Visitation that include observation of SDL-related activities and adoption of best practices.

ACKNOWLEDGEMENTS

The authors would like to thank the contributing members of the two institutions (Singapore Polytechnic and Duy Tan University) and their respective education development units for providing the resource and images for consolidation and discussion in this joint paper.

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BIOGRAPHICAL INFORMATION

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A SURVEY OF THE PROGRESS OF STUDENTS' GENERIC SKILLS

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ABSTRACT

At the National Institute of Technology, Sendai College, we are continuously examining the generic skills (GSs) of students using PROG, an objective assessment test. We report the results of the GS growth characteristics of college students from their admission to graduation. We will introduce how we use the results of the survey for the students and faculty members, both those that are currently being implemented and those that will be implemented in the future. The feedback of the results of the surveys makes it possible to quantitatively evaluate the growth of the students' GSs, which is difficult for students to recognize and to foster efficiently by themselves. Besides, the feedback of these survey results can quantitatively evaluate the students' GS training, which is difficult for teachers to evaluate accurately and train efficiently. Therefore, the efficiency and quality of our college education can be improved.

KEYWORDS

Generic Skills (GSs), evaluation of GSs, Progress Report on generic skill (PROG), Utilizations of PROG results, Standards 11, 12

BACKGROUND

A National Institute of Technology in Japan is a five-year higher education institution that provides engineering education to foster engineers with practical skills and expertise. At the National Institute of Technology, Sendai College, we are conscious of the significance of developing human resources that meet the needs of society and improving our education in accordance with the three policies (admission policy, curriculum policy, and diploma policy). In particular, we implemented the reorganization of departments and the introduction of a course system.

In engineering education, in addition to the acquisition of knowledge and skills, it is important to develop skills, called generic skills (GSs), to utilize the acquired knowledge and skills in the real world. However, it is difficult to evaluate GSs, which include intention and behavioral characteristics, by the conventional test, which is supposed to confirm the learned knowledge. Furthermore, it is very difficult to evaluate the GSs accurately using the rubric-based evaluation method, because the students' self-evaluation, the mutual evaluation between students, and the evaluation by teachers may differ.

At Sendai College, we have been conducting continuous surveys of the students' GSs using an objective method, which started in 2014 and was conducted annually until 2018. It allows us to follow of the same students for five years from their admission to graduation. Therefore, it will clarify the students' GS growth characteristics in 5 years at Sendai College. In this paper, we first outline the standardised tests used for GS evaluation. Next, we report the GS growth characteristics of our students, as clarified by the survey. Finally, as a way to make use of the results of the GS survey, we introduce how we give the students and teachers feedback and what we plan to implement in the future for the students and teachers.

GS EVALUATION METHOD

As a method of evaluating GSs, there are direct evaluations by students and teachers using rubrics and indirect evaluations by external standardised tests. In our survey, we used PROG (Progress Report on Generic Skills), one of the standardised tests in Japan (Kawaijuku Group, 2019). PROG, which is an objective evaluation, has the following advantages: 1) Evaluator's subjectiveness is not included; 2) Comparative analysis with the average of examinees (university students, etc.) other than our college can be performed.

PROG consists of two parts: a literacy part that evaluates the examinee's practical ability to solve problems using their knowledge, and a competency part that evaluates the examinee's ability to build good relationships with the surrounding environment. The evaluation items for the PROG test are determined based on the key competencies in the OECD's DeSeCo project (OCED, 2019) and the surveys on the skills required by Japanese companies. They are classified into six items for the literacy part and three items for the competency part. The competency part has three major categories, and each major category has nine middle categories and 33 elements as minor categories. Table 1 shows the PROG evaluation items. As shown in Table 1, many of the elements of the PROG evaluation correspond to those described in the CDIO syllabus2.0 (CDIO, 2019). In particular, Teamwork skills and Personal skills of PROG (major categories of competency) are equivalent to Interpersonal skills: teamwork and communication and Personal and Professional skills and attributes in the syllabus, respectively. Many presentations on the development of these skills have been made at the 15th International CDIO Conference, and the development of generic skills is now one of the important topics.

The literacy part consists of questions such as numerical reasoning and text comprehension. On the other hand, in the competency part, there are many questionnaire-type questions for examining behavioral characteristics. For example, to a question, "When talking with a person you are new to, how do you act?" the answer should be a five-grade evaluation from "Very friendly to very politely." The evaluation of each component of the competency part is quantified by comparing the statistically processed exemplary answers of 4,000 Japanese businesspersons who were rated as "excellent." PROG test scores are rated either from 1 to 5 or from 1 to 7, depending on factors, in both literacy and competency parts, with larger numbers indicating better results.

In the 2018 test, about 110,000 university and college students took the literacy part, and about 530,000 university and college students took the competency part, the total number of universities and college students in 2018 is about 3 million. Therefore, a statistical comparison of GSs between our students and university students is possible. In this paper, we compared our students' average score of PROG with the score of university students who took the same test to confirm the educational effects.

GS SURVEY RESULTS

Figure 1 shows the Generic Skill Growth Characteristics of Students of National Institute of Technology, Sendai College, Hirose Campus, and table 2 shows the PROG testees' grades each year. Five years have passed since the GS survey started, and the continuous survey from the first year of admission, 2014, was completed in 2018. Therefore, this survey will clarify

(a)Tracking results for students enrolled in 2014

(b) Results for students in 2018

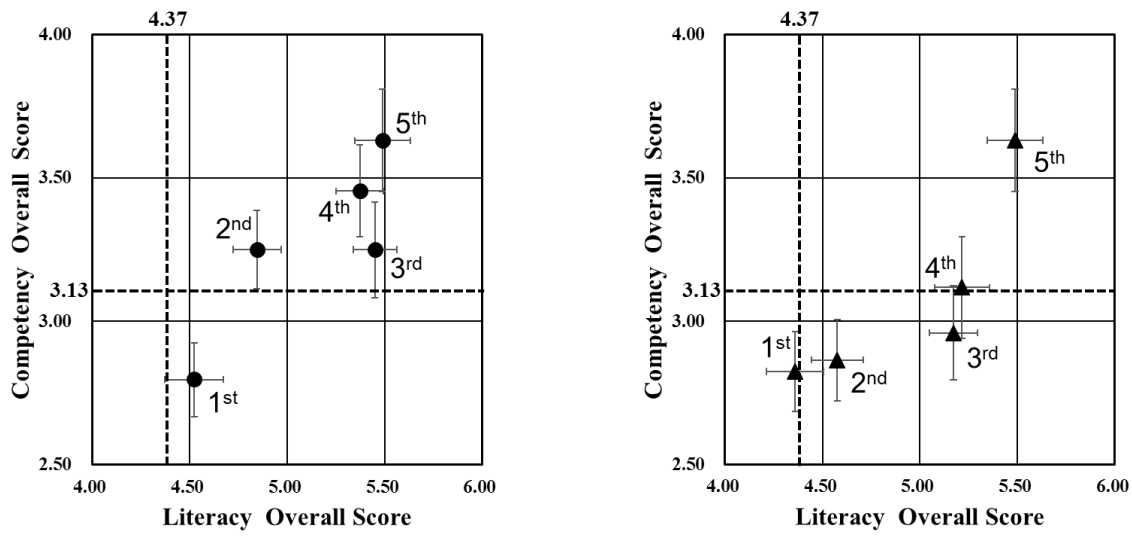

Figure 1. Generic Skill Growth Characteristics of Students of National Institute of Technology, Sendai College, Hirose Campus

How the students' GSs change with the progress of the college year in the education course at Sendai College, Hirose Campus.

Figure 1(a) shows the GS growth characteristics of the group of the same students from the first year (2014) to the fifth year (2018). Figure 1 indicates that both the students' literacy and competency grew steadily as their grade advanced. On the other hand, the dotted line in the figure represents the average value of university students who took the same test in 2018 (literacy: 4.37, competency: 3.13). The average of our college first-grade students' literacy scores exceeds that of university students,' and the second-grade students' competency scores exceed that of university students.' However, it can be seen that their competency score did not increase between the second and third grades, and the literacy score did not increase between the third and fourth grades.

Table 1. PROG evaluation items

Evaluation elements of literacy part

Literacy	Collecting information
	Analysing information
	Identifying problems
	Forming strategies
	Linguistic Processing Skills
	Nonlinguistic Processing Skills

Evaluation elements of Competency part

	main (3) categories	medium (9) contents	small (33) components
Competency	Teamwork skills	Relating with others	Approachability
			Attentiveness
			Interpersonal interest/Empathy/Receptiveness
			Diversity understanding
			Building up a network of connections
			Trust building
		Cooperating with others	Role understanding / cooperative action
			Information sharing
			Mutual support
			Consultation / guidance / motivating others
		Team management	Talk to each other
			Express opinions
			Constructive/Creative discussion
			Opinion coordination, negotiation, persuasion
	Personal skills	Self control	Self-awareness
			Stress coping
			Stress management
		Self confidence	Understanding of identity
			Self-efficacy / optimism
			Personal Transformation by learning view/opportunities
		Behavior control	Subjective action
			Outworking
			Getting into the habit of positive actions
	Problem solving skills	Problem identification	Information collection
			Understanding of the essence
			Cause investigation
		Planning solutions	Goal setting
			Scenario modeling
			Plan assessment
			Risk analysis
		Implementing solutions	Prectical action
			Correction / adjustment
			Verification / improvement

Table 2. Grades of PROG examinee

Grade	Academic Year				
	2014	2015	2016	2017	2018
1st	○	○	○	○	○
2nd	○	○	○	○	○
3rd	○	△	○	○	○
4th	○	○	○	○	○
5th	○	△	○	×	○

○ : Students of every department took the PROG test

△ : Only students of some departments took the PROG test

× : Students did not take the PROG test

Figure 1 (b) shows the average literacy and competency scores of each grade in 2018. Both figures indicate that both literacy and competency scores grew as the college year advanced. In comparison with the average scores of university students, our first-grade students' average literacy scores and the fourth-grade students' competency scores respectively are equivalent to those of university students'. Since the fourth grade of the National Institute of Technology corresponds to the first grade of the university, the 2018 survey shows that the GSs of our students grow enough as the grade progresses. However, from the first grade to the third grade, literacy grew, and competence grew less. On the other hand, from the third grade to the fifth grade, the growth of competency is large, and the growth of literacy is small. Therefore, it can be said that literacy grows from the first grade to the third grade, and then competence grows after the third grade.

By a five-year follow-up survey of the same students (Fig. 1 (a)), a survey of five different grades of the same year (Fig. 1 (b)), and a comparison with the average value of university students, it turns out that both averages of literacy and competency of our students grow. However, a closer examination of the individual results of the PROG test revealed that in some grades, their literacy or competency did not grow enough. As the students' growth characteristics of GS have been clarified, we will analyze relations between the content and methods of education and their GS growth characteristics to improve our college curriculum.

HOW TO USE GS CONTINUOUS SURVEY

The basic principle of using PROG results in our college is to make our students aware of their generic skills level and use them as a basis for their own steady growth. For that reason, we do not set a minimum score for PROG results and do not provide special guidance to students who do not achieve that score. The following describes how to use the current PROG results and plans to use it in the future.

We have been conducting continuous surveys on students' GS since 2014. In this section, we explain how we use the survey results. First, we explain how our students use the survey results. We are currently implementing two uses. The first use is "Strength Sheets and Reinforcement Books (Handbook for fostering GSs and Explanation for GSs)" for the first and second graders. Since PROG is a test mainly for college students and above, some of our students in grades 1-3 may get lower scores. Some students will think that their GSs are not good enough. Therefore, by distributing a "strength sheet," which summarizes only one's strengths and the GS score results, and by homeroom teacher's explanation of the result focusing on the student strengths, they can recognize their own strengths and weaknesses without losing confidence. Moreover, we can then try to empower the necessary GSs using the reinforcement book.

The second use is to hold a result report briefing session for upper grades (3rd to 4th graders) by the specialist of the PROG development company. Grades 3-4 are the grades just before students start job hunting and corporate internship. They are required to have an accurate self-analysis when making entry sheets for job hunting and corporate internship, but many students are not good at conducting an accurate self-analysis. Students can clarify their appealing points by comparing their PROG scores to the average scores, and by looking at the growth of their scores from a follow-up survey and considering what experience has resulted in the growth.

Next, we will explain "GS portfolio creation," which is scheduled to be implemented from 2020, and "Student's voluntary GS growth cycle." Students will make a GS portfolio that records the results of the PROG exam in addition to the regular academic portfolio. In the GS Portfolio, by recording the score of the PROG evaluation item and visualizing it in a graph, the students can easily recognize their GS growth, which is difficult for students to recognize by themselves. In addition, it would be useful for them to be able to recognize their strengths and weaknesses clearly by comparing their GS scores to the average of their classmates and university students. In the GS Portfolio, they set their own one-year goals of GS growth at the beginning of the academic year and then do self-evaluation at the end of the academic year, as shown in Figure 2. Students spend a year with "strengthening their strengths" and "improving their weaknesses" in mind, based on their goals, which are the ones they want to achieve. Living in that way is expected to foster a more effective and efficient GS than living, not paying attention to them. By continuing to live like that for one year, re-recognition of PROG exams, growth, and resetting of goals in the next year, they will spontaneously improve their lives, and as a result, they will be able to realize a spontaneous and effective GS growth cycle.

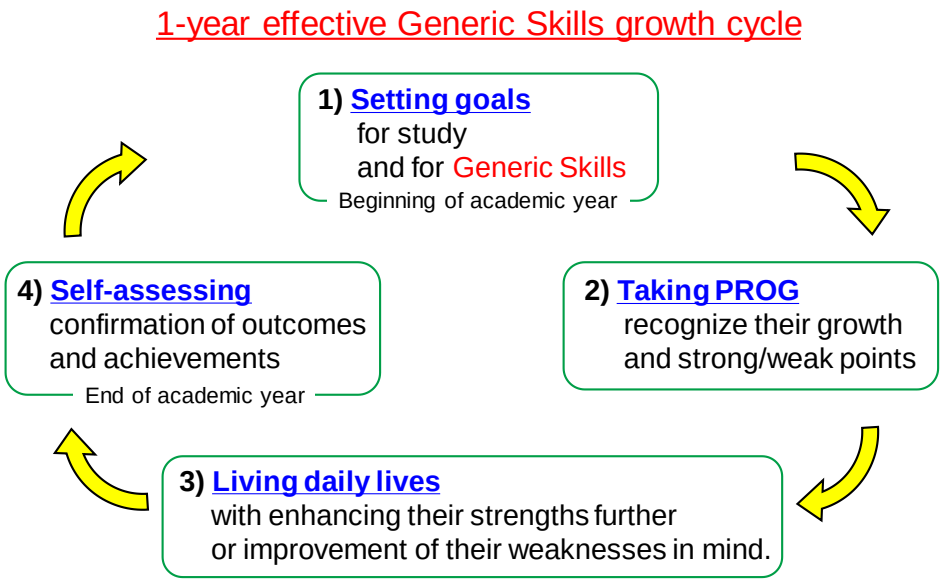

Figure 2. GS growth cycle of students

Next, we explain how teachers make use of it. From the beginning of the survey, the person in charge of the PROG development held a briefing session on how to analyze the results (Figure. 3) and the GS trends of each class. In the briefing session, teachers will be explained the strengths and weaknesses of the class in terms of their GSs and will be given notes on class management and suggestions for improvements. With these explanations, homeroom teachers and other teachers teaching different subjects can learn the helpful features of the class that cannot be measured with conventional examinations.

In addition, the teachers in charge of senior students (grades 4-5) use the results of PROG to support students' careers. PROG developers have published a survey on the relationship between PROG scores and the students employed by companies (PROG Hakusho2018, 2018). Based on the results of this survey, teachers were able to give appropriate advice such as what kinds of GSs they would need to work for the company or industry they wanted to enter. For students, it also has the advantage of making it easier to set GS goals.

MOVING FORWARD

We are currently preparing to use the PROG results for class arrangement. We plan to organize classes not only based on grades but also based on GS characteristics of students from next year.

Finally, a follow-up survey revealed GS growth trends from admission to graduation. In other words, we think that we can analyze the educational effects on students' GSs in terms of the curriculum, such as what element grew in each grade. While it is difficult for teachers to evaluate the students' GSs accurately, using the PROG to quantify their GSs objectively has made it possible to measure the educational effect accurately without a large burden. In the

Figure 3. GS feature analysis briefing session for teachers

future, we plan to improve the class and curriculum for GSs by analyzing the educational methods and curriculum contents used in each class and the GS growth of students in detail. We also plan to develop a diploma supplement for GSs.

CONCLUSION

At the National Institute of Technology, Sendai College, we have been continuously examining the generic skills of students using PROG, an objective evaluation, since 2014. A five-year continuous survey has revealed the generic skills growth characteristics of students from their admission to graduation. The follow-up survey showed that both students' literacy and competency grew as their grades in college advanced. On the other hand, it has also revealed that there are some grades in which students' literacy or competency did not grow much.

As feedback from the continuous survey, we distribute "strength sheets" to students and hold "result utilization briefings." In the future, we will try to practice the spontaneous growth cycle of students using the "generic skill portfolio". On the other hand, as feedback to teachers, we hold the "result report briefing session" to manage the class and to utilize it for students' career support. We will use it for class management from next year. We are currently conducting a detailed analysis of the curriculum, lesson contents, and the results of the PROG to improve the curriculum and lessons. Based on these results, we will develop diploma supplements for GSs and improve the quality of lessons.

ACKNOWLEDGMENT

This research is supported by Japan's Ministry of Education, Culture, Sports, Science, and Technology's program for accelerating university education. We thank all the faculty members, including the principal of the National Institute of Technology, Sendai College, for contributing to the improvement of education. We also thank Mr. Kondo of RIASEC Inc. for their cooperation in analyzing the results.

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AVAILABILITY OF CDIO AS A DRIVER OF CREATING SHARED VALUE

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ABSTRACT

The purpose of this paper is to examine the applicability of CDIO to business education. Particularly, I examine the effectiveness of the CDIO framework in relation to Creating Shared Value (CSV), a concept that has been attracting attention in recent years in corporate management theory. As an example, this paper introduces a Project-Based Learning (PBL) class conducted in 2018. The class emphasizes collaboration with companies and focuses on experiencing actual business. In other words, students execute a real project given by a company. The feature of this class is that it does not end at simply the planning stage, but it moves to the actual executing stage. The class is also conducted with a focused awareness of CSV. The students learn not only to conduct business but also to create social value through business activity. In other words, the significance of this class is not just to experience business, but to find shared value through business activities. Although some challenges remain, it should be considered that the CDIO process can be useful for experiencing CSV through business education.

KEYWORDS

Creating Shared Value, Project-Based Learning, Business Education, Standards 6, 8, 11, 12

INTRODUCTION

The purpose of this paper is to examine the applicability of CDIO to business education. Particularly, I examine the effectiveness of the CDIO framework in relation to Creating Shared Value (CSV), a concept that has been attracting attention in recent years in corporate management theory.

According to Crawley et al. (2014), the CDIO framework was developed to reform engineering education in order to enable engineering students to enhance their competencies to become successful engineers. However, CDIO is not limited in application to engineering programs. It can also be applied to most other programs in higher education. Crawley et al. (2014) point out that business education is one of the areas of potential application. In fact, various studies on the application of CDIO to non-engineering fields have included business education.

For example, Bienkowska et al. (2016) introduces several cases of implementing CDIO in management courses in engineering programs, including a thesis writing course. In the thesis writing course, students work with real-life challenges in collaboration with firms and learn about project management. They conclude that CDIO could be useful outside an immediate engineering context, although it is not a typical engineering application. In another example, Tangkijviwat et al. (2018) introduce a case of applying CDIO to the field of mass communication, illustrating how students' performance has been improved. Students learn media planning and production as well as financial management in a class titled Principles of Media Production for Multimedia. The students designed logos, labels, and packaging for a customer's products. The conclusion was that CDIO-based education could enhance the competency of graduates to meet stakeholders' requirements. In addition, there are other cases where CDIO is applied to six non-engineering programs including Business Administration and International Business programs in 3 different schools (Malmqvist et al., 2016) and where CDIO is applied to an entrepreneurship course between an engineering school and a business school jointly (Pasos et al., 2018).

This paper introduces another example of applying CDIO to business education and discusses how CDIO is available for business education by which students learn the importance of CSV through business operations.

First, I will review the concept of CSV, followed by a case study of a Project-Based Learning (PBL) class conducted in 2018. After describing the case, I will discuss the availability of CDIO to business education with a CSV perspective.

WHAT IS THE CONCEPT OF CSV?

Creating Shared Value, or CSV is a framework for creating new markets and corporate value that provides useful suggestions for today's corporate management. It argues that companies should realize the economic value and social value simultaneously through their business activities. In other words, companies should design their business to realize both economic value and social value at the same time as the core strategy.

Although various similar concepts have been discussed before, such as in Kanter (1999) and Porter & Kramer (2002, 2006), the concept of Creating Shared Value is said to have been widely proposed by Porter & Kramer (2011).

Companies should create useful value through corporate activities, and as a result, society should be enriched. However, Porter & Kramer (2011) argue that the value of corporate activities is treated unjustly in modern society under the false recognition that corporate activities and the creation of social value are in a trade-off relationship. As a result, companies try to show the significance of their existence in society by conducting social contribution activities represented by CSR and philanthropy. However, CSR and philanthropy embrace the idea of returning profits earned by companies to the society. This is not an activity that creates new value. In other words, CSR and philanthropy are not activities that create value, but merely a "distribution" of corporate profits. Therefore, there is a trade-off between profit creation and social value creation in corporate activities. So long as we assume this position, the creation of social value cannot be the purpose of corporate activities. Rather, what a company should focus on in the first place is value creation that includes social value.

In order to combine corporate value and social value, Porter & Kramer (2011) propose the concept of "shared value," stating that the principle of shared value "involves creating economic value in a way that *also* creates value for society by addressing its needs and challenges." and that "businesses must reconnect company success with social progress (p.64)". In other words, it is an approach that creates social value by addressing social needs and problems through business activities, and as a result, creates economic value. By introducing the concept of shared value, Porter & Kramer (2011) argue that "the purpose of the corporation must be redefined as creating shared value (p.64)". This is the outline of the concept of CSV.

CASE STUDY

This section introduces a PBL class conducted in 2018 at Hokkaido Information University (HIU). The class consisted of 7 senior students (4th grade) and 5 junior students (3rd grade). The class emphasizes collaboration with companies and focuses on experiencing actual business. Students execute a project given by a company. The central feature of this class is that it does not end at simply the planning stage, but it moves to the actual executing stage.

In the class, students worked with the Sapporo Printing Cooperative to develop teaching materials for kindergartens, which prints a circular with craft materials. 23,500 copies of this circular are printed and distributed to 120 kindergartens in Sapporo City free of charge. As will be described in detail later, the students chose the Sapporo TV Tower as the theme of the task.

Sapporo City and The TV Tower

Before I describe how the project proceeded, I will outline Sapporo City, and it's TV Tower.

Sapporo, with about 1.97 million population, is the capital city of Hokkaido, the northernmost island of the four main islands of Japan. It is a popular tourist destination for people from both Japan and overseas. The TV Tower is located in the very middle of the city, with a 90-meter-high observation deck. Since its construction in 1957, it has been loved by citizens as a symbol of the city. More than 420,000 tourists visit every year.

The project was executed in the following phases, following the CDIO process.

Conceive and Design Phases

First, a person from the Cooperative visited the class and explained the outline of the project. Students were given a task to work on. The task given in 2018 was to develop the content of the teaching materials for kindergarten children. The students then discussed their ideas (Figure 1).

Figure 1. Students' discussion

The discussion took place in HIU's multi-purpose active-learning room, whose walls are covered with whiteboards. The students designed their own space, moving and arranging chairs for easier discussion and so that everyone could easily see the whiteboard during the discussion. CDIO standard 6 states that the workspace supports students' learning in which they are directly engaged in their own learning and learn from each other interactively. This discussion class is a good example of how important designing a workspace is.

Since this teaching material is circular (see figure 2), it contains advertising. Therefore, the students must set a prospective target company as a sponsor. This is another task given by the Cooperative. In other words, it was required not only to generate ideas but also to think about how those ideas could be commercialized.

Figure 2. The teaching materials

As a result, the students chose the TV Tower Company as a potential sponsor and planned "The TV Tower Coloring Contest." The plan was to recruit colorings of the TV Tower from children and display the entries on the observation deck of the Tower. Since the TV Tower is one of the most popular tourist attractions in Sapporo City and is also known to all citizens as a symbol of the city, this idea encourages kindergarten children to develop an understanding of the TV Tower from an early age. The students' plan was compiled into a proposal.

Next, the students attended a planning meeting, where professionals gathered and heard their proposal. Figure 3 shows their presentation at the meeting. Various discussions took place, and they received some criticism, but as a result, their plan was adopted. Here we can see the Conceive and Design phases of the CDIO process.

Figure 3. Students' presentation at the planning meeting.

Implement and Operate Phases

Since this teaching material is circular, the students then solicited the TV Tower Company in order to get advertising. They made a business proposal and presented the benefits of sponsoring the plan. Figure 4 shows how they presented their plan to the TV Tower Company. They proposed that if the company recruited coloring works and displayed them on the observation deck, parents and grandparents would visit there to see the works of their children and grandchildren, and the company's income (i.e., the entrance fee of the deck) would increase.

Figure 4. Business proposal by the students.

They also proposed that this project would not only increase the profits of the company but also provide families an opportunity to enjoy their own company, which is often lost in the modern daily lives of people. When children work on coloring, parents can enjoy talking with and sometimes helping and advising their children. Grandparents can enjoy seeing their

grandchildren's works with their families on the observation deck. That is, the students argued to the company that their proposal would benefit them not only in terms of profitability but also in terms of social value for the company of families.

After presentation and negotiation, the students received the company's consent. It agreed to contribute funds as well as to recruit and display children's works. As a result, 88 works were collected and displayed at the observation deck. Here we can see the Implement and Operate phases of the CDIO process.

DISCUSSION

Availability of CDIO to Business Education

From the perspective of business education, the students learned a lot from the process of this project, which is based on the CDIO framework. It is a good example of active learning that corresponds to CDIO standard 8. In particular, the students learned through the first-hand experience that making plans is totally different from executing them. At the stage of moving the plan into effect, there are many unforeseen factors that need to be confirmed. For example, the design of the TV Tower has its own copyright. In order to use the TV Tower in teaching materials, the copyright issue must be resolved. They negotiated with the company in order to solve problems like these. In this way, they learned what was needed to make the plan effective.

Furthermore, these activities were conducted with a constant awareness of CSV because the project was originally designed with the CSV structure in mind. Figure 5 illustrates and summarizes the CSV structure of the project.

Of course, the publisher (i.e., the Cooperative), makes a profit through this project. They receive advertising fees and printing fees. However, the development of teaching materials for kindergarten children was not only to generate profits for the publisher but also to provide educational opportunities for kindergartens. That is, the project was a good opportunity to contribute to education through the business for the publisher.

By using this teaching material, kindergarten teachers can save time on making materials by themselves. For kindergarten teachers, making teaching materials is a complex and time-consuming task. They can get various craft materials for free because they are included in the circular. Teachers can use the time they save on other tasks, which can improve the quality of education. From this perspective, this project has social and educational values. It helps kindergarten teachers to save time, to find good teaching materials, and to improve the quality of education.

Sponsor companies, meanwhile, can achieve increased advertising effectiveness: parents and families do not tend to quickly forget the crafts that their children worked on. They tend to keep the children's works almost forever. That is, the advertisement is not likely to be thrown away, despite it is circular. This project solves the problem of sponsor companies that their circulars are thrown away quickly. From this perspective, it has significant business value.

For families, as mentioned above, the result of the project offers enjoyable experiences for parents to talk and work on coloring with their children at home. It helps them to regain and enjoy their family's company. Further, by selecting the TV Tower, a symbol of the city, it also becomes an activity to help raise children's awareness of the city they live in. Perhaps, it

motivates them to appreciate their hometown. From this perspective, this project has social value.

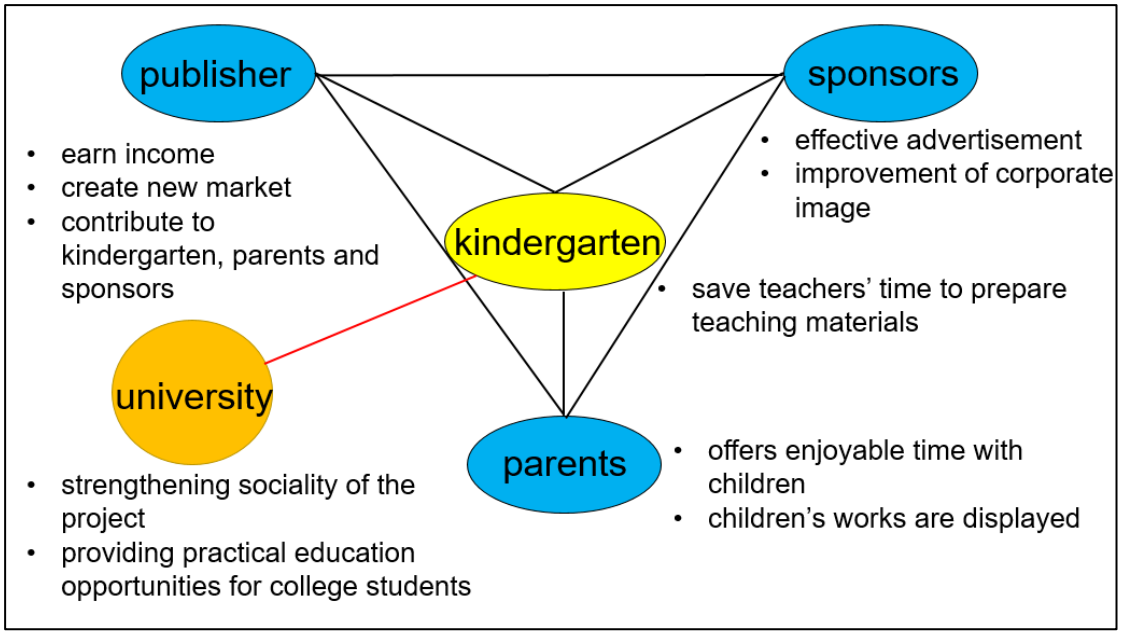

Figure 5. The CSV structure of the project.

Finally, the university can provide practical educational opportunities for its students through this project. Students learn about how the real business world operates, as well as realize the importance of fostering social value through business activities. The commitment of the university strengthens the sociality of the project.

As I have outlined above, this project has both business value and social value, which means it creates shared value. The students have learned not only to conduct business but also to create social value through business by participating in this project. In other words, the significance of this project is not just to experience business, but to find shared value through business activities.

Through this activity, it becomes apparent that the CDIO approach is useful for students to enhance their understanding of the importance of CSV when conducting business. They learn that a business plan is not realized by itself, but only after considering its social value. They learn it by following through to the actual executing stage, not by staying and ending at simply the planning stage. This follow-through to the end is a hallmark of the CDIO process.

Business education needs to include a treatment of sociality or social contribution through business activity. The only real way to achieve this is by having students experience these things first-hand through carrying out real business projects. The CDIO approach is, therefore, a useful way to provide students with experience in real business projects, because it includes the Implement and Operate stages. One could even say that the CDIO approach is necessary for students to understand the importance of CSV.

Challenges

Figure 6 shows a part of, not the whole of, the curriculum map of the Faculty of Business Administration and Information Science at HIU. The PBL classes are at the core of the curriculum. Students take the PBL classes from the 1st grade to the 4th grade, including an introduction to PBL. The purpose of the PBL class is to develop people who can realize a prosperous society from a broad perspective based on the acquired knowledge. The required competencies are the ability to collect necessary information from various opinions and materials, the ability to express one's thoughts accurately, and interpersonal communication.

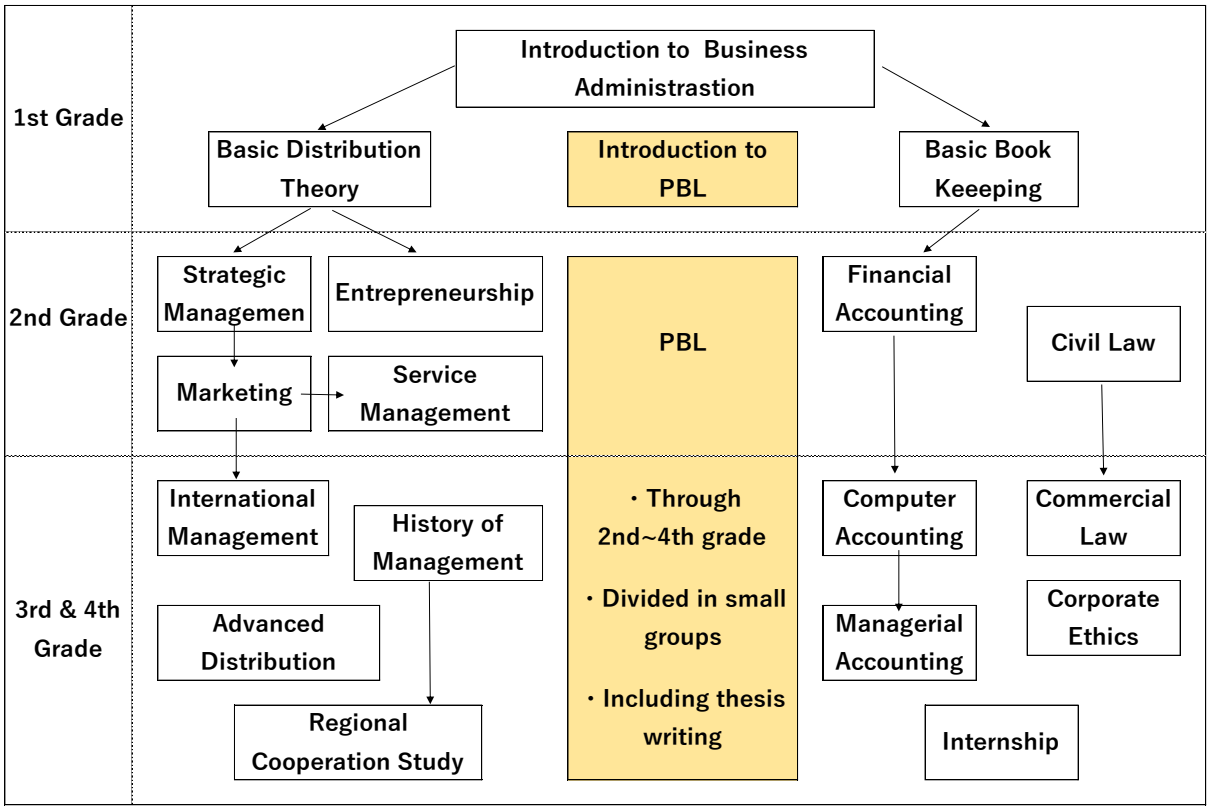

Figure 6. Curriculum map of Faculty of Business Administration and Information Science.

For these purposes above, the class aimed to apply the CDIO framework and make it more effective based on corresponding subjects. Since this project is the first attempt, however, there are some challenges that are yet to be overcome. In conducting this project, the class focused on achieving results too much. There was a lack of evaluation for both the students' performance and program itself, which has a bearing on CDIO standards 11 and 12.

CDIO Standard 11 requires that instructors must evaluate students' learning by using a variety of methods matched appropriately to learning outcomes. These methods may be, for example, rubrics, rating scales, and peer and self-assessment, among other things. However, conducting the program admittedly took more time than expected, which compromised the time necessary for sufficient evaluation.

Further, CDIO Standard 12 requires that a program should be evaluated by evidence of program progress, and improved based on that evidence. In this case, because Standard 11 was not sufficiently addressed, Standard 12 could not consecutively be satisfied.

Taking the above points into consideration, establishing and implementing effective evaluation methods, and improving the program incrementally over the course of time are future goals for this class.

CONCLUSION

This paper introduced a PBL class conducted in collaboration with a company and examined the availability of CDIO to business education. By examining the activity using the CDIO framework, it should be considered that the CDIO process can be useful for experiencing CSV through business education.

Education, including but not limited to business education, should not be unrelated to society or industry. It should always respond to stakeholders' requests and/or needs. In today's world, business education, in particular, should strive to foster in students a consciousness of social value. Within the CDIO Initiative as well, there is a movement to explicitly incorporate sustainability that society demands (Malmqvist et al., 2019). CDIO, therefore, stands to enhance the social aspect of business education.

As Pasos et al. (2018) pointed out, this kind of education is a time-consuming process. However, it is beneficial for instructors to take the CDIO framework into consideration. They should implement effective evaluation methods and make efforts to improve their programs continuously.

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BIOGRAPHICAL INFORMATION

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USING CDIO TO DEVELOP PROJECT LEARNING ACTIVITIES FOR YOUNGER STUDENTS

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ABSTRACT

A persistent misconception about technology as an education field and the work of the engineer exists with younger students (13-16-year-olds). These young students need to determine at this age their own interests in pursuing future studies. To better support their choices, initiatives have been undertaken in collaboration with primary and secondary school science educators to develop learning activities promoting technology and discovery by mobilizing students around an open-ended project with project-based learning (PBL) approach. The project's goal is to provide a learning activity during which young students (boys and girls) could experience in teams the design-build-test project development cycle through an open exploration mindset, anchored with a socially significant goal. During the project definition, it was found that science educators need better support to teach technology using more interactive and open methods. This paper presents the multiple activities that were combined to achieve this goal. The project started by building upon the knowledge acquired with undergraduate students through the development of active learning projects. The next step was to adapt those projects to younger student's interests and motivations, such as social and environmental issues. To this end, a co-creation process was implemented; secondary school educators from the school board, Commission scolaire Marguerite-Bourgeoys, undergraduate engineering students, engineering professors, and Fablab personnel from École Polytechnique Montréal were involved in the development of hands-on activity for younger students. The open-ended social design challenge -a hydroponic system-, based on plant growth, motivated the students to conduct their own experiments while respecting the educational program requirements. The activity has been tested, with positive but also mixed results. Open-ended projects increase motivation with young students. However, the link between the project realization and a better understanding of the work of engineers could not be confirmed. More experiences are needed to better manage personnel and material resources to provide a long term sustainable initiative.

KEYWORDS

Technology education, young students, open-ended project, PBL, Standards 4, 7, 8, 10

STATE OF TECHNOLOGY EDUCATION IN QUEBEC

The state of science and technology education in Canada appears to be very good, Québec's schools scored 7th overall in PISA 2018. Nevertheless, the science and technology curriculum has some strongly documented criticisms for the way problem-solving is implemented. Educators involved in teaching sciences with better integration of concepts from several STEM (Science, Technology, Engineering, and Mathematics) fields into one coherent learning sequence. In nation-wide studies on student's motivations for STEM (DeCoito, 2016, and Parkin, 2018), students strongly reaffirm their preference for meaningful hands-on project learning environments.

Another issue is the male-female imbalance observed in technology education and careers. Authors report that for technology education, males have more positive attitudes and confidence than females for using technology in learning (Yau, 2012) or learning about technology (Kulturel-Konak, 2011). If the context and methods used to learn technology were modified (active learning, significant context, creative thinking), could this socially constructed imbalance (Yau, 2012) be changed?

A project-based learning (PBL) context seemed well adapted to promote technology learning. PBL has been found to promote learning in STEM students at all performance levels and individual factors such as gender, ethnicity, and language proficiency (Han, 2015).

Pedagogical support personnel's experience indicates that science education is easier for educators to teach, as compared to technology - which is viewed as the practical application of science. Educator's lack of resources and practical knowledge prevent them from being fully comfortable to teach technology, and consequently, teachers stick to the textbook. This is problematic considering that the Quebec educational system pushes 13-14-year-old students to decide between two profiles for secondary 3: a pure science approach to concepts or an applied science approach. At 14-16 years old (secondary 4 and 5), students are making a choice of math and science courses that can restrict or require extra courses to have access to certain disciplines in their future studies. At this age, the exact knowledge of the possibilities available in technical careers are sometimes biased or not well known.

In an effort to improve this situation by providing a better understanding of the technical careers, an experiential learning project in the development and application of technologies for society was found to be an interesting opportunity.

CREATING AN OPEN-ENDED TECHNOLOGY SUPPORTED SOCIAL PROJECT

Partners

The initiative is based on past experiences of teaching undergraduate engineering students at ÉPM and bring experiences developed in project work to younger students. The motivation was to foster the curiosity of 13-15-year-olds to experience the link between technology and society. Representatives from a Montreal school board, Commission scolaire Marguerite-Bourgeoys, confirmed their interest in the project. Through them, interested professors and classes were identified to integrate this co-developed activity in their program.

Requirements

Following the first team meetings, it was decided a CDIO inspired methodology would be applied to the development of the learning activities as well as in their delivery to the students. Many outreach programs exist at ÉPM, some as short single activities (2-3 hours) but also in a long summer camp format (1-2 weeks). A short activity creates interest but does not give an outlet for the long term involvement of students, and curiosity rapidly disappears in the weekly flow of school activities. The summer camp attracts mostly students with already close contact with people involved in technology (parents, close friends, and family). The search for a different format of activity was felt necessary to develop and improve the link between the people who develop technologies and their impact on society.

Based on the science and technology course content defined by the provincial education ministry, it was found an open-ended social design challenge based on plant growth on a green wall covered a significant number of poorly contextualized content objectives (Table 1).

Table 1. Science and Technology course content

Required subjects in the program	
Matter and solutions	History of life
Energy	Biotechnology
Fluids and waves	Technical drawing
Cells and genes	Mechanical engineering
Human systems	

Furthermore, the exploration and iteration around a core of achievable functioning prototype elements ensured, at a minimum, a positive but still challenging outcome. This contributes greatly to student motivation (Viau, 2000). The cost of the project was significantly higher than what an ordinary school can afford. The cost of the machines and materials was greatly simplified by the stakeholders, but it was not the main constraint.

Activity Goal

The important goal defined by the stakeholders was to bring students to see technology as an accessible and interesting field where they can contribute to help society in solving important and significant problems, not just science for science's sake. To achieve this, a more active approach to teaching technology was chosen.

Project Definition

A group of undergraduate engineering students and Fablab personnel designed and built the project as well as the in-class activities. Iterations with the pedagogical experts and in-class teachers followed to improve the activity further in multiple co-creation cycles.

The project was constructed to be able to follow different paths and outcomes depending on the class response and motivation during the activity. A completed student team project contains a structure, container, computer-controlled light source, and pump (Figure 1). Some elements were supplied but required assembly, soldering, programming, or other activities to complete the project. Needs research, design iterations, and exploration were the main components of the activities in class.

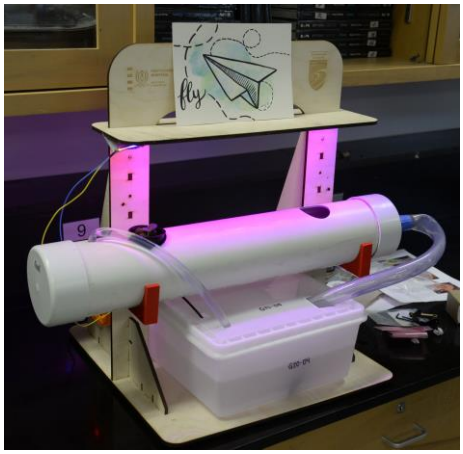

Figure 1. Completed student project

For this first trial experience, the objective was to plan positive outcomes in many alternative project paths to be able to modulate: complexity, outcomes, and technical subjects explored. During the project, students will go through a complete product design cycle (Figure 2).

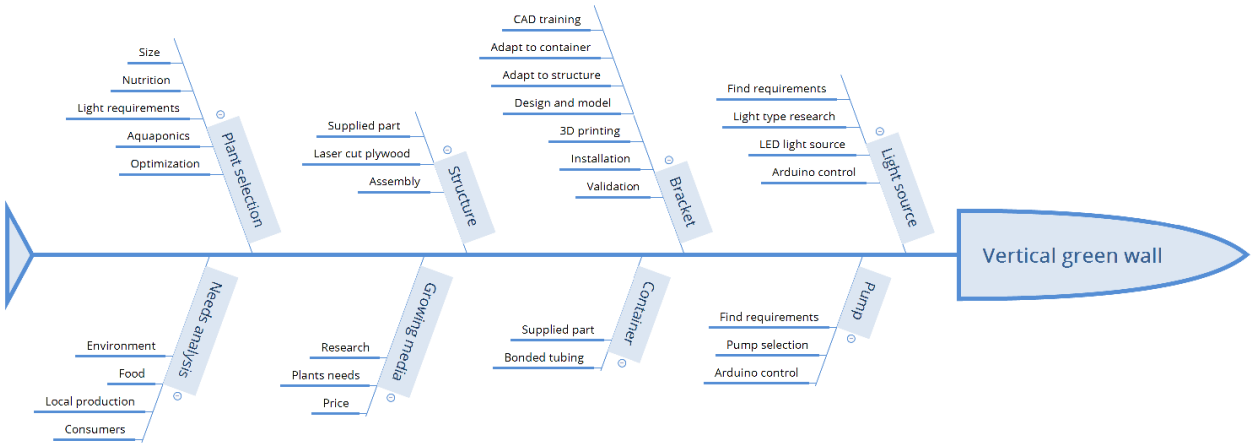

Figure 2. Activity planning

Engineering students (student mentors) are in class to give formal content but, more importantly, to provide mentor figures and role models closer to the young students than an engineering professor. The activity spans over 12 weeks, with one 75 minutes period every week. A CDIO design process is applied where young students research needs, design a product or service, implement the design, and operate it. All fabrication equipment required is brought to the school where the young students use the equipment themselves to manufacture or assemble their parts.

Developed Documentation and Materials

To support the activity, an important effort in creating documentation and providing design tools for the different stakeholders in the project was created or adapted from existing efforts (Figure 3).

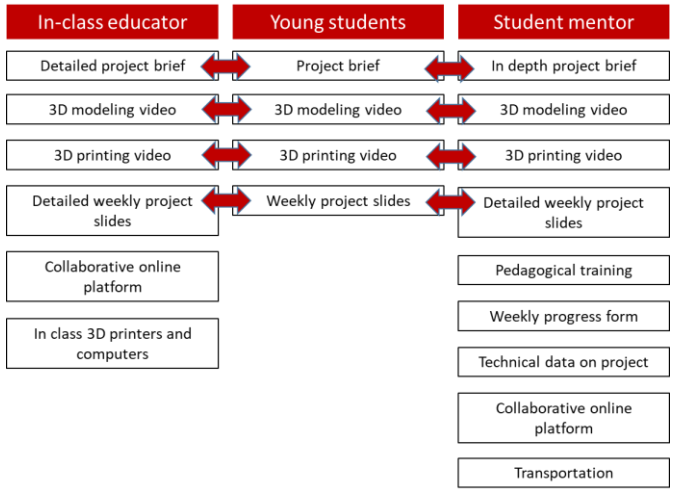

Figure 3. Developed materials and support

THE PROJECT IN CLASS

The project was presented to two classes of 24 students from January to March 2019. For this pilot project, the activity was optional and was added to the traditional content that was still given to the young students. Each project prototype will be built by teams of 4-5 young students. A team of two engineering student mentors will be in class for each class period.

Training of In-Class Engineering Student Mentors

Engineering students were trained to have basic knowledge about student-mentor relationships and a few pedagogical skills to interact with teenagers. Extended in a few training sessions, the course contained basic etiquette (punctuality, dress code, professionalism), relational aspects (sharing personal experiences, being a role model, adapting quickly to diverse situations, leading in-class discussions, asking open-ended questions, connecting with students, respecting students' rhythm, etc.), and finally an introduction to technology (basic programming skills, demystifying concepts, simplifying, generating curiosity, and questions to be explored). It was presented to the student mentors in various forms, amongst which: formal training, technical exercises, and role-playing. The team of 8 student mentors included male and female students, from diverse engineering fields and levels of study. About half of them already had some experience of interacting with young students in shorter activities.

Activities in Class

From the initial technical activity planning, a weekly in-class plan was detailed (Figure 4). The main items chosen to develop were: design process, design software tools, 3D printing, Arduino programming, assembly, and fabrication techniques.

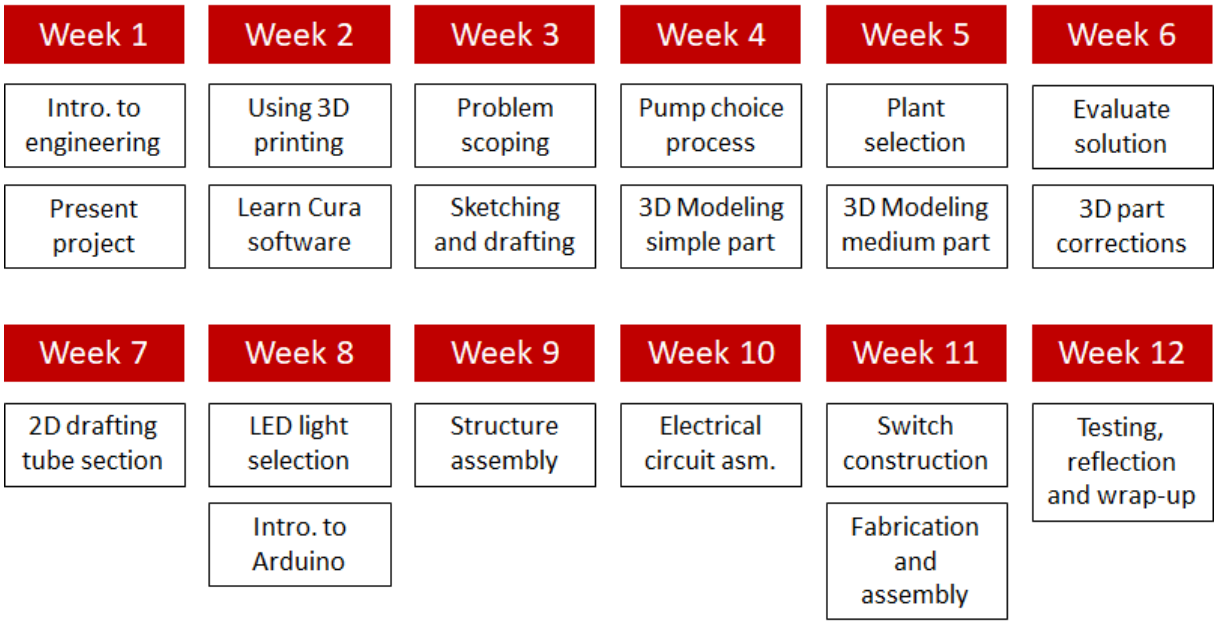

Figure 4. In-class activities

The task intensity can seem quite high, but a process-oriented approach was favored in place of results only approach to manage project difficulties. An incomplete result will be managed by student mentor support to coach the young student to find a quick win solution by himself or understand the origins of the incomplete result.

Logistics

The project required intense logistics and project planning. Student mentor availability, material sourcing, design, sub-assembly construction, budget burn rate, project progress, and transportation were all closely followed by a senior project manager.

RESULTS

Student Projects

All student teams completed the hydroponic system project with a functional prototype. All prototypes subsystems worked: all structures were correctly assembled, and some were improved, custom-designed brackets supported the main tank, the pump system circulated water, the Arduino controlled lighting followed programmed durations. The level of quality varied from one team to another and from one subsystem to another. Again the objective of the activity was processing and not prototype performance per se for this first 12-week design cycle.

One of the open-ended design elements student teams had to develop was the main tank support brackets. The different geometries generated hands-on opportunities to discuss optimal material use and structural integrity with student teams. Some student teams had structural failures for which they designed new versions to correct the situation. Multiple design variations of the tank brackets from the two groups can be seen in Figure 5.

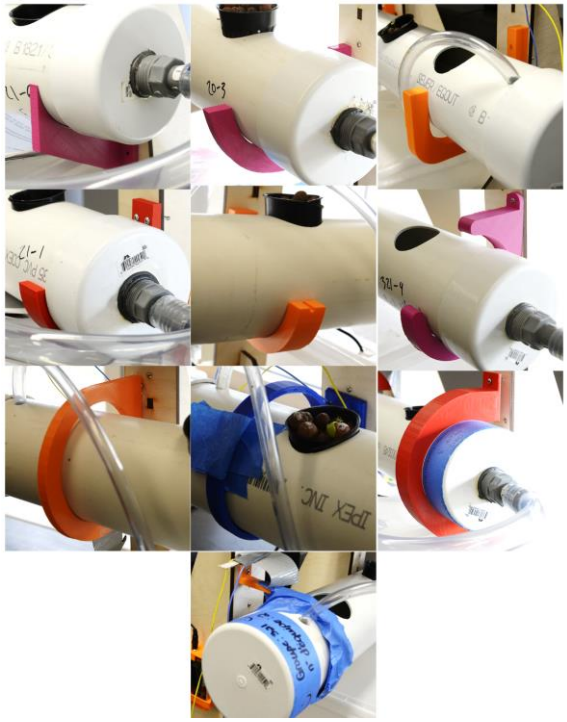

Figure 5. Main tank support bracket variations

Stakeholder Perception of Results

After the project completion, multiple feedback activities were completed:

- Young students completed a project survey at the end of the activity
- Student mentors wrote a reflexive essay at the end of the activity
- School board stakeholders wrote a complete activity report
- Polytechnique Montreal wrote an internal process and activity review

The critical learning points extracted from all this information can be found in Table 2.

Table 2. Critical learning points

School board project review excerpts	Impact on young students ● Project learning has an impact on student autonomy, not on content (Prince, 2004) ● Good introduction to “grit,” does not always work the first time ● Can work for students with manual or theoretical preferences ● Ambitious complexity level is well received by students for its diversity and in context competencies ● Imperfection of student mentors makes their charm ● Young students want even more liberty in the project process Impact on administration ● Good alignment with program requirements essential ● Project brings context to traditional content ● Requires time investment from the in-class teacher, not all are ready ● Need better training for teachers on the tools used

	● Existing school system makes challenging the integration of PBL ● Teacher must consider evaluation from a different perspective ● Surprised by the co-construction process of the activity Content and format ● Online video training is not sufficient for learning 3D modeling tools ● Improve support documentation ● Look into Shorter 2-day activity to experience the design process ● Multiple other project subjects and contexts could be explored for future development
Student mentors reflexive essay excerpts	Impact on young students ● Amazing to see the eyes of the young students twinkle when they first start their prototype, priceless! ● Time given builds closer relationships with young students ● Kids are fascinated by 3d printers ● Need a more weekly reflexive review of activities with young students Personal gain ● Sentiment of implication and applied grit to make the project work ● Supplied training (mentorship, process, tools) was sufficient ● I would do it again, anytime (by all student mentors involved) Content and format ● More important to be good in animation than good technically (technology easier to learn in this context) ● Match experienced student mentor with new mentors ● Use a better week to week process progress documentation ● Involve the in-class teacher more in the first weeks ● Software needs were too simple, and students could do more ● With more task flexibility in the project, a more complex project could be completed ● Give more flexibility in materials supplied for the design ● Complete project view needed to accompany young students ● Need better support from project leaders and designers ● Slack tool helped manage communications between stakeholders
Polytechnique Montréal project review excerpts	Impact on young students ● Take into account the socio-cultural context of the young students ● Better demystify the engineering profession by tagging the activities in the project and presenting in the context ● Plan project so all young students must contribute at all times ● Same student mentor must go in the same class to build confidence ● Varied learning materials and formats worked very well Impact on administration ● Continue to adapt to the teacher's planning and evaluation (Conseil supérieur de l'éducation, 2018) ● Better train the educators before the activity (8h minimum) ● Need to build better links to co-construct future projects Content and format ● Build student-mentor teams in advance ● Train student mentors very closely and in a structured way ● Insist on the need for iteration in problem-solving ● Plan closely on what elements young students have control over ● Software, tools, machines must be functional! ● Must have a single point resource identified to manage problems ● Real-time project resource planning is essential

Young student's self-reported survey analysis	• Students would appreciate the project even if they did not show interest in engineering • Links between project and engineering were not clear for students • 3D modeling and printing is a hit • Satisfaction of designing, assembling an efficient, functional and robust product • Project proposals of interest to young students: robotics to help humans, technologies to save fauna, renewable energies, sound or visual pollution, universal access

Looking more closely at the young student self-reported survey using technical, social, and professional segmenting of data, the following trends can be seen (Figures 6, 7, and 8). The interest was looking at the opinions of boys and girls on the activity.

In Figure 6, the number of students still feeling at a very beginner level after the 12-week activity remains high. The group has shifted to a higher perceived competence level, but more reflection on the training material supplied is needed to increase this shift incompetence further.

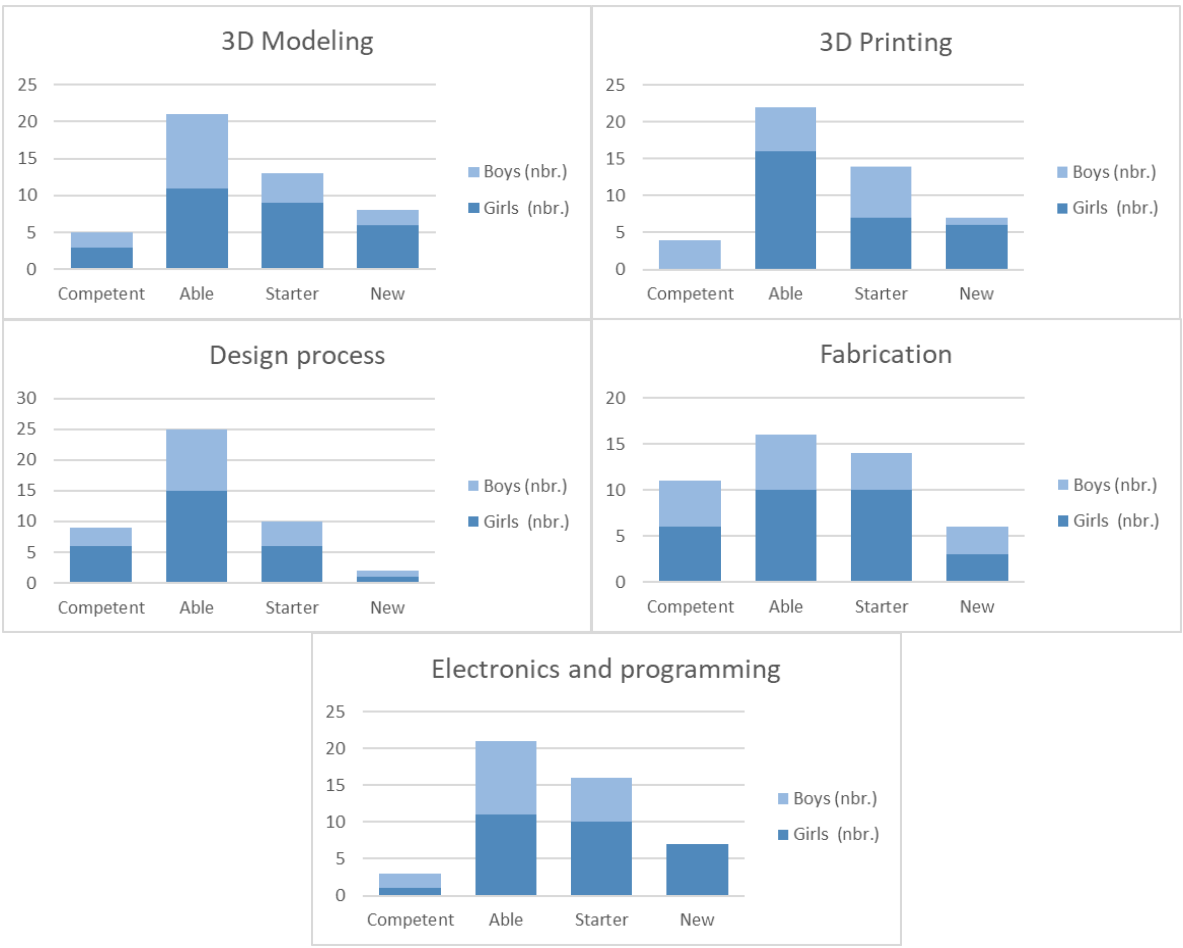

Figure 6. Technical aspects in survey

The disparity between boys and girls found in Figure 7 is interesting. With similar teamwork mentoring, the perceived competence has increased more with girls than boys. The one on one long term mentoring might be one of the positive actions that favours this result.

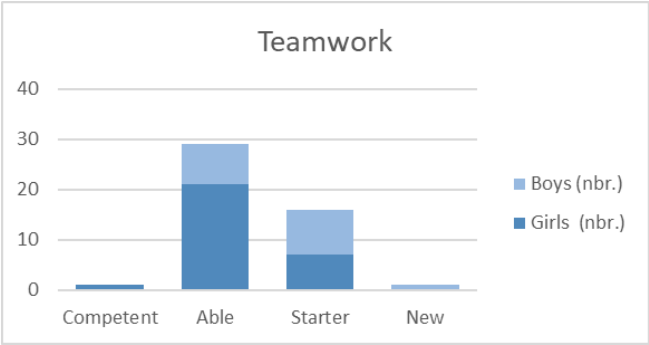

Figure 7. Social aspect in survey

While project appreciation is high, as seen in Figure 8, the transfer to the interest and knowledge of engineering is not as good. More work is needed to better highlight the links between the content given in class during the project and specific engineering practice and fields of study.

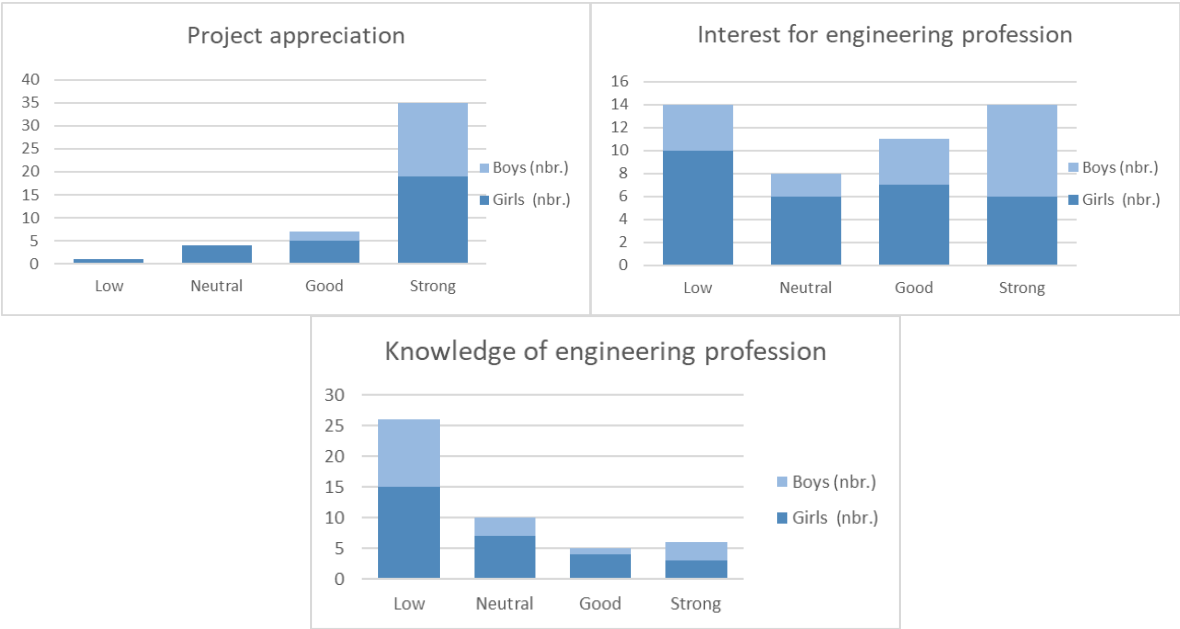

Figure 8. Professional aspects in survey

CONCLUSION

In review, the project subject and context was a success. Students appreciated working on a hands-on project but also demonstrated to their educators their understanding of what they were working at a surprisingly detailed level. The in-class educator found the PBL experience challenging but very rewarding. The level of confidence of the in-class educator with the

content increased over the 12 weeks to the point that when faced with technical problems with the 3D printing machine, the educator debugged the machine herself. However, some difficult issues remain.

Providing a sustainable long term project-based learning platform is difficult. In this experience, the level of coordination of the resources needed required huge amounts of energy from the already busy staff. Financing this initiative can also become difficult since right now, it is very dependent on specific, highly motivated individuals in place at the different institutions. Figure 9 highlights the important aspects and challenges faced during this project experience.

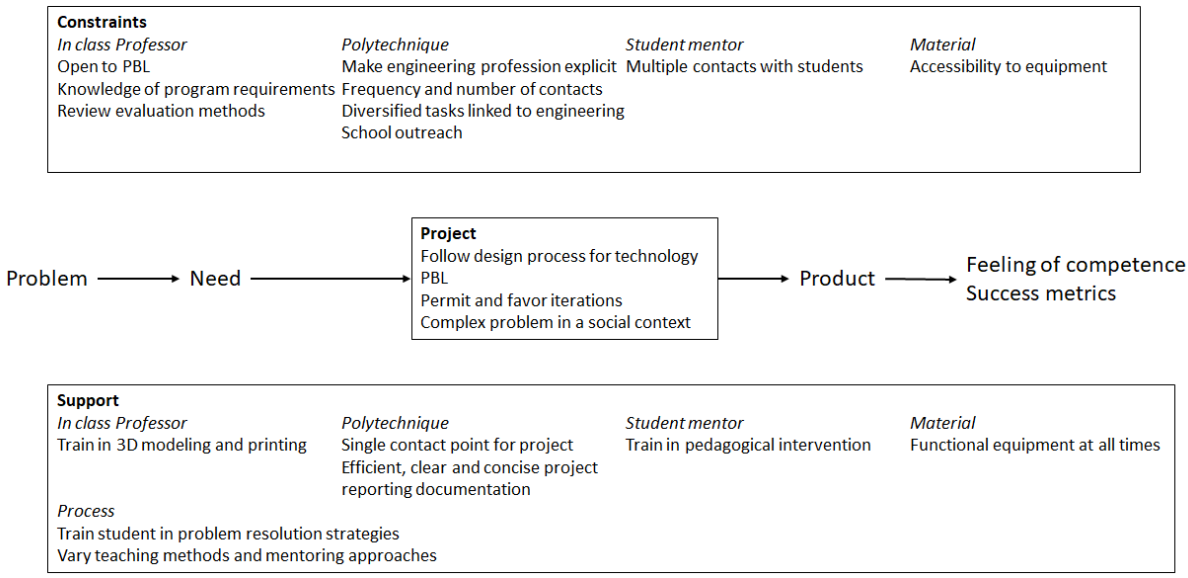

Figure 9. Project highlights and lessons learned

At the last stakeholder review meeting, the conclusion was that although the project in its present form provided motivation and hands-on experience of the design process, a shorter and less intensive approach might bring similar results. The reflection on how to better define the problem-solving activities will act as steps to realize a better open-ended project. Already, some new activities have been influenced by the work done.

ACKNOWLEDGEMENTS

This project could not have been done without the extreme involvement and energy of Roberto Calvi engineering physics student, who led the design of all technical elements. A very warm thank you to all our student mentors for their openness and patience with this work in progress: Lucas, Mayari, Florence, Hugo, Richard, Vincenzo, and Alexis.

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EFFECT OF CONSTRUCTIVE ALIGNMENT IMPLEMENTATION ON CHEMICAL ENGINEERING KINETICS COURSE

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ABSTRACT

Most engineering courses at the undergraduate level are delivered by using a lecture-based teaching approach. In the past, this technique was successful because the students had motivation and passion for learning for improving themselves, but the goal of the study at the university was changed nowadays. In Thailand, some students in the university do not have goals or motivation to improve themselves, so the techniques and the course design need to change to meet the student behaviour. The constructive alignment was chosen to design the course of chemical engineering kinetics and reactor design for third-year students at the department of chemical and materials engineering, faculty of engineering, Rajamangala University of Technology Thanyaburi. There are three parts of the course which need to align together. They are intended learning outcomes (ILOs), teaching and learning activity (T&L), and assessment method (ASM). This action research has studied the alignment of ILOs, T&L, and ASM to increase the engineering skills for chemical engineering students. The intended learning outcomes were the first one, which needs to design according to the course description and the CDIO skills, for example, teamwork, critical thinking, and communication. Then, the assessment methods were selected to measure student skills such as quizzes, assignments, examinations, and rubric for both formative and summative assessments. The last one is teaching and learning activities. T&L needs to design align with ILOs and ASM because they are the indicator of the success of constructive alignment. As mentioned earlier, only lecture techniques are not suitable for present students but still necessary, so we need to add some active learning techniques to combine with short lecture approximately 15 minutes. For example, jigsaw classroom, think pair share, group discussion, etc. The data were collected during the class and after the class. It was found that the behaviour of the students changed with the teaching and learning activities that we used. The students participated actively in the class. Most students said they were excited when the teacher chose their names in a completely random way and asked a question during the lecture and help them always awake. In the past, the number of students who can pass this course was quite low, but when we designed the course with constructive alignment, it can help the teacher to cut off some part that is not important and focus on the important part so the students can understand more about the course.

KEYWORDS

Constructive Alignment, Intended Learning Outcomes, Teaching and Learning Activity, Assessment Methods, Standards 7, 8, 11

INTRODUCTION

In this study, the constructive alignment of the course chemical engineering kinetics and reactor design is presented and discussed. The challenges in higher education today are changes in universities as institutions, and at the level of internal organization, changes in knowledge creation, changes in the educational models, changes aimed at tapping the potential of information and communication technologies, and changes for social responsibility and knowledge transfer (Granados, 2018). So, teaching and learning in higher education need to change as well. CDIO (Conceive-Design-Implement-Operate) framework was used to generate the CDIO skills of the students, such as engineering reasoning and problem-solving, experimentation and knowledge discovery, system thinking, and personal and professional skills (Malmqvist, Enelund, Bingerud, & Almefelt, 2018). In the course level, implementation of CDIO standards 7 and 8 (new methods of teaching and learning) is needed for improving student skills, which are important in the 21st century work society. An innovative course design to transform into an integrated, real-world acoustic context that relates to students' personal experience can help the student to learn advanced mathematical solution methods in a new way (Kari & Högfeldt, 2018).

In chemical engineering, four years of experience in the university consist of many types of courses like other curricula in engineering—for example, lecture, project, cooperative education, laboratory, etc. According to Dale's cone of experience, there are many levels of percentage of people generally remember. The lowest one is reading. Most people can remember only 10% of what they read. The highest percentage goes through real experience, and they will remember 90% of what they do as they perform a task, as shown in Figure 1 (Dale, 1969). The curriculum graduate attributes were specified that the students need to achieve each attribute at the highest level, so the teaching and learning method must match with the cone of experience.

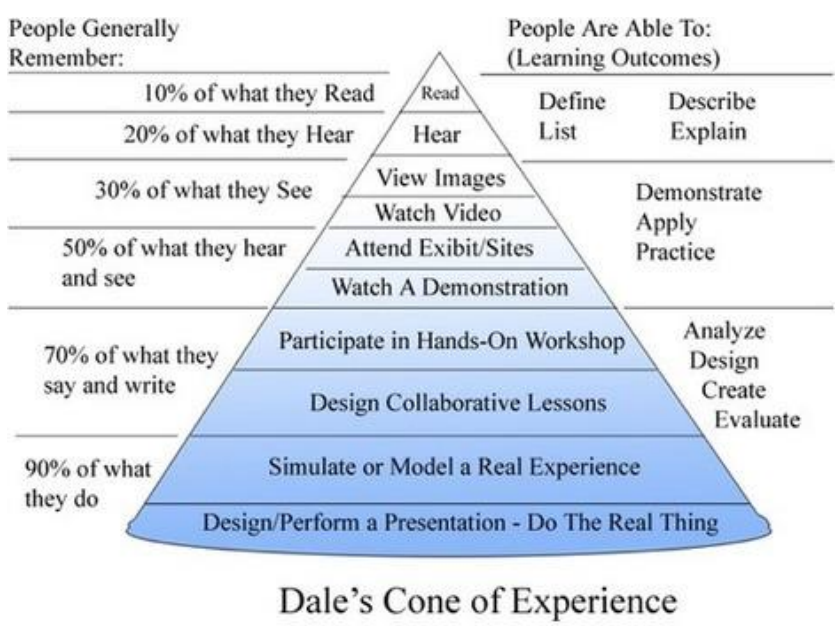

Figure 1. Dale's cone of experience (Dale, 1969)

This paper aimed to implementation of constructive alignment principle on the Chemical Engineering Kinetics and Reactor Design course. This course is the lecture-type course, which has the time to study 3 hours per week and students' self-study 6 hours per week. Therefore, the course was designed by using constructive alignment to help students achieved the learning outcomes of the course. The constructive alignment was born when John Biggs realized how silly it was to give the exam and assignment, which the student told him what he had told them about applying the subject to education. So he asked the students to apply what they knew from the subject and collect their evidence of applying in a portfolio, which is the intended learning outcome of the course (Biggs, 1999). The intended learning outcomes are the first component that we have to consider in constructive alignment. Then, the assessment method and teaching and learning activities designed to align with the intended learning outcomes. The meaning of the intended learning outcome, assessment methods, and teaching and learning activities are shown in Figure 2.

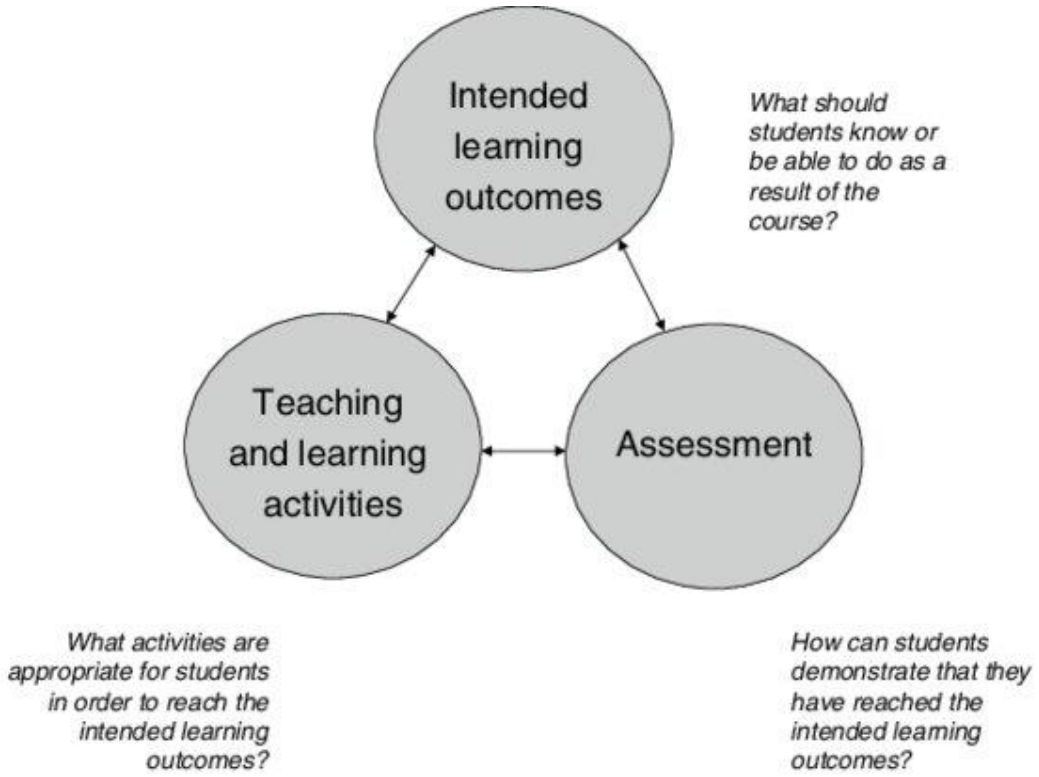

Figure 2. Diagram of constructive alignment (Edström et al., 2007)

COURSE INFORMATION

Chemical Engineering Kinetics and Reactor Design or Chemical Reaction Engineering is the course for third-year chemical engineering students. The course description is the application of thermodynamic and kinetic fundamentals to the analysis and design of chemical reactors, type of reactors, single reactor and multiple reactor systems, isothermal and non-isothermal operation, homogeneous reactors and introduction to heterogeneous reactors. As it is the course for third-year students, so this course needs background knowledge from the first and second years. The fundamental knowledge of the students before registered to this course are basic mathematics such as calculus, basic science such as chemistry and physics, basic

knowledge of chemical engineering such as the principle of chemical engineering (mole and energy balances), chemical engineering thermodynamics, and applied mathematics for chemical engineering, etc. So, this is an integrated course that the third-year students of chemical engineering need to practice. Especially, this course like the heart of chemical engineering because how to design the chemical reactor is the skill of a chemical engineer, which is different from another engineer.

INTENDED LEARNING OUTCOMES

From the constructive alignment principle, the intended learning outcomes of the course is the most important thing which we need to consider first. In the curriculum of chemical engineering, there are two pieces of information on the course for the lecturer. The first one is the course description, as mentioned earlier. The second one is curriculum mapping, which is informed about the scope of graduate attributes of the course. From this information, the teacher has to generate the intended learning outcomes of the course. Bloom's taxonomy was used to identify the intended learning outcomes of this course (Bloom B.S., Engelhart M.D., Furst E.J., W.H., & D.R, 1956). There are three domains of learning objective in Bloom's taxonomy. They are cognitive domain (mental skills), affective domain (attitude), and psychomotor (physical skills). In 2002, Krathwohi revised Bloom's taxonomy of the cognitive domain, as shown in Figure 3 (Krathwohl, 2002).

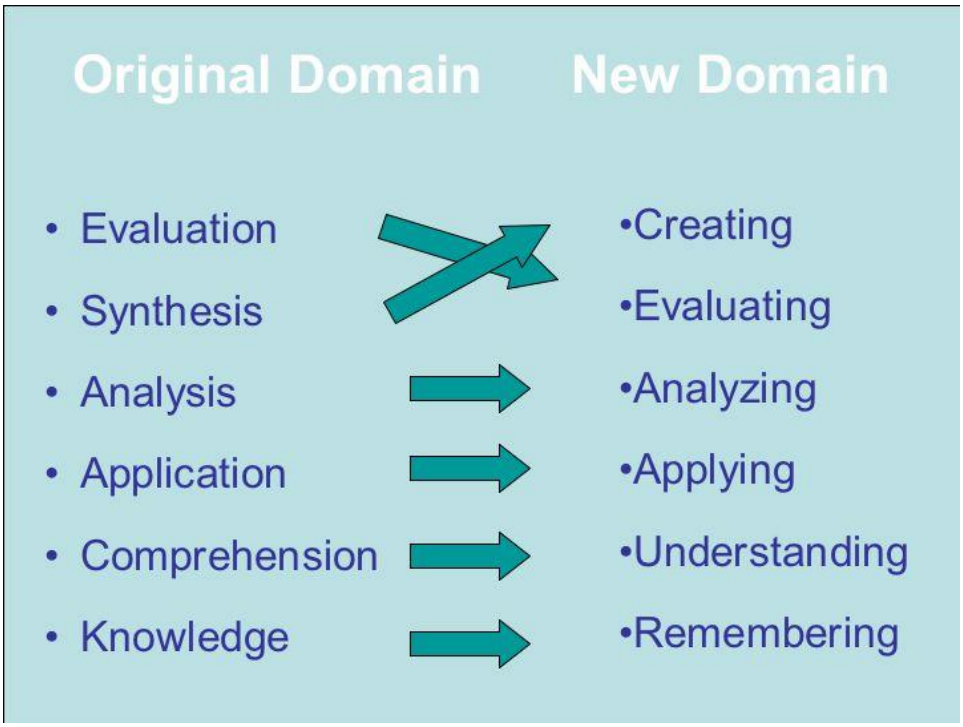

Figure 3. Revised Bloom's taxonomy by Krathwohi (Krathwohl, 2002)

According to revised Bloom's taxonomy, the intended learning outcomes of this course were modified. It is expected that by the end of the course student should be able to:

1. Understand the dependence of temperature, pressure and/or concentration on rate laws
2. Analyse rate data using an integral and differential method

3. Apply the basic principles involved in the analysis of experimental data to derive rate laws
4. Analyse how selectivity and yields are affected in series and parallel reactions
5. Differentiate the type of reactor between batch, semi-continuous and continuous reactors
6. Derive general mole balance equations for batch, semi-continuous and continuous reactors from first principles
7. Develop stoichiometric tables for batch, semi-continuous and flow reactors
8. Analyse basics energy balance of a reacting system
9. Apply energy balance equation to flow and batch reactor systems operating with and without heat exchange
10. Apply energy balance equation to describe equilibrium conversions
11. Evaluate the requirement of thermodynamic consistency of a rate law for reversible reactions
12. Understand the fundamentals of heterogeneous reactor design

ASSESSMENT METHODS

After the design of intended learning outcomes, the assessment method is the next component, which we have to consider because an assessment is a tool that we can use to check the achievement of the intended learning outcomes. The first alignment between intended learning outcomes and assessment method is very important because many times, the lecturer analyses the results of the class incorrectly. For example, the intended learning outcome is the student can apply the basic principle of the subject, but in the assessment, the lecturer asked the student to explain or to analyze the basic principle of the subject. So, the results from the assessment showed a very low score, or the conclusion is the student can explain, but they cannot apply the knowledge. Graduate attributes such as teamwork skills, communication skills are the most difficult attribute to assess (Falls, 2015). Falls proposed peer assessment and/or evaluation surveys to assess team dynamics.

There are three purposes of assessment in pedagogy. They are assessment for learning, assessment as learning, and assessment of learning. The assessment for learning and assessment of learning assess by the teacher, but an assessment as learning was done by the student (Bennett, 2017). The design of the assessment method to align with the intended learning outcomes needs to understand the purpose of the assessment. If we need to assess for learning, we can use both formative and summative assessment. If we need to assess as learning to help the student in the class or during the learning activity, we can use formative assessment. What are the formative and summative assessments? Formative assessment performed during the teaching and learning process to monitor student learning and to improve teaching and learning activity for the teacher. Summative assessment performed at the end of the course to judge the student after the course such as a midterm exam, final project, or final report, etc. (Hanna & Dettmer, 2004)

From intended learning outcomes, there are many levels of learning, such as understanding, applying, analyzing, and creating. Table 1 presents examples of activities that can be used to assess the different types of intended learning outcomes.

Table 1. Examples of assessment method for different intended learning outcomes

Type of intended learning outcomes	Examples of appropriate assessments
Understand	These are the verbs which we can use for understanding in intended learning outcome Interpret, Classify, Summarize, Compare, Explain To assess the understanding level of learning, we can use the activities like papers, exams, problem sets, class discussions, or concept maps.
Apply	The verbs for this type of intended learning outcomes are applied, execute, and implement To assess the applying skill, we can use activities like problem sets, performances, labs, prototyping, or simulations. In this course, the quizzes (short paper exam) were used to assess the understanding and applying of the student.
Analyze	We can use these verbs to explain about analyzing. Analyze, Differentiate, Organize, Attribute To assess the analyzing skill, these are activities that suitable case studies, critiques, labs, papers, projects, debates, or concept maps
Evaluate	Evaluate, Check, Critique, Assess are the verb that can use to identify the intended learning outcome To assess the evaluating skill, we can use the activities like journals, diaries, critiques, problem sets, product reviews, or studies
Create	The highest level of the cognitive domain, we can use these verbs to create, generate, plan, produce, design. To assess the creativity of the student, the activities are research projects, musical compositions, performances, essays, business plans, website designs, or set designs In this course, the students have to design a chemical reactor to show their ability of this level.

TEACHING AND LEARNING ACTIVITIES

The last part of the constructive alignment design of the course is to align teaching and learning activity with intended learning outcomes and assessment methods. Before the alignment, we have to understand the principle of teaching approaches and modes of delivery. There are a lot of teaching approaches which we can use to design the teaching and learning activity. For example, project-based learning, problem-based learning, case-based learning, challenge-based learning, experiential-based learning, studio-based learning, scenario/story-based

learning, and gamification/simulation. In each teaching approach, we can use many types of modes of delivery to transfer knowledge to the students. Examples of delivery modes are jigsaw classroom, flipped classroom, team teaching, mini-lecture, think-pair-share, debate, concept questions, role play, and fishbowl class discussion, which we know as active learning. There is research on removing lectures from the course. They found that the results not only increased student satisfaction but also bolstered the intended learning outcomes (Christian Thode Larsen, Gross, & Bærentzen, 2015).

This course has three hours per week of contact sessions. There are fifth teen contact sessions in one semester. In each week, the class was design for one major intended learning outcome. So the teaching approach each week was changed depending on the intended learning outcome and the assessment method of that week. For example, the intended learning outcome is to understand the dependence of temperature, pressure, and/or concentration on rate laws, and the assessment method of formative assessment is the quiz of explaining the dependence of temperature, pressure, and concentration on rate law. The teaching and learning activities are assessment as learning, mini-lecture for 15 minutes, concept questions during the lecture, an example of calculations about the topic, and the last one is an assignment for practicing. Figure 4 shows the teaching and learning activities in the classroom.

Figure 4. Classroom activities

After the implementation of constructive alignment, the first advantage is for the teacher. When we get the class information during the teaching and learning process, and at the end of the course, it is easier to analyze the results because we will see the alignment of each component (intended learning outcome, assessment method, and teaching and learning activities). So if we want to use the information to improve the next class, we will know where the weak point of the class is, and we can fix it effectively. The second advantage is for the student. From constructive alignment, the students need to know the intended learning outcomes. Therefore they can assess themselves about the achievement of the course so the student can improve themselves by this method.

This course also uses educational technology to motivate the student in the classroom, such as www.mycourseville.com, Facebook, and line application. These websites can use to random the student name during the discussion, which makes the student always excited. The

communication between teachers and students is very easy via these technologies as well. For example, the students can submit their assignments online by using the internet, and the students can check their scores on the website so they can monitor their progress of learning. Figure 5 shows the improvement of student outcomes after the implementation of the constructive alignment principle as you can see in Figure, the average scores increased significantly.

Figure 5. Student score after implementation of constructive alignment

CONCLUSIONS

The constructive alignment principle was implemented in the chemical engineering kinetics and reactor design course. The intended learning outcomes were changed to follow the revised Bloom's taxonomy. The assessment methods were designed to align with intended learning outcomes. The teaching and learning activities also aligned with intended learning outcomes and assessment methods. The results after implementation of the constructive alignment principle help the teacher to analyze the course easily and know how to improve the course and help the students to improve themselves follow the intended learning outcomes through teaching and learning activities that align with assessment methods. Therefore, the achievement of the course is better than the unaligned course.

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BIOGRAPHICAL INFORMATION

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INTERNATIONAL COOPERATION BETWEEN TWO PROJECT LEARNING ENVIRONMENTS - A CASE STUDY

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ABSTRACT

The CDIO Standards (www.cdio.org) set to focus on learning environments that support and encourage hands-on learning activities. Thus, workspaces ought to inspire students both in disciplinary and social learning. Students can learn from each other and interact with several groups in the same environment. The learning experiences focus on leading the acquisition of disciplinary knowledge simultaneously with personal and interpersonal skills, and product, process, and system building skills. In order to achieve this, active learning methods are needed to engage students in problem-solving activities. International connections and activities are typical in project-oriented organizations in many engineering domains. Especially in larger ICT companies, it is typical that projects are implemented as multi-site assignments, and different activities are running 24/7. Thus, it is important to create possibilities for students to experiences this type of environment already during their engineering studies. Project office "theFIRMA" operates in the ICT unit at Turku University of Applied Sciences (TUAS), Finland. The project office provides ICT-focused development projects to small and medium-sized companies and third sector organizations. Multicultural and multidisciplinary teams work together in challenging assignments to meet the goals of the projects. Students attain relevant disciplinary and interdisciplinary skills by participating in the projects in different roles. The cooperation discussions between TUAS and Singapore Polytechnic (SP) started in 2016, and after the decision to establish a similar learning environment to SP, planning of the cooperation model between the two learning environments was initiated. The new project office AGILE@SoC was established at SP in 2019. The activities were started with four project teams assigned to work on two industry paid projects, one being an international collaboration with TUAS. Students were organized in teams of five and were supervised by one lecturer per project. This first run of the program aims to evaluate the SP students' and supervisors' experience in the interaction with customers and overseas project teams. To identify operation gaps for future improvement for the operations of the AGILE@SoC office and to further improve the project-based teaching model.

KEYWORDS

Keywords: International Cooperation, ICT, Learning Environment, Project Office, Standards 6, 7, 8

INTRODUCTION

One of the key challenges for educators is to find the best ways to develop programs to equip their graduates for the transition from student to the industrialist. Cooperation projects with the industry is one approach, which can be used to support the transition (Thomson, Prince, McLening & Evans, 2012.) The CDIO 2.0 Standards 6, 7, and 8 focus also on developing the program in this context. The CDIO Standard 6 (Engineering workspaces) sets the focus on workspaces and laboratories that support and encourage hands-on learning. Thus, workspaces ought to inspire students both disciplinary and social learning. Students can learn from each other and interact with several groups in the same environment. The CDIO Standard 7 (Integrated Learning Experiences) focuses on leading the acquisition of disciplinary knowledge simultaneously with personal and interpersonal skills, and product, process, and system building skills. The CDIO Standard 8 (Active Learning) adduces the importance of learning methods that engage students in problem-solving activities. The focus is on engaging students in manipulating, applying, analyzing, and evaluating ideas. (CDIO Standards 2.0.; www.cdio.org)

Topics in globalization, new technologies, migration, international competition, changing markets, transnational environmental, and political challenges are all addressed as drivers for the need for new learning methods (Scott, 2015). The different fields of education are facing disruption with the uncertainty of not knowing the jobs they need to prepare their students for since they are also unsure about the types of jobs that will be available in the future. Hence, deep cooperation with the industry is needed throughout the education to make sure that the skills taught in school meet the ever-changing needs of the industry. Much higher education institutions have set a priority to prepare a student for the world of work and employability (Magnell & Geschwind, 2013).

Project offices (POs) offer students the possibility to develop their skills in an authentic environment while doing cooperation with industry. Students will be able to pick up technical skills and competencies through working on real-world industry projects, instead of the traditional classroom learning environment. At the same time, POs offer a wide range of services for companies and, thus, answer to the demand for applied education as a regional developer. International connections and activities are typical in project-oriented organizations in many engineering domains. Especially in larger ICT companies, it is typical that projects are implemented as multi-site assignments, and different activities are running 24/7. Thus, it is important to create possibilities for students to experiences this type of environment already during their engineering studies.

In addition to industrial cooperation, cooperation between educational institutions is important, since it enables the development of innovative international partnerships, student mobility, the establishment of networks, experience and knowledge exchange, and generation of ideas (Laaziri, Khoulji, Benmoussa & Larbi, 2018). Fostering a global mindset in students by raising their awareness of economic and social developments around the world. Students will also be appreciative and immerse in a new culture.

In this paper, the focus is set on describing the international cooperation model between two POs, establishing the new project office to Singapore as well as analyzing the outcomes and experiences from the first two customer projects that were implemented in collaboration. First, the core functions of theFIRMA are described. Second, setting up AGILE@SoC is being described. Third, creating a cooperation model between the two project offices is being presented. Thereafter, the outcomes of the first two cooperation projects are being analyzed and presented. Finally, the current activities are being discussed, and future development thoughts are presented.

THEFIRMA – PROJECT OFFICE

Project office "theFIRMA" has been working in its current form from 2015, when the earlier project learning environments of TUAS School of ICT were merged. The project learning environment provides ICT-focused development projects to small and medium-sized companies and third sector organizations. Typical assignments include web development, small-scale game prototypes, graphic design, and end-user training (Säisä, Määttä & Roslöf, 2017). Students in theFIRMA usually start as project members in real projects where more experienced students mentor them. While students' skills and professional self-confidence grow, they start assisting new junior-level students, or they might even become student project managers. In addition, it is also possible to apply for more responsible roles, such as student marketing manager, head of system administration, or student CEO. Since autumn 2016, it has also been possible to study a whole competence track (curricular structure equivalent to a major subject) in theFIRMA. In other words, this means that the students who are in theFIRMA competence track, do a major part of their third- and fourth-year studies in these projects. Personal learning goals are set for each student to ensure that their skills fulfill the overall learning goals of the degree program. On a yearly basis, about 50 customer projects are done, with 150 students mentored by teachers and other staff members of TUAS. (Määttä, Säisä & Roslöf, 2017)

Multicultural and multidisciplinary teams work together in challenging assignments to meet the goals of the projects. Students attain relevant disciplinary and interdisciplinary skills by participating in the projects in different roles. Based on the results of the alumni survey done in 2018-2019, communication, teamwork, problem-solving, interpersonal skills and motivation and enthusiasm have had the most impact on being employed (Säisä, Määttä & Roslöf, 2019).

SETTING UP AGILE@SOC – PROJECT OFFICE

The new project office AGILE@SoC (aka Authentic Group-based Industry Learning Experience/Environment) was established at SP in 2019. The activities were started with four project teams assigned to work on two industry paid projects, one being an international collaboration with TUAS. Students were organized in teams of five and were supervised by one lecturer per project. This first run of the program aims to evaluate the SP students' and supervisors' experience in the interaction with customers and overseas project teams. To identify operation gaps for future improvement for the operations of the AGILE@SoC office and to further improve the project-based teaching model. Students who participated in this run of the programme will have the opportunity to continue as the first management team for the AGILE@SoC office next semester of their study.

CREATION OF INTERNATIONAL COOPERATION

The cooperation discussions between TUAS and Singapore Polytechnic (SP) started in 2016, and after the decision to establish a similar learning environment to SP, planning of the cooperation model between the two learning environments was initiated. During the PO planning phase, staff members from SP visited TUAS a few times to discuss the concept in more detail. The discussions consisted of the project process, acquiring customers, and evaluation of credits for students, among other things.

During the planning phase, TUAS created a minimum viable product (MVP) description of theFIRMA concept as well as the next steps on how to broaden the concept after it being created and tested. This MVP was shaped as theFIRMA platform that describes the required organization and roles, premises, processes, digital environments, and security. In addition, the platform describes four development phases: current state of activities, near-future improvements (expanding services), branch office in Finland, and international project office phases. The international cooperation between two project offices began at the beginning of 2019. The first round of cooperation is divided into three sections, which are presented in Figure 1.

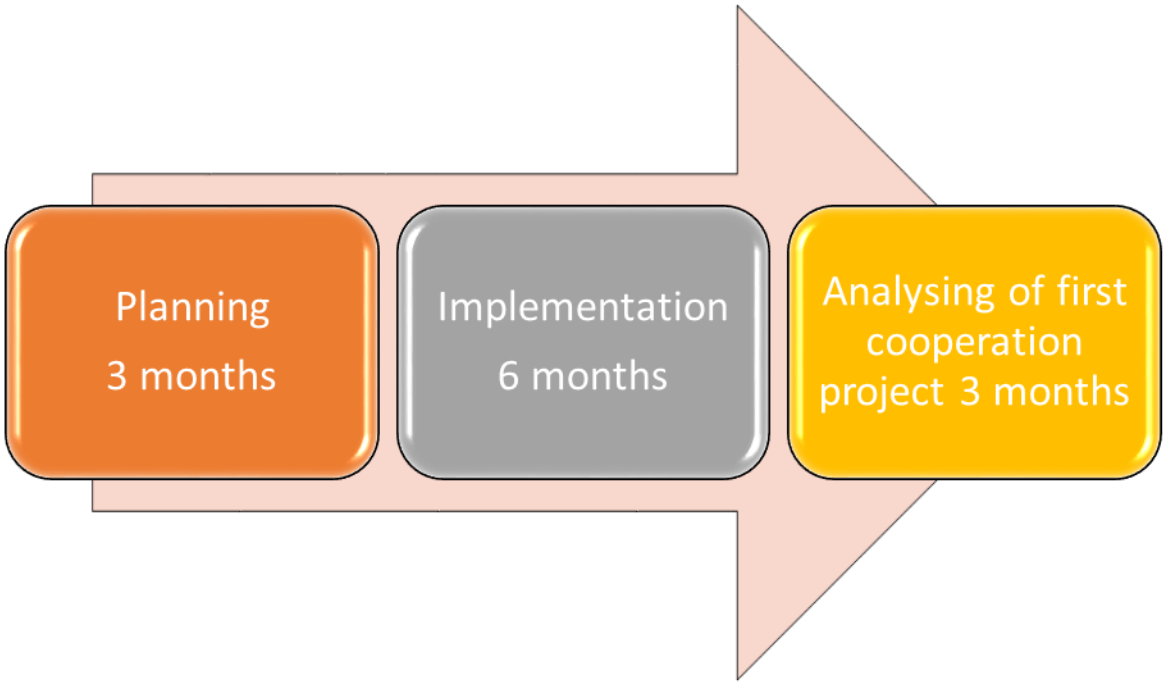

Figure 1. Phases of the cooperation

Initiation of The Cooperation Projects

The planning phase lasted three months, from January to March 2019. At the beginning of the planning phase, it was agreed that international cooperation would start with two customer projects, one from each organization. First, both project offices ought to find two suitable customer projects for cooperation and write a one-page description of each potential project. Thereafter, an online meeting between the POs was held, and one project for each learning environment was chosen. After the decisions, both project offices made a contract with the chosen customer from their home country. For the first round, it was agreed that each project

office would invoice the customer project from their home country. For future cooperation projects, the invoice will be split between the organizations. The contract was made between schools and companies from the same country. After the contracts with the customers were made, I started the recruitment of students for the teams.

Implementation of The First Projects

The implementation phase lasted six months, from April to September 2019. Project from Finland was implemented for a startup company that is creating a model for people to move a little more during their lunch breaks. The idea is to choose a restaurant a bit farther than the restaurant downstairs in the company building. Users collect the (kilo)meters while walking or jogging to a restaurant and back to an app. When users have collected several kilometers to an app, they get awards, such as free coffee or discounts on lunch.

Project from Singapore was for the client "Kidzania, Rakan Riang Pte Ltd." Kidzania Singapore is located on Sentosa, an island resort off Singapore's southern coast. In order to reach out to more customers and provide more collaboration opportunities with various Hotels within Sentosa, Kidzania wishes to develop a web application that allows users to upload their photographs were taken at places of interest; for example, the Zoo, Night Safari or Kidzania. Customers will then be able to choose from a variety of products from Kidzania to have the photographs printed on. The finished product will be delivered to either the customers' hotel room or for self-collection at Kidzania.

For each project, there were two competing teams: one from Finland and another from Singapore. The teams designed their own versions for the customer who got to choose which version they prefer. In addition, there were mentors from both institutions that were responsible for mentoring the local team. The teams did the work independently, but there were organized online meetings between mentors and teams working with the same project on a monthly basis. Progress of the project, technical solutions, and potential difficulties we discussed in these meetings.

In the project done to a customer located in Finland, teams chose different approaches to address the assignment. TUAS team first chose to do the project as a native application. There were some technical difficulties during the project. In short: measuring the distance between point A to point B appeared to be difficult when the user is not keeping the phone open during the walk. Reason for this is related to information security regulation (GDPR): it is forbidden to follow the movement of a user while the phone and the application are not active. Both teams struggled with the same problem, but they were able to find a working solution for the prototype within the given timeframe.

In the Singapore project, the project was divided into two phases. During phase one, the project teams conduct regular meetings with the client to gather system requirements and feasibility studies. The teams then developed a prototype for the client to seek confirmation on how the user interface design should look like. The system requirements and prototype screenshots were shared with the Finnish team, and clarifications between the teams were communicated via emails. During phase two, the team concentrated on system development and user guide documentation. Upon completion, the client was invited to a final presentation/demo of the system by the teams to provide their final feedback and adjustments required before the handing over of the project.

Analyzing of Cooperation

After these first projects between theFIRMA and AGILE@SoC were completed, the project results and experiences on the international cooperation between the POs were analyzed. This phase lasted three months, from October to December 2019.

Both customer projects ended up well, even though the implementation phase was a challenging time to time. For the Singapore project, the difficulties faced by the students are mainly the change in requirements during the first project phase as the client was unsure of how their customers interact with the web application. The teams were about to overcome this by seeking regular clarifications and confirmations with the client. After the client had seen and approved the prototype, the challenges were mainly connected to the technical development issues. To overcome any knowledge gaps required, the teams acquired knowledge via online resources and conducted regular meetups with their mentors. The teams were able to resolve all issues smoothly. For the project in Finland, the main difficulties were related to technical solutions in measuring the movement of the user. However, both teams were able to provide a working solution for the challenge. After the international cooperation phase, TUAS continued the work with the customer by testing the prototype with potential users and developing a monetization model for the concept.

Overall, both projects went well, mentors helped students with the projects, and the teams performed well within the project. Another takeaway includes that the processes were developed for the handling of contracts with companies; it seemed that the students did not feel added pressure due to the fact the projects had a price tag. Instead, students enjoyed the friendly competition among the teams working on the same project, and they were able to learn from each other's approach to the project. It was a great experience working on an overseas project.

For the international cooperation between the POs, the process of acquiring suitable customer projects for the cooperation, negotiating the contracts with customers, implementing the agreed projects, and analyzing the results was rather straightforward. However, there were some unexpected events, too. For example, after the decision of a suitable customer project for international cooperation, the already confirmed customer from Finland decided not to participate. Hence, TUAS had to find new potential customer pilots for cooperation with a rapid schedule. Luckily, a new appropriate pilot case was found, and the cooperation was able to continue within the agreed time frame.

OUTCOMES OF THE COOPERATION

For TUAS, one of the main reasons for starting international cooperation was to offer students a great learning opportunity to work in multi-site assignments. This learning goal achieved during the cooperation with AGILE@SoC. Scheduling the meetings with another team that is working only a couple of "office hours" at the same time needs a lot of planning. Not to forget, all the students still had their other courses, and thus, they were able to work with the project approximately 10-25 hours on a weekly basis. Yet, communicating the needs of the customer for the team abroad in a way that they really understand the needs and can provide technical solutions to meet the needs of the customer was a great learning experience.

For SP, Students who participated in this run of the programme will have the opportunity to continue as the first management team for the AGILE@SoC office next semester of their study.

Outcomes of the cooperation between the two POs have been so far smooth, and thus, deeper cooperation is being planned between the offices. The future cooperation of the POs has been divided into three fields, as shown in Figure 2.

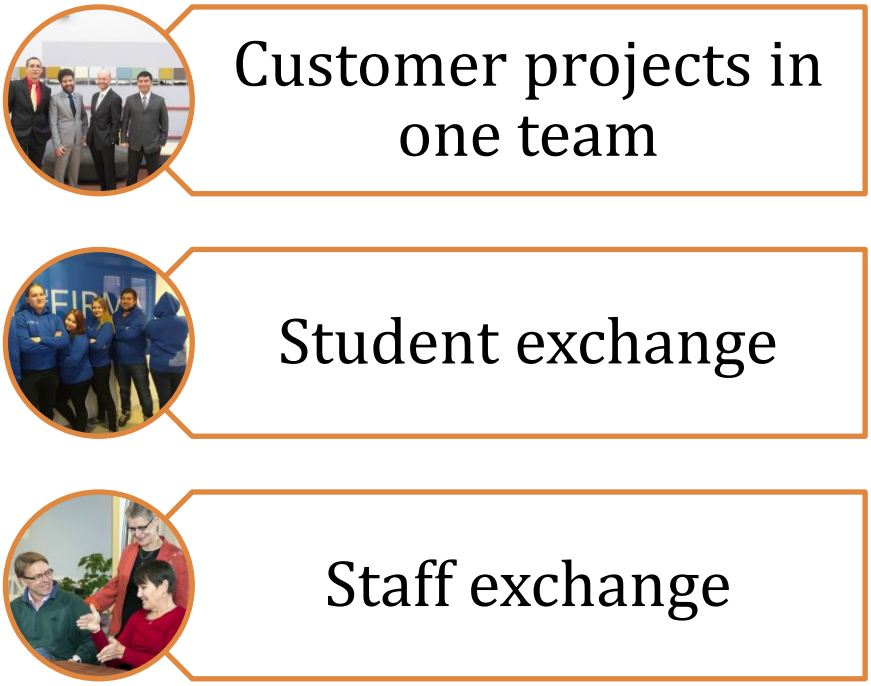

Figure 2. Future fields of cooperation

The next phase of the cooperation is to combine teams from the POs. Hence, there will be one project from Singapore and another project from Finland, but only one team working for each customer project. The team is constructed of the students from both TUAS and SP. The student project manager is responsible for customer communication and for leading the daily activities of team members. As always, teachers mentor teams and make sure that the project results meet the quality requirements of the project.

Another field of cooperation is to start student exchange between the POs. The idea is that students come for a fixed period of 4-6 months to work in the PO abroad. By working in the other PO, students gain both technical and soft skills that are needed in working life. In TUAS, students can focus on front-end and back-end development, system administrators, or project management using both waterfalls as well as agile methodologies.

The third field of cooperation is to start staff exchange between the POs. The main aim of the staff exchange is to share best practices from home PO and, at the same time, learn new technologies and methodologies in the PO abroad. Even though some of the best practices are shared already in different meetings between the POs, a more effective way of sharing and gathering is to participate in daily operations. The staff exchange broadens the CDIO perspective to standards 9 and 10, which requires institutions within the initiative to work toward supporting and developing the teaching and more general competencies of the faculty (Thomson & Gommer, 2018).

DISCUSSION AND CONCLUSIONS

In this paper, the focus was set on describing the international cooperation model between two project offices, establishing the new project office to Singapore as well as analyzing the outcomes and experiences from the first two customer projects that were implemented in collaboration between Finland and Singapore.

The first two customer projects met the goals set for the projects. Some challenges occurred while finding suitable customer cases as well as in the implementation phase when the needs of the customer changed during the project. In addition, some technical difficulties were encountered, but the teams were able to provide solutions for them. All these events are very typical for real-life projects, and they were significant learning experiences for the students.

The goals of the CDIO Standards 6,7 and 8 became a reality during the process. The outlines of Standard 6 Engineering workspaces were used when planning the new PO to Singapore. Integrated Learning Experiences from CDIO Standard 7 were highly valued in designing of the international cooperation where students can join an authentic multi-site experience while working in the projects. The CDIO Standard 8 Active Learning was particularly present when students were applying theory to problem-solving activities to find suitable solutions for the challenges that they met during the implementation phase.

The next phase for AGILE@SoC is to increase the number of paid industry projects. The first run involved students from the third year of their study, AGILE@SoC will be working on increasing involvement from students at various stages of their study to provide more interaction opportunities among seniors and their juniors.

Currently, the cooperation between theFIRMA and AGILE@SoC is heading towards the next phase: doing a cooperation project with one team that consists of students and mentors from both Finland and Singapore. In addition, student and staff exchange between the POs are being planned to broaden to cooperation and to deepen the authentic experience of international cooperation for students. For future operations, the communication tools, mentoring processes are taken into a closer plan in order to make sure that the geographically spread team can do their best while working for the common goal.

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OUTCOMES-CENTERED CURRICULUM DESIGN OF AR TECHNOLOGY BASED ON BLENDED TEACHING

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ABSTRACT

In order to strengthen the construction of a scientific and reasonable AR technology curriculum system with obvious industry characteristics, and make its learning more substantial, interesting and efficient, this paper proposes to systematically design its expected learning outcomes, teaching content and requirements, class hour allocation of each teaching link, the implementation plan of practical teaching project, course assessment, and evaluation, and teaching methods and means of AR technology curriculum by utilizing the design framework of outcomes-centered curriculum based on TOPCARES. In addition, in order to bring into great play to the autonomy of teachers and students, and further stimulate the enthusiasm and creativity of students during the process of AR learning, this paper proposes a high-level design method of outcomes-centered blended teaching, and advocates to carefully design and develop the teaching resources for blended teaching according to the characteristics of teaching content, students' needs, environment, and conditions, etc. At present, we have formed an outcomes-centered AR technology teaching system with level 3 project running throughout, with basic modules, advanced modules and extension modules gradually progressing and complementing each other, and have developed a large number of supporting teaching resources, which can ensure the smooth progress of blended teaching and obtain good learning outcomes.

KEYWORDS

Augmented Reality, Blended Teaching, TOPCARES, CDIO Syllabus Outcomes, Integrated Curriculum

INTRODUCTION

Outcomes-centered curriculum system implies that when a curriculum is planned and designed, the expected learning outcomes (ELOs) should be clearly identified and considered in the formulation of its curriculum plan at first. After that, the course contents, practice projects, learning activities, teaching methods, and assessment and evaluation scheme should be designed or chosen to be consistent with the achievement of the ELOs. And then, we need to gather evidence from multiple sources to prove whether the ELOs have been achieved. Finally, the evaluation results need to be feedback in time to ensure that elements in the teaching and

learning environment are acting in concert to promote the achievement of ELOs (Yu et al., 2019).

In this paper, we will take the construction of the AR technology course as an example to systematically explain how to carry out the outcomes-centered blended teaching design and practice under the guidance of TOPCARES education methodology. Here, TOPCARES is an integrated talent cultivating model with the obvious characteristics of Neusoft creatively put forward by Dalian Neusoft University of Information (DNUI) in 2008 by inheriting, integrating, and innovating the latest achievements of CDIO international engineering education reform (Wen, 2011).

It is the crystallization of the educational and teaching reform achievements of DNUI over the past ten years and has been widely recognized by the international engineering education community in recent years (Wen, 2011; Yu, 2013; Yu, 2016). Recently, with the blended teaching has become an important trend of higher education teaching reform, the focus of DNUI's TOPCARES teaching reform has shifted to blended teaching. In order to accelerate the reform of blended teaching based on TOPCARES, AR Technology course took the lead in participating in this round of reform and has become one of the pilot courses of blended teaching reform. Up to now, our AR Technology course team has carried on a series of pioneering exploration and practice in the aspect of blended teaching reform, and achieved good learning outcomes in the actual teaching process.

In the next section, an outcomes-centered theoretical framework for curriculum design based on blended teaching is proposed. Then, the curriculum design and practice of AR Technology based on blended teaching are systematically described. Finally, the research work of this paper is summarized, and further research is prospected.

AN OUTCOMES-CENTERED CURRICULUM DESIGN FRAMEWORK

As for outcomes-centered curriculum design, TOPCARES requires that teachers take into account questions such as "What to teach," "How to teach," "How to learn," "Where to learn," and "How to assess" on the basis of a full investigation and research of the curriculum, and combine the imparting of curriculum knowledge with the cultivation of students' ability organically, and design the teaching contents, teaching methods and organizational forms in an integrated way, and develop the teaching material and construct the teaching resources in a standardized way, so as to ensure that students can learn and apply what they have learned, and achieve the ELOs (Yu et al., 2019). Under the guidance of TOPCARES education and teaching philosophy, we put forward an outcomes-centered curriculum design framework that can meet the needs of blended teaching, as shown in figure 1. It mainly includes the following steps:

Step 1: Clearly identify students' learning needs by conducting regular curriculum investigation and research. Here, we suggest that teachers should fully investigate and study the current situation and development trend of curriculum-related industries, job opportunities, and science and technology, and know more about the actual situation of students' learning, self-development, curriculum construction, and school running.

Step 2: Reasonably formulate the overall teaching objective of the course according to the learning needs of the students and the orientation of the course in the professional talent

cultivating program. Here, the overall teaching objective is a comprehensive overview of the ELOs of the course.

Step 3: Carefully draw up the list of ELOs of the course by comprehensively analyzing the overall teaching objective, the characteristics of the course, and the TOPCARES ability index system that should be supported by the course. It is worth noting that the list of ELOs here is written for students rather than teachers, which should take full account of students' performance rather than teaching activities (Trinh & Nghia, 2014). In addition, the ELOs here refers not only to the learning outcomes to be delivered but also to the students' learning experience and the value realized by students (Stevens & Levi, 2013). In this sense, a curriculum is a learning process based on a series of ELOs that have a clear, logical relationship with each other.

Step 4: Scientifically develop the targeted curriculum syllabus by scientifically planning and designing the cultivation path to achieve the ELOs. Once the correct cultivation paths are established, the corresponding teaching contents, teaching methods, and means, assessment, and evaluation scheme will be clear.

Step 5: Systematically organize the teaching contents and requirements of this course according to the curriculum syllabus. In addition, all teaching contents, including theoretical teaching, practical teaching, and special activities, are further subdivided into online and offline teaching and learning contents according to the requirements of blended teaching and the cultivation path of the ELOs.

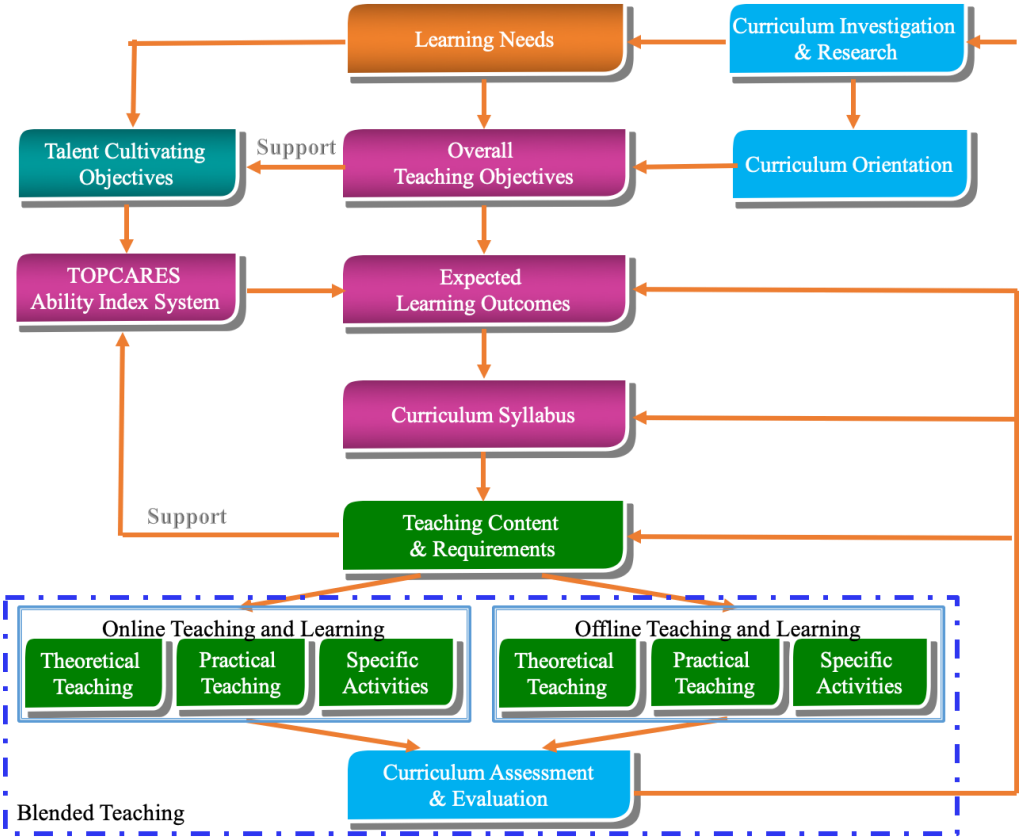

Figure 1. TOPCARES Theoretical Framework of Curriculum Design

Step 6: Reasonably formulate the formative and summative assessment scheme and evaluation standards of the curriculum. Its purpose is to create a fair, competitive environment, enable students to get timely and comprehensive feedback, help students develop critical thinking, and help teachers to test the achievement of students' ELOs and improve their teaching skills purposefully (Yu et al., 2019). In the process of teaching implementation, it is required to regularly collect and timely feedback assessment and evaluation information, so as to promote the continuous improvement of curriculum construction.

Step 7: Standardize all teaching contents of the course, and make clear requirements on the teaching methods and organizational forms suggested to be used by teachers, the learning methods and resources suggested to be used by students, and teaching conditions to be met in the teaching and learning process (Nilsson, 2010).

According to the above introduction, a good and specific list of ELOs is obviously the key to the success of curriculum construction. For this reason, we propose that the principle of SMART should be followed when formulating the ELOs (Yu et al., 2019), that is,

(1) ELOs should be **Specific** rather than general. It is suggested to use behavioral verbs to describe ELOs as much as possible, such as Bloom's Taxonomy Action Verbs.

(2) ELOs should be **Measurable**. It is recommended that you ask yourself what activities or tasks can be used to evaluate whether students have really achieved their ELOs and to what extent they have achieved them.

(3) ELOs should be **Achievable**. They must conform to the level of students and convince them that they can be achieved through reasonable efforts.

(4) ELOs should be **Relevant** to the students' life or career goals and contribute to the achievement of the final goals.

(5) ELOs should be clear **Time-bound**. They must be in line with the learning period and total class hours of the course.

CURRICULUM DESIGN AND PRACTICE OF AR TECHNOLOGY BASED ON BLENDED TEACHING

In order to deepen the understanding of the theoretical framework of outcomes-centered curriculum design based on TOPCARES, we will take the AR Technology curriculum as an example to describe how to apply it in more detail.

Course Introduction

AR Technology is one of the main courses of digital media technology, which is explicitly required by the national standard for teaching quality of animation, digital media art, and digital media technology. Its prerequisite courses include Object-oriented Programming, User Experience Design, Foundations of Game Engine, Game Programming Basics, Foundations of Game Design, etc. It requires students to be able to fully apply the knowledge, skills, tools, and technologies they have learned before, such as object-oriented programming, product prototype development, interactive media development, to the AR technology training and project practice. Its follow-up courses include Virtual Reality (VR) Technology, VR Application

Development, Comprehensive Training of Digital Media Technology, and Graduation Design (Thesis), etc. It still requires students to master the AR development technology, and design and develop a practical and original AR application with certain technical complexity and good user experience. Obviously, the effective achievement of its ELOs will play an important role in consolidating what has been learned in the early stage, and guiding and paving the way for the successful implementation of the follow-up practical teaching and training. Moreover, it will also play a very important role in the construction of professional characteristics and the achievement of the talent cultivating objectives.

Next, we will systematically introduce how to apply the proposed theoretical framework of outcomes-centered curriculum design to implement the blended teaching design and practice for this course.

Step 1: Identify Students' Learning Needs

In order to identify students' learning needs for this course, we regularly investigate the needs of employers, students, teachers, and other stakeholders. Through a lot of investigation and research, we find that:

For the employers, they often hope that students' AR technology, knowledge, and their AR development abilities should be presented in a visible, measurable, and applicable patterns.

For the curriculum team and even the department of digital media technology, they especially hope that the course will have distinct industry characteristics, can effectively develop students' TOPCARES abilities, achieve influential honors and achievements at home and abroad, and effectively support the achievement of the cultivating objectives and graduation requirements of digital media technology.

For the students, they really want to have at least one XR (the general term of AR, VR, and MR) project practical experience, one certificate of award for a high-level professional competition, one intellectual property related to digital media technology, one high-quality graduation thesis, one high-level representative XR work, and one good employment opportunity upon graduation.

To sum up, it is clear that helping students design and produce excellent AR work will be the core task of this course.

Step 2: Formulate the Overall Teaching Objective

By systematically sorting out the priority of learning needs of this course and combining the development status and trends of AR-related industries and technologies, we further clarified the overall teaching objectives of this course, namely:

"Based on the popular game development tools Unity and the world's leading AR platform Vuforia, this course will introduce the basic theory and technical methods of AR application design and development, such as AR video, AR animation, AR special effects, AR interaction, and AR games, step by step and comprehensively. This course will implement a blended teaching model, which is driven by actual AR projects, with the training of TOPCARES abilities as the mainline, and organically combines online and offline teaching. Through the study of this course, it can help students to establish the knowledge system of AR project development, master the techniques and methods of AR application design, development, and testing,

cultivate the ability of team cooperation and innovative practice of students, and the ability to design and to develop an original AR application with certain technical complexity, better user experience, and certain practicability by comprehensively applying the knowledge that they have learned before."

Step 3: Draw Up the List of ELOs

By further dividing the overall teaching objectives of this course into three levels: knowledge, ability, and quality, then mapping them to some specific TOPCARES ability indicators, and designing the corresponding training path for each ability, we draw up a list of ELOs according to the proposed SMART principle above (Yu et al., 2019), as shown in Table 1.

Table 1. List of ELOs for AR Technology Course

Classification of Learning Objectives	Expected learning outcomes	Supported TOPCARES-CDIO Level 3 Capability Indicators	Training path
Knowledge	Summarize the development history of AR	1.4.1 Knowledge related to XR application development	Teaching Visiting
	Describe the definition and category of AR		
	Explain the differences and connections between AR, VR and MR		
	Describe the working principle and main components of AR system		Demonstration
	Install and configure AR development environment		
	Use the Vuforia SDK to implement image recognition, cuboid recognition, cylinder recognition, object recognition, user custom recognition, virtual button and other functions		
	Describe the current situation and development trend of AR industry	1.3.3 Knowledge related to digital media industry	Teaching
Ability	Write AR project design plan and give oral report	4.1.3 Written communication 4.1.4 Electronic and multimedia communication 4.1.6 Verbal and interpersonal communication 8.6.4 Development project management	Project-based learning
	Make AR project development plan according to software engineering standardization requirements		
	Write project report according to software engineering standardization requirements		
	Produce a video for work presentation, make a PPT for project report, and make a defence speech on the project site		
	Design and develop a simple AR video application	3.1.5 Solutions and recommendations 8.8.1 Design implementation process	Case teaching Practice teaching Project teaching
	Design and develop a simple AR animation application		
	Design and develop a simple AR special effect		
	Design and develop an AR interactive large screen application		
	Design and develop an AR application with a clear theme and practical value that integrates video, animation, visual effects and interaction by teamwork	2.4.2 Integrated innovation capability 4.3.2 Teamwork operation 8.8.1 Design implementation process	Project-based learning Inquiry learning
	On-site installation and debugging, test and optimize the effect of works	8.9.1 Operational design and optimization	
Quality	Attendance on time, no reason to leave early, and complete and submit assignments on time	5.1.2 Learning attitudes and habits	Autonomous learning
	Actively learn new knowledge and incorporate it into the individual works		
	Use individual or team works to participate in subject competitions or exhibitions	5.3.2 Attitudes and habits towards honors	

Step 4: Develop the Curriculum Syllabus

Considering that there are still some practical problems in the actual teaching process, such as students' works are mainly based on imitation and lack of innovation, students' many ideas can't be implemented, the quality and complexity of AR works are not high, and the ability of independent learning and comprehensive application is insufficient, the curriculum team proposes to integrate the software engineering ideas and standards into AR project practice, introduce professional competitions and current frontiers into AR project topics, incorporate independent learning and project complexity into the assessment requirements, and apply OBE implementation principles and the modular and integrated curriculum design method to build an outcomes-centered teaching content system with level 3 project running throughout the whole, and with the basic module, advanced module and expansion module gradually progressive and complementary, as shown in Figure 2. Here, the outcome of the level 3 project is an AR game application with a clear theme and practical value, which integrates video, animation, special effects and interaction, and other features and is designed and developed by students through group cooperation (Yu et al., 2019).

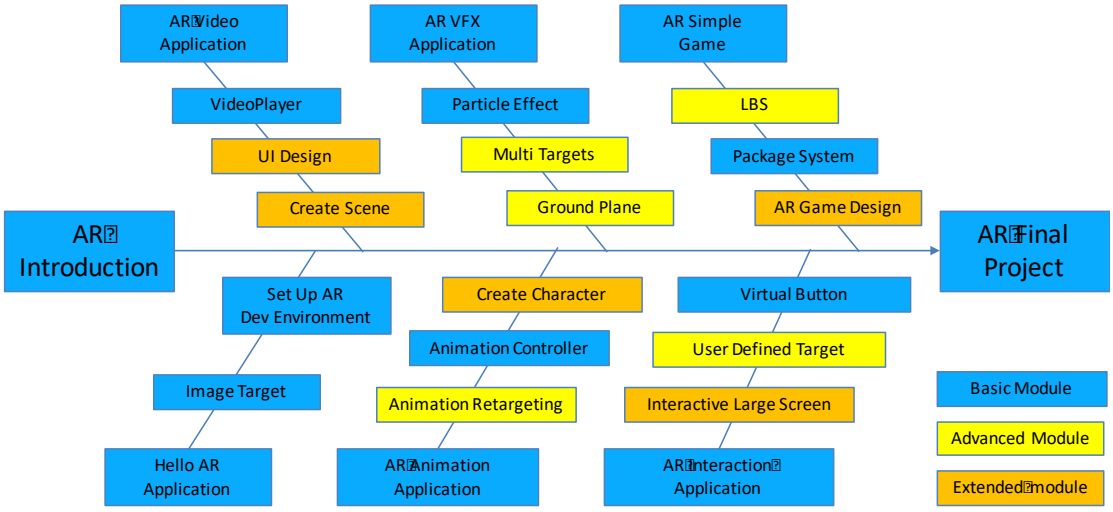

Figure 2. Teaching Content System of AR Technology Course

Then, we systematically plan and design the way to achieve each expected outcome, the teaching methods, and means of all teaching contents, the cultivation path of each TOPCARES ability, and then develop the curriculum syllabus of this course.

Step 5: Organize the Teaching Contents and Requirements Based on Blended Teaching

With the rapid development of the new generation of information technology, blended teaching has become a key point and an important way to promote the reform and development of higher education in China. In order to meet the needs of blended teaching and effectively support the achievement of ELOs, on the basis of the above-mentioned teaching content system, we have designed the teaching content, teaching requirements, key points, and difficulties, as well as teaching implementation suggestions of each unit scientifically and reasonably. Moreover, we have further clarified the contents and requirements of pre-class, in-class, and after-class teaching and learning. An example of this is shown in Figure 3.

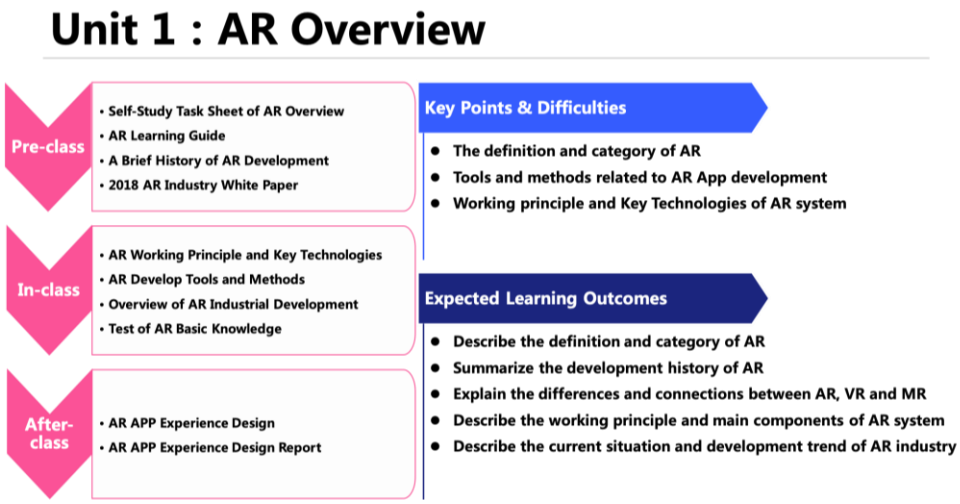

Figure 3. Design Example of Teaching Content

Step 6: Carry Out the High-Level Design of Blended Teaching

As an important part of teaching content and requirements, the main task of the high-level design of blended teaching is to give a brief description of how to implement effective blended teaching for specific teaching content. It requires us to design scientifically and systematically how to organically integrate pre-class, in-class, after-class, online and offline learning tasks and teaching activities around teaching objectives, and clearly explain the teaching methods and means used, learning outcomes evaluation schemes, learning support services that can be provided, etc.

Step 7: Formulate Assessment Schemes and Evaluation Criteria

ELOs are the core of curriculum construction and the primary basis for the establishment of assessment and evaluation criteria. In order to reasonably evaluate the achievement degree of students' ELOs and to create a fair competition environment, we adopt a comprehensive assessment method combining formative assessment and summative assessment, and construct a diversified assessment mechanism including classroom test, homework, project roadshow, and final defense (Yu et al., 2019), as shown in Figure 4.

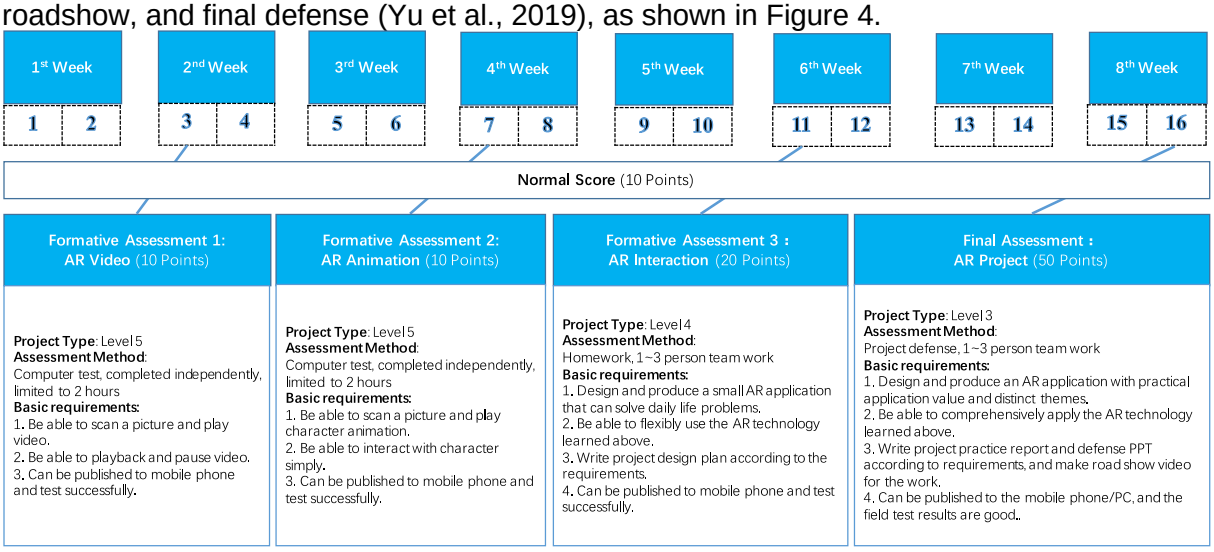

Figure 4. Assessment and Evaluation Scheme of AR Technology Course

Meanwhile, in order to standardize the performance evaluation criteria, enable students to get timely and comprehensive feedback, as well as to help teachers purposefully improve the level of teaching, we have constructed and implemented a series of evaluation criteria suitable for formative assessment and summative assessment. All these evaluation criteria are based on the ELOs and pay attention to the examination of students' abilities such as communication and teamwork, analysis and problem solving, innovative thinking, and learning.

Step 8: Design & Develop All Online and Offline Teaching Resources

The standardized construction and efficient application of teaching resources is an important guarantee for the smooth implementation of blended teaching and the achievement of ELOs. Therefore, we organize all teaching resources in a granulated way based on the core concept of the subject, the relationship between teaching content and resources, set up the teaching context, and form a resource set that focuses on knowledge points/skill points and clearly expresses the knowledge framework. Then we carefully select and develop all teaching resources that match the pre-class, in-class, after-class, online, and/or offline learning tasks according to the ELOs, discipline characteristics, students' cognitive rules, and different blended teaching methods.

Blended Teaching Implement

At present, all teaching resources of AR technology course have been developed in accordance with the corresponding construction standards, including curriculum standards, teaching calendar, course guidance, teaching materials, and handouts, lesson plans, teaching courseware (PPT), teaching micro-videos (covering all the key points and difficulties of the course), teaching cases, excellent example works, assessment-related materials (such as assignments, practical projects, test papers, etc.), project material resources and source code, reference materials and learning guidance materials (such as FAQ, self-study task list), etc., and have passed the first acceptance of DNUI with excellent evaluation results.

Up to now, all teaching resources have been uploaded to the school's blended teaching management platform. After a round of blended teaching practice, DNUI specially set up a review team composed of the education experts from the functional departments such as teaching management and quality assurance, the professional teachers from the teaching school and department, and the experts from outside school to evaluate the implementation effect of blended teaching of this course. According to the feedback evaluation results, we know that through the implementation of the blended teaching reform, this course can stimulate the majority of students' learning interest, generally improve students' learning initiative and the achievement of ELOs to a great extent. In addition, more than one-third of the students have won some honors in some academic and professional competitions and applied for software copyrights or patents by using the outcomes of level 3 project of this course. In general, this blended teaching course has achieved initial results in the construction stage, achieved the expected goal, and its evaluation result is excellent.

Unfortunately, there are still inevitable problems in the implementation process of blended teaching, such as:

Due to the great diversity of individual students, the difficulty of personalized guidance for teachers is increased.

Because students learn several courses at the same time, they cannot make full use of the after-class time to study.

Due to the insufficient interactive design of the learning platform, it is not very helpful to support students' independent and cooperative learning.

Due to the lack of artistic appeal in the design of teaching micro-video, its attraction is insufficient. All these problems and challenges need to be overcome and solved in the future.

CONCLUSION

In order to effectively improve students' learning satisfaction and guarantee the achievement of ELOs, this paper proposes an outcomes-centered theoretical framework for curriculum design based on blended teaching, and take AR Technology curriculum as an example to describe how to apply it to implement the blended teaching reform and practice of this course. Although this course has achieved good results through a round of blended teaching practice, there are still some problems mentioned above. However, developing, implementing, and evaluating outcomes-centered curricula are complex, multifaceted, and iterative processes. In the future, we will further standardize and optimize the proposed outcomes-centered theoretical framework for curriculum design based on blended teaching with the deepening of TOPC teaching reform, optimize the design and update the teaching resources, and introduce artificial intelligence technology in the blended teaching implementation process, in order to further improve the quality of blended teaching.

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STREAMLINING ACADEMIC CHANGE PROCESSES THROUGH ENGINEERING PRINCIPLES

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ABSTRACT

Adaptability, innovation, and efficiency are core engineering skills that students have to acquire to keep pace in a fast-changing world. It is, therefore, important that change processes in engineering education reflect and promote these skills. Further, as stated by, e.g., the Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG, 2015) and the CDIO Standard 12 (2010), efficient assurance, enhancement, and evaluation of educational quality is vital. However, change and quality management within universities are often slow and unwieldy (Graham, 2012; Kamp, 2016). Despite being the manifesto of engineering education, systematic problem solving is rarely incorporated into program organization and development. We have applied the CDIO concept to create a new, sustainable line of communication between students and faculty, in the form of a short program-level student questionnaire where the results are used as input to further discussion. Key concepts in the design of our method have been a *collaboration* between students and faculty, *iterative feedback loops*, and *simultaneous bottom-up and top-down* work by student representatives and the program director, respectively. These approaches have minimized the risk of failure and delay as well as actively utilized the creative power of the student body. In the questionnaire, distributed four times per year, students can anonymously share any opinions about the program. The program director and a student representative work *together* to evaluate the responses, immediately forwarding feedback to the correct recipient. Students are informed about key outcomes to ensure a trustful relationship between them and the faculty and promote active participation. With our method, issues are detected and handled at an early stage, allowing the focus within the program to remain on education, innovation, and quality enhancement. In this work, we will detail our methodology for streamlining communication as characterized by the engineering methods taught at universities. We will demonstrate some results obtained so far in improving the time-efficiency of quality management, through active student representation and trustful faculty dialogue. Still being in the early stages of operation, we will also reflect on the future outlook of our strategy. Finally, we will discuss the benefits of utilizing the CDIO concept for implementing change processes in higher engineering education.

KEYWORDS

Programme development, quality enhancement, student involvement, Standards 1, 5, 12

INTRODUCTION

The importance of efficient assurance, enhancement, and evaluation of educational quality is described by, for example, the Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG, 2015) and the CDIO Standard 12 (CDIO, 2010). These frameworks require that students should have the opportunity to make their voices heard and that there are appropriate processes to take care of student complaints. However, the possibility of educational innovation from a bottom-up approach is not explicitly supported by these frameworks. From a system perspective, this is problematic since students and teachers are only minor players in educational quality systems at the same time as they are major players when implementing change in reality. In fact, these arguments call for a complementary process where student input is strategically used for educational quality enhancement (Leander Zaar & Andersson, 2020).

Educational quality enhancement consists of change processes that, in many cases, involve behavioural changes for both teachers and students. However, there are many research reports discussing failures to create real and sustainable change in a higher education setting (Henderson et al., 2011), and it is also established that there are substantial internal barriers for creating change (Henderson & Dancy, 2007). Two keys to creating sustainable change seem instead to come from the active involvement of faculty in the change process (Graham, 2012) and to have quality enhancement processes that are connected with day-to-day work (Kleijnen et al., 2014). These conclusions about faculty involvement are also consistent with the outcomes from a previous pedagogic project at our university, where sustainable change was most easily detected when faculty had been actively involved in the process (Kjellgren et al., 2018).

Kilstrup, Hellgren, and Andersson (2011) have pointed out that "*Difficulties in implementing new ideas and activities in an organisation may be reduced if the development process is taking place within the organization and is performed by the persons that are influenced by the changes*." Since students are also influenced by educational change processes, we wanted to go one step further and try to develop a method to strategically use student input in a bottom-up approach to quality enhancement of a study programme. In addition, actively using student input may also lead to new innovative ideas.

In light of these observations, the overall aims of our work were to create a process for quality enhancement and program development that actively involves students and teachers, makes it easy for all stakeholders to get an overview of the state of the program and allows for sustainable change. A major goal with our project was also to "practice what we preach" as an engineering university, meaning that it was important to us that both our work and our results were characterized by engineering principles. With the help of the CDIO Standards, we have strived to create a method that is simple, logical, and time-efficient.

The CDIO Standards are based on the fundamental principle that products, processes, and system lifecycle development and deployment can be understood through the CDIO model (Conceiving--Designing--Implementing--Operating) and that this model also is the appropriate

context for engineering education (CDIO, 2010, Bennedsen et al., 2016). Hence, it should be natural to use the CDIO model for developing and creating educational change at an engineering university. In our work, we show an example of how the CDIO process is combined with appropriate feedback loops to develop an internal process for using student input as a strategic input to programme development.

Similarities between internal faculty change and the CDIO approach have been reported before (Berglund et al., 2015). The benefits of using CDIO to *drive* internal change is demonstrated by, e.g., Papadopoulou et al. (2019), who utilized CDIO principles in both the development and implementation of a faculty course and by Pham et al. (2012), who used the CDIO approach to design active learning exercises and interactive teaching methods. These examples imply that a CDIO-based work process can be used to improve faculty competence and student learning. Here, we extend this idea by showing how the CDIO approach can be used for general development processes at an engineering university. We will describe our strategy and show how the different stages of development relate to the CDIO model. Finally, we will also shortly discuss how our methodology can complement standard quality assurance processes and how it can be used to support an efficient change culture in higher education.

METHODOLOGY DEVELOPMENT THROUGH A CDIO PERSPECTIVE

We have (more or less) used the CDIO model during the development of a programme quality enhancement process. In this concrete example, we show how the different steps in the CDIO model match our steps in the process development. We also reflect upon the importance of feedback loops during the development process and how to strategically work to use student input for actual quality enhancement.

Conceive

In a usual course development cycle, an end-of-course questionnaire is followed up by a summarizing course analysis written by the teacher. This then serves as input to further course development before the next course offering. However, such a development cycle has some major disadvantages from a programme perspective. Firstly, it does not help a programme director to obtain runtime information about the programme. Secondly, important programme level issues may not reach the programme director until it is too late. Hence, an efficient channel for free and open student input directly to the programme level should be a useful tool for facilitating programme management and for using creative student input for further programme development. In addition, these ideas are also in line with demands for taking care of student views in evaluations of educational quality as, e.g., expressed by Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG, 2015) and by the CDIO Standard 12 (CDIO, 2010).

Naturally, a more direct line for collecting student opinions is also beneficial for the students themselves. In a traditional development cycle, students are rarely given feedback about their input: course analyses and suggested changes are usually not discussed with students, and solutions to problems they bring up may not become available during their time in the course or the programme. As a result, students may not be motivated to give input at all or feel like they are not being listened to. In other words, these factors limit both the opportunities and incentives for students to actively participate in improving their education. With our work, we wanted to develop a methodology that would increase the ability to provide real-time solutions,

allow students to easily raise both complaints and ideas, and ensure that students know they are included in the change processes.

An important part of our methodology and the formulation of our idea has been to lead by example and utilize the problem-solving abilities and the engineering principles that are taught at our university. Formulating the problem in an engineering language is also expected to make it easier to accept for both teachers and students. Our process thus had to be structured, have a logical flow of information, and be easily manageable for both students and teachers.

Design

From a discussion between the master responsible student and the programme director about the basic concepts of the problem, the development work was divided into two parts.

i) Develop an open student questionnaire - lead by the master responsible student (FLZ) - through an innovation process that also included other students at the programme.

ii) Develop a process to take care of the student input - lead by the programme director (MA) - which should be compatible with efficient management of quality enhancement.

Meetings between the master responsible student and the programme director took place during the development process in order to be able to identify other important design concepts and avoid conflicting interests in the solution.

The questionnaire was developed through an iterative feedback loop, where students were actively involved. The inclusion of stakeholder feedback in educational change processes is an explicit scale 5 criteria in several CDIO standard rubrics (e.g., in standard 3, 4, and 5). Standard 12 also makes clear that feedback about program development should, in turn, be provided to stakeholders. In a CDIO programme, it should be natural to think of engineering principles not only as a learning outcome but as a means to produce an agile environment for quality management, leading us to add stakeholder feedback iteration as a tool in the design of our methodology.

An initial version of the questionnaire was put forth by the master's responsible student and distributed digitally to the students in the programme. The invitation to answer the questionnaire also included an explanation of the basic ideas behind it, and students were also asked (as the last question) to give their opinions about the trial questionnaire itself. The questionnaire was then updated according to student needs and suggestions through an iterative process. Finally, the methodology was more deeply discussed in a student meeting, and the following issues were considered as particularly important for students:

- The questionnaire should be short.
- The questionnaire should be distributed *during* the study period so that issues can be resolved before the exam period.
- Student should be informed about how brought up problems will be solved or given an explanation if no solution is possible.

These comments emphasize the importance of inclusion and time-efficiency in change and quality management; the *collection* of these comments illustrate how these concepts can be used in a development process. By including the stakeholders of our methodology in the

design phase, their needs could efficiently be taken into account, and their ideas put to use. This approach allowed us to implement our strategy within a year of conceiving the idea, receive runtime feedback on its reception among everyone involved, and avoid misunderstandings and mistakes.

The process for handling outcomes of the questionnaire was developed by the programme director, simultaneously with the development of the questionnaire itself by the master responsible student. The original plan included forwarding relevant parts of the obtained student input to one of the following recipients:

- Course responsible teacher - if it only concerns one course.
- Programme director - if it can be solved directly by the programme director.
- Programme board - if strategic discussions are required.
- Track responsible faculty member - if it only concerns one track in the programme.
- Student meeting - if more student input is needed to start a change process.

During the development work, it became clear that it was also necessary to include the educational administration and the students themselves in this scheme. When the final version of the questionnaire was ready together with an initial process to forward the input to the right recipient, the methodology was presented and discussed within the programme board, which immediately accepted it as a good idea.

Implement

The questionnaire has two standard questions, which are always posed:

Q1: So far, what has worked well during this period?
Feel free to discuss your courses, your schedule, your teachers, program administration, or the program in general.

Q2: What improvements would you suggest?
Feel free to discuss your courses, your schedule, your teachers, program administration, or the program in general.

However, it is also possible to add one or two other questions. The aim of such questions could, e.g., be to follow up on answers to previous student questionnaires, to obtain a broader perspective of issues brought up by individual students, or to initiate a constructive dialogue between students and faculty (Leander Zaar & Andersson, 2020). The questionnaire is distributed to students four times per year (two weeks into each study period), and students can anonymously share any opinions about the programme. In our case, we used a university-specific web service for forms that provides a link to the questionnaire, and the link was then forwarded to the students by E-mail (this is similar to how Google Forms works).

The programme director and a student representative then work together to evaluate the responses, immediately forwarding feedback to the correct recipient. This ensures that the recipients only receive information that concerns them and that course-specific information (handled on course level) is separated from programme relevant information (handled at a programme level). The programme director now also becomes aware of course-specific issues that need to be handled quickly, can talk to the teacher before the course ends, and can also,

in collaboration with the department, discuss support to the teacher if needed. Some types of course-specific issues can then be solved before the course ends (e.g., missing course information or unclear information) without affecting the students too much. Strategic issues are handled by the programme director in the appropriate forum, which could be a programme board meeting, a track meeting, or a student meeting. Students are informed about key outcomes from these discussions on the programme's website, which helps to ensure a trustful relationship between them and the faculty and to promote active participation.

Operate

The methodology described above has now been in operation for two years, and we have gathered some practical experiences about how it works. A few general observations are:

- Essentially all student input has been good and constructive. However, in a few cases, it was not possible from the responses to connect a course-specific comment with a course.
- About 15% of the students answer the questionnaire.
- Feedback to students has been written for about 4-5 issues per questionnaire.
- Nearly all suggested improvements are either under consideration or have already been provided.
- The methodology seems to have been generally accepted by the teachers.
- It is possible to use student input to create change processes that are finalized.

A few practical examples of successful change processes that have been initiated by our methodology – including improved processes for providing information to students, changes in tracks, and better use of the official learning management system – are reported elsewhere (Leander Zaar & Andersson, 2020). In addition, collegial discussions seem to become less polarized when student input is provided as one of the starting points. Although the work to also streamline faculty and administrative discussions is still in progress, the indications we have so far pointed to that the CDIO principles are an appropriate foundation when developing quality enhancement processes in this context as well.

DISCUSSION

The main idea of our methodology is to build up a bottom-up quality enhancement process that is complementary to the top-down quality assurance process. While the latter is based on the concepts of accountability towards society and the use of external reviews, our methodology is based on the concepts of active participation of students and teachers, internal problem-solving, and the support of educational innovation initiatives. External quality assurance processes are not able to go into details without creating too much administration and high administrative costs. Hence, their main role is to help the organisation to identify potential strategic areas for further development, whereas they are much less useful for helping individual teachers to improve student learning and to support innovation. Our methodology has the opposite characteristics – its main role is to identify issues that improve student learning within a specific programme, support innovative ideas, and create actual change based on this knowledge. It is less useful for identifying overall strategy changes at the university level, although it can initiate faculty discussions on such issues. Besides being designed as a programme quality enhancement cycle, our methodology is also complementary to the standard course development cycle at our university (Naimi-Akbar et al., 2018, Kjellgren

et al., 2018). While the course development cycle focuses on changes for next year's course offering, our methodology can be used for creating changes already during an ongoing course offering.

It was recognized early on that time-efficiency for both students and teachers is a key design parameter for bottom-up quality management. Without implementing time-efficiency in the information flow, time, and available resources will not be spent optimally, and the internal motivation to participate in the change process will drastically decrease. Inefficient information flow will also decrease the available time for creating actual change. Although efficient information flow is a necessary condition for an efficient change culture, it is not a sufficient condition. Teachers must also feel an inner motivation to actually create change. Hence, there must also be a low barrier for teachers to create change and some reasonable economic support and appreciation to those who execute the work. From our experience, it seems as if teachers are delayed by the barriers that have to be overcome if problem-solving is done on an individual basis. Hence, an efficient collegial change dialogue is also required to support the change process. This is provided in our process by having a strategy to find the best forum for further discussions of different issues that are raised in the questionnaire. The work to fully set this up is ongoing, but what has been done so far looks promising.

One barrier towards creating change that teachers face may consist of insufficient constructive and useful student input. In our experience, teachers take student opinions very seriously, perhaps more so than rules dictated by policymakers. However, educational change processes that concern students and their role in the change process are often managed in a top-down fashion involving external reviewers, programme directors, faculty members, and pedagogic developers. Although quality assurance systems (ESG, 2015) and CDIO standard 12 both require that student opinions are collected and included in programme and course analysis, students – despite being the very epicentre of education – seldom *actively* participate in change processes. This arguably makes it more difficult for teachers to update their courses to suit student needs. For this reason, and because there is an innovative power within the student body that is now often overlooked, continuous student-faculty dialogue should be a natural way to swiftly improve engineering education at a CDIO university. Furthermore, by clarifying the student needs from the student input, it also becomes easier for teachers to use their own innovative ability to come up with new ideas that suit their own students both from a learning and a programme perspective.

From a change management perspective, it is quite well understood that change processes controlled from above have a large tendency to fail, while change processes involving faculty have a larger probability of leading to actual change (Henderson, 2011, Graham, 2012, Kleijnen, 2014). Georgsson and Holmgren (2012) have even shown that there are advantages of going one step further in quality management by including student-faculty communication through student representation in a programme board that advises the programme director. However, this board works in traditional development cycles, by, e.g., following up on end-of-course analyses. This *after-the-fact* mindset delays quality enhancement restricts the ability to handle urgent issues and stifles innovation. In our work, we have strived to resolve this by creating a method for collecting students' opinions *during* courses, as well as welcome their creativity in change processes.

The rubrics for the highest level of CDIO Standards 12 Programme evaluation, version 2.1 (Bennedsen et al., 2016), states that "There is documented evidence that systematic and continuous improvement is based on continuous program evaluation results." Our methodology clearly meets this goal for one of the key stakeholders (students), and in addition,

it attempts to take care of their innovative power to initiate further programme development. A similar process could possibly also be envisaged for other stakeholders provided that there is a mechanism for gathering information from them in an efficient way. An interesting observation is that since we have developed our process using CDIO-like ideas, the development process is by itself a design-implement experience for us and for the development of new processes at a university. This couples to CDIO Standard 5 - Design-Implement Experiences, where the standards for such experiences are described for students' experiences. A question that naturally arises in connection to our work is if a similar standard for developing internal processes at a CDIO university should also be part of the CDIO Standards?

CONCLUSIONS

We have developed a time-efficient methodology for strategically using student input for programme development, which is consistent with the rubrics for the highest level of CDIO Standard 12 Programme evaluation. In addition, our methodology promotes innovative power in the interactions between students and teachers. The process which we used during the development of the methodology followed the CDIO model, which we suggest to be a workable model for handling internal change processes at an engineering university. Through our work, we have demonstrated the value of not only teaching engineering principles but also actively utilizing them in educational change and quality management.

ACKNOWLEDGEMENT

We sincerely thank all the students at (and connected to) the Master's programme in Engineering Physics at KTH, who gave us invaluable input during the development of the questionnaire.

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SPREADING THE MODEL: CDIO OF CDIO COURSES USING CREATIVITY TECHNIQUES

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ABSTRACT

The CDIO approach to engineering education has reformulated higher education in scientific, technical and technological disciplines, through the promotion of active learning in connection with the conception, development, implementation and operation of real engineering products, processes and systems. The model is already making a transformative impact worldwide in more than 120 universities that collaborate and learn together. However, spreading the model is a challenging issue as, in spite of the verified clear benefits of shifting to CDIO-related teaching-learning methodologies and of the efforts of CDIO members, for continuously supporting potential new partners in their endeavors, transforming engineering education and motivating professors to change their way of teaching is always a complex and extremely multifaceted process. The CDIO standards provide a comprehensive set of aspects, which should be tackled when trying to incorporate the CDIO model to an already existing engineering degree or set of degrees, or when trying to design a new programme accordingly. The workshops from the CDIO conferences and the published papers of the CDIO proceedings also constitute a relevant source of information and inspiration. Nevertheless, in some cases, professors wishing to conceive, design, implement and operate new courses, based on the CDIO model, may possibly feel overwhelmed by the required dedication or even find difficulties when facing the process of reinventing or creating a course following the model. Reluctance of professors to change and their doubts when trying to create CDIO-related courses are among the common factors that can limit the further expansion of the CDIO model.Trying to develop a systematic approach to “the CDIO cycle of innovative CDIO courses” we present a set of creativity promotion canvases (one for each stage of the process) adapted to the strategic planning of novel engineering courses following the CDIO approach. The “conceive” canvas helps professors to match the learning objectives of the course with the type of engineering products, processes or systems to be developed. The “design” canvas guides professors through a process of matching outcomes with topics and activities and supports through the analysis of requirements for the application projects. The “implement” canvas focuses on the resources needed for developing the projects and connects topics and lessons with the steps of the project to be developed. The “operation” canvas concentrates on key processes during the real implementation of the course, including group formation, teamwork promotion, conflict solving, coordination of participants, including professors, and evaluation. The application of these user-friendly creativity promotion canvases is explained through a real case study and its potential illustrated by the results of their application to strategically planning a set of CDIO courses with a group of 30 professors in a Spanish university.

KEYWORDS

Continuous Improvement of Education, Faculty Development, Change, Standards 9, 10

INTRODUCTION

The CDIO approach to engineering education has reformulated higher education in scientific, technical and technological disciplines, through the promotion of active learning in connection with the conception, development, implementation and operation of real engineering products, processes and systems (Crawley, 2007). The model is already making a transformative impact worldwide in more than 120 universities that collaborate and learn together. However, spreading the model is a challenging issue. In spite of the verified clear benefits of shifting to CDIO-related teaching-learning methodologies and of the efforts of CDIO members, for continuously supporting potential new partners in their endeavors, transforming engineering education and motivating professors to change their way of teaching is always a complex and extremely multifaceted process. The CDIO standards provide a comprehensive set of aspects, which should be tackled when trying to incorporate the CDIO model to an already existing engineering degree or set of degrees, or when trying to design a new programme accordingly. The workshops from the CDIO conferences and the published papers of the CDIO proceedings also constitute a relevant source of information and inspiration.

In fact, according to our experience, becoming member of the International CDIO Initiative and fostering CDIO-related methodologies within a university is a much more straightforward process than those linked to getting engineering programmes of study accredited by most international accreditation agencies and boards. Nevertheless, in some cases, professors wishing to conceive, design, implement and operate new courses, based on the CDIO model, may possibly feel overwhelmed by the required dedication or even find difficulties when facing the process of reinventing or creating a course following the model. Reluctance of professors to change and their doubts when trying to create CDIO-related courses are among the common factors that can limit the further expansion of the CDIO model. Since the incorporation of UPM to the International CDIO Initiative in 2015, our team has been involved in the creation of several CDIO courses in 5 engineering programmes (Díaz Lantada, 2014, 2015, 2016, Lumbreras Martín, 2015, 2016). We have also taken part in different seminars, workshops and international design competitions and schools, in which we have supported colleagues to get familiar with the basics of the CDIO model and to plan project-based learning courses in varied fields of engineering. In this period, we have understood that innovative methodologies are attractive and rewarding. However, in some cases, easy-to-use resources for training engineering educators may help to expand innovative methodologies.

Trying to develop a systematic approach to “the CDIO cycle of innovative CDIO courses” we present a set of creativity promotion canvases (one for each stage of the process) adapted to the strategic planning of novel engineering courses following the CDIO approach. The “conceive” canvas helps professors to match the learning objectives of the course with the type of engineering products, processes or systems to be developed. The “design” canvas guides professors through a process of matching outcomes with topics and activities and supports through the analysis of requirements for the application projects. The “implement” canvas focuses on the resources needed for developing the projects and connects topics and lessons with the steps of the project to be developed. The “operation” canvas concentrates on key processes during the real implementation of the course, including group formation, teamwork promotion, conflict solving, coordination of participants, including professors, and

evaluation. The application of these user-friendly creativity promotion canvases is explained through a real case study, linked to a course on “Design and manufacturing with polymers”, and its potential illustrated by the results of their application to strategically planning a set of CDIO courses with a group of 30 professors in a Spanish university.

CREATIVITY PROMOTION CANVASES FOR THE CDIO OF CDIO COURSES

In order to support the systematic promotion of the CDIO model, a set of creativity promotion canvases or templates has been developed for the conception, design, implementation and operation of CDIO courses. One canvas is designed for each stage of the process, according to main questions, unknowns and challenges that typically arise during the creation of project-based and CDIO-related teaching learning experiences. The canvases help developers (higher education professors in this case) to systematically consider the key aspects of the challenge being tackled (new CDIO courses). These templates operate in a similar way to other design or creativity promotion canvases from different engineering disciplines, such as those used in the well-known business model generation methodologies (Osterwalder, 2010). According to our experience with novel CDIO courses, the most straightforward approach to the CDIO of CDIO experiences relies on systematically planning the teaching-learning experience. From the very beginning (and in parallel) one should consider, both the desired learning objectives, professional outcomes and topics of the course, together with the engineering project that will help to articulate the experience, to apply the acquired knowledge and to promote the objective professional skills. Table 1 summarizes the driving questions that have helped in the design of the creativity promotion canvases. We consider such questions to be the more relevant one can ask, for the straightforward and reliable conception, design, implementation and operation of innovative CDIO courses. In our view, systematically considering and answering such questions, before the first implementation of a new CDIO course (and counting with the support of the CDIO canvases explained in the following section), helps to successfully replicate the model.

Table 1. Summary of questions and challenges that typically arise in new CDIO experiences

Stage	Questions linked to the CDIO course	Questions linked to the related CDIO project
C	-Which are the learning objectives of the course? -Which is the social and industrial context of the course?	-Which engineering systems benefit from the course? -Which engineering system are the students going to project?
D	-Which are the professional outcomes we would like to promote? -Which are the thematic blocks of the course?	-Which are the requisites for the CDIO projects and for students? -How do the CDIO project stages relate to the thematic blocks?
I	-Which contents should be included in the course programme? -Which contents support the projects to be developed?	-How do the contents explained relate to the stages of the projects? -Which are the human and material resources required?
O	-Which are problems may arise and how can we solve them? -How is the course assessed and its progress monitored?	-How can we make the CDIO projects and experience sustainable? -How can we monitor and mentor the CDIO project to keep them in pace?

The four CDIO canvases, developed according to Table 1, are presented in the following pages (Figures 1-4) and illustrated by showing their application to a CDIO course on “Design and manufacturing with polymers”. In such course, students work in groups for designing toys with different polymeric components and following design for injection molding principles and for developing the production tools (molds) used for manufacturing such toys (Díaz Lantada, 2017). The course is taught at UPM (Master’s of Science in Industrial Engineering) since 2005.

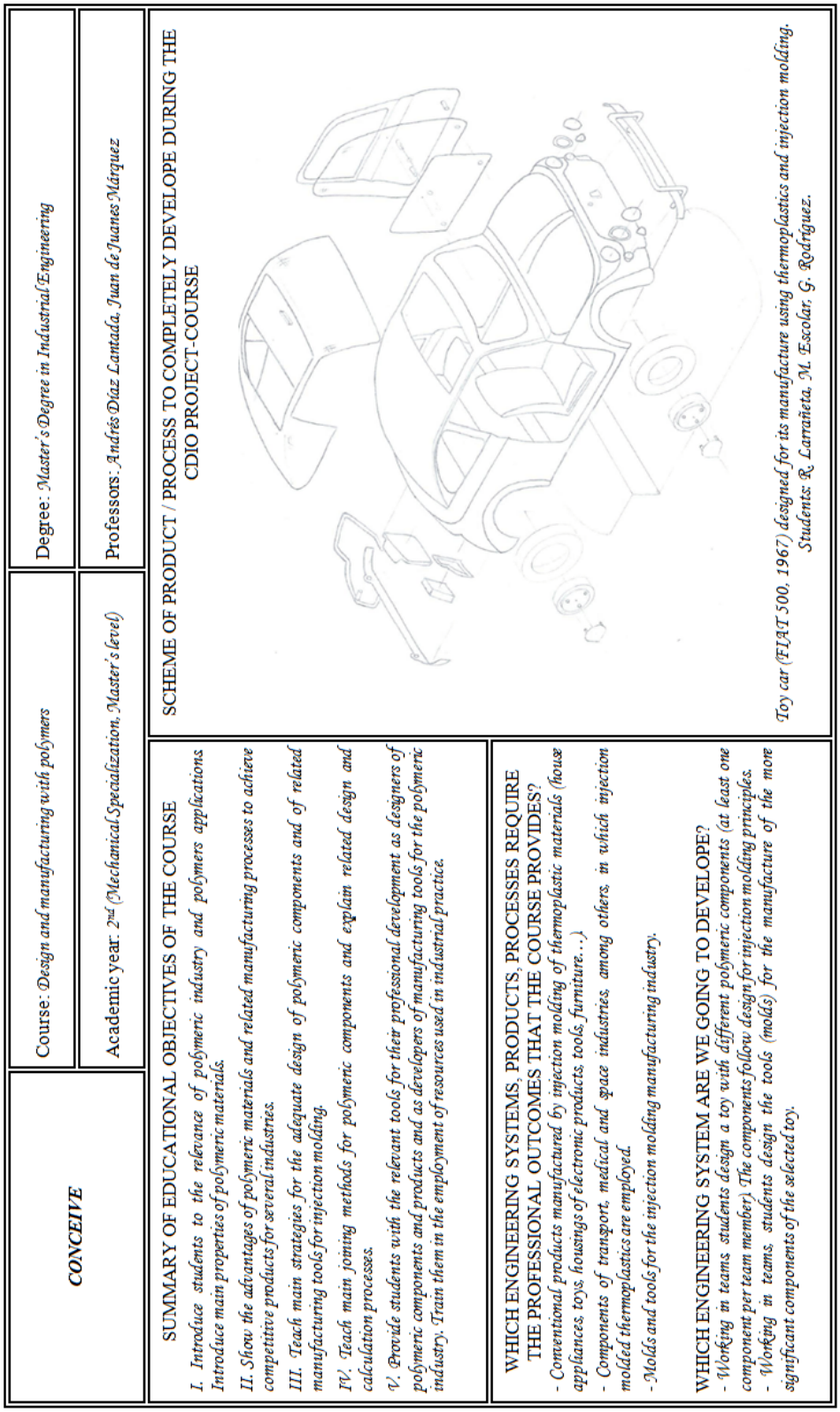


Figure 1. Creativity promotion canvas for the “Conceive” stage: Application to course on “Design and manufacturing with polymers”.

DESIGN	Course: *Design and manufacturing with polymers*	Degree: *Master's Degree in Industrial Engineering*
	Academic year: *2nd (Mechanical Specialization, Master's level)*	Professors: *Andrés Díaz Lantada, Juan de Juanes Márquez*

ENGINEERING OUTCOMES TO BE PROMOTED DURING THE COURSE		REQUISITES FOR THE CDIO PROJECTS TO BE DEVELOPED
EUR-ACE®: ■ Knowledge and comprehension □ Analysis in engineering ■ Engineering projects □ Research and innovation ■ Practical engineering application □ Judgment performance ■ Communication and teamwork ■ Lifelong learning	ABET: ■ Ability to apply engineering knowledge □ Ability to design and perform experiments ■ Ability to design products and processes ■ Ability to work in multidisciplinary teams □ Ethical and professional responsibility ■ Ability to communicate effectively □ Broad education to understand impacts ■ Compromise with lifelong learning □ Knowledge of contemporary issues ■ Ability to use modern engineering tools	*- The CDIO project is linked to the complete development of a toy made of polymeric components; whose manufacturing tools (injection molds) should be also designed.* *- Teams of 3 to 4 students.* *- At least one significant polymeric component per student.* *- CAD tools must be employed for the design of the different components and tools.* *- Geometries and joints must be designed and optimized on the basis of explained theory and with the support of FEM and CAM modeling tools.* *- Thermoplastic materials must be selected and compared employing resources used in industry for optimizing polymeric parts (i.e. Moldflow).* *- The geometry-material-process triad must be considered for optimization purposes.*

THEMATIC BLOCKS	PLANNED ACTIVITIES (for the CDIO projects)
I. Introduction to polymers and their industrial applications.	*- Selection and validation of polymeric materials for a selected toy.*
II. Design oriented to manufacture using polymeric injection molding.	*- Basic design of the different toy components.*
III. Design of joints between polymeric components in complex products.	*- Design and calculation of joints between polymeric components.*
IV. Design optimization considering: Geometries, materials and processes.	*- Optimization of geometries using mechanical and manufacturing simulations.*

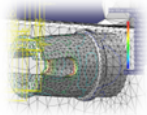
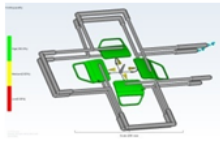
SCHEME OF STAGES AND EXPECTED RESULTS			
CONCEIVE	DESIGN	IMPLEMENT	OPERATE
			

Figure 2. Creativity promotion canvas for the "Design" stage: Application to course on "Design and manufacturing with polymers".

IMPLEMENT	Course: *Design and manufacturing with polymers*	Degree: *Master's Degree in Industrial Engineering*
	Academic year: *2nd (Mechanical Specialization, Master's level)*	Professors: *Andrés Díaz Lantada, Juan de Juanes Márquez*

PHASE	REQUIRED MATERIAL RESOURCES	REQUIRED HUMAN RESOURCES
Conceive	*Paper* *Pencil, marking pens* *Course bibliography*	*Students* *Professors*
Design	*Paper* *Pencil, marking pens* *CAD-CAE-CAM resources* *Course bibliography*	*Students* *Professors*
Implement	*Rapid prototyping techniques* *Rapid tooling techniques* *3D printing machines* *Vacuum casting equipment* *Machining equipment* *Commercial components (motors, batteries, standardized elements)*	*Students* *Professors* *Lab technicians (department)* *External lab technicians*
Operate	*Laboratory injection machine* *Molds with interchangeable parts* *Polymers for injection molding, if the whole cycle is to be fulfilled*	*Students* *Professors* *Lab technicians (department)* *External lab technicians* *Communication experts*

RELATIONSHIP BETWEEN SYLLABUES AND CDIO PROJECTS' STAGES

	CONCEIVE	DESIGN	IMPLEMENT	OPERATE
1. Polymeric industry	X			
2. Polymers and properties	X	X		
3. Design for injection	X	X		
4. Materials selection	X	X		
4. Snap fit design		X		
5. Pressure fit design		X		
6. Screw joints design		X		
7. Polymeric hinges designs		X		
8. Mold design: Basics			X	
9. Mold design:			X	X
10. Mechanical simulations		X	X	X
11. Injection simulations		X	X	X
12. Polymeric prototypes			X	X
13. Advanced applications			X	
14. Smart polymers				X

IMPLEMENTATION SCHEME

Basic design → *Detailed engineering*

Figure 3. Creativity promotion canvas for the "Implement" stage: Application to course on "Design and manufacturing with polymers".

OPERATE	Course: *Design and manufacturing with polymers*	Degree: *Master's Degree in Industrial Engineering*
	Academic year: *2nd (Mechanical Specialization, Master's level)*	Professors: *Andrés Díaz Lantada, Juan de Juanes Márquez*

KEY PROCESSES FOR THE CDIO PROJECTS

- GROUP FORMATION: *Proposal to arrange teams by personal decision of students.*

- PROMOTION OF TEAMWORK: *Providing a complex project, so that all students must be involved for a successful final result in just a single semester.*

- CONTROL AND MENTORING: *Intermediate and final presentations. Scheduled meetings.*

- PROBLEM AND CONFLICT SOLVING: *Conciliation meetings, teambuilding activities.*

- COORDINATION OF PROFESSORS: *Initial, intermediate and final meetings.*

EVALUATION OF REQUIRED ECONOMICAL RESOURCES
(TOTAL €/YEAR): *2.000€ for CAD-CAE-CAM software, 200€/prototype*

- FUNDING SOURCES: *Enterprises that propose challenges or topics for the development projects, annual support by our department and teaching units, sponsorship of UPM's Product Development Laboratory.*

- SUSTAINABILITY PLAN: *Annual maintenance of CAD-CAE-CAM software licenses, materials and machines for prototyping, maintenance of computers and equipments, acquisition of standardized components, establishment of agreements with the industrial sector for sponsoring the developments and projects, compromise of Rectorate with CDIO experiences, funding provided by educational innovation calls, among other options.*

COURSE ASSESSMENT

- Measures to promote individual assessment: *Weekly / monthly deliverables focused on analyzing real polymeric components and injection molding molds.*

- Measures to promote positive interdependence: *Providing a complex project, so that all students must be involved for a successful final result. Possible "face-to-face" challenges for teams with similar products.*

- Final mark (%team & %individual): *70% for teamwork and 30% for individual deliverables*

- CDIO projects assessment:
  - - Process: *Adequate following of planned process and activities for the different stages.*
  - - Results: *Based on final design quality (and related prototypes).*
  - - Teamwork: *Final dedication survey (hours and credits).*
  - - Communication: *Based on oral presentations and written deliverables.*
  - - Creativity: *Number of provided solutions and their related viability.*
  - - Other aspects: *Proactivity, participation in class, relationship with other courses.*

- Tools and resources for measuring satisfaction:
  - - Of students: *Continuous observation, periodic conversations, final results of the CDIO projects, surveys (both official and ad hoc).*

  - - Of professors: *Final survey, conversations with colleagues, debates in congresses (i.e. CDIO International Conferences), acceptance of papers in journals.*

Figure 4. Creativity promotion canvas for the "Operate" stage: Application to course on "Design and manufacturing with polymers".

CDIO CANVASES APPLIED IN A WORKSHOP FOR SPREADING THE CDIO MODEL

Once the CDIO canvases of Figures 1-4 were conceived and proven useful for summarizing the key aspects of CDIO courses and related CDIO projects, as illustrated before with the example of the "Design and manufacturing with polymers" course, they were further applied to mentoring colleagues with the CDIO of new CDIO experiences. To cite an example of how the CDIO model can be spread with the support of these creativity promotion tools, we summarize here the results from a workshop organized in 2019 in a Spanish university, with the objective of explaining the fundamentals of the CDIO model and of mentoring a group of interested colleagues, along the planning of new CDIO experiences and courses. The workshop lasted for two days (10 hours) and counted with the participation of 30 colleagues from different engineering disciplines. Empty CDIO canvases, to be filled in during the workshop, were provided at the beginning of the workshop sessions.

The following presentations (1 hour each) were given during such workshop:
- Introduction to the International CDIO Initiative and to the CDIO model.
- Two case studies linked to the creation and teaching of CDIO courses.
- Assessment of courses employing active learning methodologies.
- Management of a set of CDIO courses: Common problems & operative advices.

The following hands-on activities and debates were also carried out:
- Guided application of the "Conceive – Design – Implement – Operate" canvases to different potential new courses. Around 45 minutes were devoted for interacting with each canvas
- Discussions linked to main challenges and common solutions for the different stages of project-based learning courses. One-hour closing debates, one per day, helped to promote creativity along the workshop.

During the workshop, interesting ideas for creating new courses or reformulating ongoing ones, so as to follow the CDIO model and to promote active learning, were put forward by participants with the support of the provided tools and as a result of guided discussions. The most interesting courses and the related CDIO projects, which may help to involve students in the active application of the knowledge and skills acquired are listed in Table 2. Direct inspection of Table 2 helps to understand the multidisciplinary nature of the CDIO model and its valid application to almost all engineering disciplines. If the adequate driving questions are asked and if mentoring from colleagues throughout the CDIO community is promoted the model can further spread and reach many more universities and countries in a sustainable way.

Table 2. Summary of CDIO courses and related projects, proposed after an introductory workshop to CDIO, in which the developed canvases were employed.

Engineering course or area	Potential topic for CDIO projects
Electronics	Development of a control for a deposit
Electronics	PCB for analogic digital converter
Informatics	Design of websites
Theory of machines and mechanisms	Development of positioning mechanisms
Biomechanics	Devices for improving mobility
Materials Science and Engineering	Design of appliances using composites
Electricity	Project of a remote sustainable installation
Mechanical systems	Development of a laser dartboard
Theory of vehicles	Design of a testing bench for vehicles
Transport methods	Development of a transporting chain

CONCLUSIONS

CDIO has already transformed engineering education but its impact can be even larger if the model is further spread in a systematic way, so that additional countries, universities and engineering programmes may use CDIO as backbone for their scientific-technical higher education systems. Based on experiences by our team, a set of straightforward creativity promotion tools for the conception, design, implementation and operation of project-based teaching-learning experiences following the CDIO model has been developed. These tools take the form of “CDIO canvases”, with which professors can interact, for answering driving questions and for considering main challenges, linked to the creation of innovative CDIO teaching-learning experiences.

This study has presented the CDIO canvases, as tools for spreading CDIO, illustrated their use by summarizing the most relevant aspects of a successful CDIO-PBL course and highlighted their potential for rapidly ideating new CDIO initiatives by presenting the results of an introductory workshop to the CDIO methodology performed with colleagues from several engineering disciplines. We expect that these tools may support creativity in education, as other canvases have proven useful for innovating in business and for start-up creation.

Finally, we would like to highlight that, in order to train colleagues with the use of these creativity promotion canvases, apart from presenting and explaining their use in current study, a related workshop for the CDIO of CDIO courses has been proposed by our team for the 16th International CDIO Conference in Thailand (2020). In such workshop, we expect colleagues to work in reduced groups for generating, analyzing and discussing ideas for innovative CDIO experiences. We hope that it may contribute to the systematic promotion of CDIO model’s spreading.

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BIOGRAPHICAL INFORMATION

Andrés Díaz Lantada is Professor in the Department of Mechanical Engineering at ETSI Industriales – UPM. His research activities are aimed at the development of biodevices using modern design, modeling and manufacturing technologies and he incorporates these results to subjects linked to product development. He is Editorial Board Member of the International Journal of Engineering Education and CDIO contact at UPM. He has received the "TU Madrid Young Researcher Award" and the "TU Madrid Teaching Innovation Award" in 2014 and the "Medal of the Spanish Academy of Engineering to Young Researchers" in 2015.

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Juan Manuel Muñoz Guijosa is Professor in the Department of Mechanical Engineering at ETSII – TU Madrid. His research activities are linked to several fields of Mechanical Engineering. After his PhD he was visiting researcher at MIT and worked some year for Bosch GmbH linked to the automotive industry. Since his reincorporation to TU Madrid he has been linked to subjects on "Mechanism and Machine Theory", "Vibrations Theory", "Engineering Design", among others, and participated in several research projects. More recently he has been visiting research professor at the TU of Tokio and at Drexel University.

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THE USE OF AUTHENTIC ASSESSMENT IN CDIO PROJECT

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ABSTRACT

In engineering education, it is of great concern that students may not be capable of transferring the skills they have gained from their education to real-world problems. The industry is also encouraging the Polytechnics to expose students to multifaceted, complex problems where there are no fixed standard answers to one problem. These apprehensions have given rise to the use of authentic assessment in CDIO for the Year-3 module Structural BIM eSubmission in the Diploma in Civil Engineering with Business. These paper aims to discuss the use of authentic assessment in CDIO project in the module Structural BIM eSubmission and how it can help to prepare students for the industry by providing opportunities for them to use the knowledge gained from the 35 modules they learned over the last two years to work on a real-world project (three-storey high bungalow house), a CDIO project through the stages of Conceive-Design-Implement-Operate. Authentic assessment is infused into this project, aiming to achieve the four elements highlighted by Gulikers et al. (2004) as follows:
(a) product and performance produced in real-life
(b) making valid inferences
(c) a full array of tasks and multiple indicators of learning
(d) presentation of work
This paper also discussed the potential of the CDIO project with an authentic assessment to adequately assess all the capacities and outcomes we want to recognise and help in student's learning and its success factor for implementation. AA has the potential to adequately assess all the capacities and outcomes we want to recognise and helps in student's learning. We should work towards minimising the impact of the above-discussed problems because, at the polytechnic level, we have more valid reasons, resources, and support from the industry to drive AA.

KEYWORDS:

Civil Engineering, Authentic Assessment, Standards 2, 3, 7, 8, 9, 11

INTRODUCTION

In engineering education, it is of great concern that students may not be capable of transferring the skills they have gained from their education to real-world problems. The industry is also encouraging the polytechnics to exposed students to multifaceted, complex problems where there are no fixed standard answers to one problem. Exposure to real-world problems promotes critical thinking, problem-solving skills, and team working skills. These life-skills are

a necessity in the industry. With the technological revolution, the availability of information online is also changing the way our students learn. It may no longer be adequate to just provide engineering students with a sound technical knowledge foundation in 21st-century engineering education. Schools need to foster effective, integrative learning of scientific knowledge and the development of professional skills and attitudes that may assist future engineers' practice. Archibald and Newmann (1998) acknowledged that "traditional tests" neglect the type of competencies required to deal with problems successfully beyond school. These apprehensions have pushed for the need to use of authentic assessment in CDIO for the Year-3 module Structural BIM eSubmission in the Diploma in Civil Engineering with Business.

The module Structural BIM eSubmission aims to prepare students for the industry by providing opportunities for them to use the knowledge gained from the 35 modules they learned over the last 2 years to work on a real-world project (three-storey high bungalow house), a CDIO project through the stages of Conceive-Design-Implement-Operate. Authentic assessment is infused into this project, aiming to achieve the four elements highlighted by Gulikers et al. (2004) as follows:

(a) product and performance produced in real-life
(b) making valid inferences
(c) full array of tasks and multiple indicators of learning
(d) presentation of work

LITERATURE REVIEW

An authentic assessment (AA) allows students to explore, discuss, and meaningfully construct concepts and relationships in contexts that involved real-world problems and projects that are relevant to the learner (Donovan, Bransford & Pellergino, 1999). This will allow the students to see the purposes of why they are learning certain modules and integrate what they have learned into use. More importantly, for Polytechnic education, AA should and can help in developing professional competencies, skills, and attitudes required for a particular discipline or industry, as highlighted by Newmann & Associates (1996) and Wiggins (1993). Furthermore, it is imperative for engineering education to expose students to complex, open-ended, and ill-structured real-life problems to encourage higher-order thinking processes. It is also critical that the AA is aligned with real-world expectations (Biggs, 1996; Linn, Baker & Betebenner, 2002). Gulikers, Bastiaens & Kirschner (2004) and Messick (1994) have also highlighted that when the assessment setting simulates the professional practice, students will innately cultivate professional competencies and skills which are relevant and prepare them for their future career. It can then be argued that AA can help to prepare them for the industry because as emphasized by Newmann & Associates, (1996) and Messick (1994) AA focus on simulating the real-world and will probably cover the relevant aspects of the required work performances and competencies of the particular profession.

Several theories and criteria have been proposed for AA; for example, Newmann, Marks, and Gamoran (1996) have defined the construction of knowledge, disciplined inquiry and value beyond school as the key criteria whereas Wiggins (1993) has identified 9 comprehensive criteria for AA which include perceivable performances.

In line with Newmann et al. (1996) and Wiggins (1993), Gulikers et al. (2004) stressed that the level of authenticity of AA depends greatly on the level of correspondence to the professional practice. Students are expected to employ and exhibit a similar kind of skills, competencies,

attitudes, and construction of knowledge like a professional when AA is being adopted (Gulikers et al., 2004). In addition, Cronin (1993) and Newmann & Wehlage (1993) have emphasized that authenticity should be conceptualised as a continuum and a dimensional construct.

The other benefit of AA is the ability to actively involve students and touch their intrinsic motivation (Mehlinger, 1995). This is important for civil engineering students as most of the students did not choose this course as their first choice; hence motivating them intrinsically will enhance their learning. Furthermore, intrinsic motivation is one of the key pedagogy adopted by our course.

AA is multi-facets and the five-dimensional framework by Gulikers et al. (2004) which includes, tasks; physical context; social context; form and criteria is comprehensive and has been studied on vocational education, which yields positive results. Therefore, the proposed AA will be adopting the Gulikers et al. (2004) five-dimensional framework.

DESCRIPTION OF AA IN A CDIO PROJECT

Design of Task

Authentic Assessments are tasks that are either replica of or analogous to the kind of problems faced by adult citizens and consumers or professionals in the field, and these tasks simulate or replicate the diversity and richness of the context of performance (Wiggins, 1993). The high level of authenticity is achieved by adopting a real project in the industry. The set of architectural drawings given to the students is a bungalow house that has been built in Singapore. To increase the genuineness and reflecting the real-world, each group will be given a different set of architectural drawings of the same level of difficulty. Students are required to analyse, calculate, and design the structures of the bungalow house, which need to meet the Architectural, Building Construction & Authority, and the client's requirements. This ill-structured, complex and relatively open-ended tasks encourage diversification and a real-world feel which expose students to the messiness of real-life decision making, where there may not be a right or a wrong answer per se, although one solution may be better or worse than others depending on the particular context (Lombardi, 2007). Thus providing students the opportunity to perform structural design tasks akin to a design engineer where their performance represents the construction of knowledge through the use of disciplined inquiry that has some value or meaning beyond success in school (Newmann, 1997). The task requires them to go through the 4 stages of CDIO, which they need to tap on prior knowledge, established relationships by integrating and linking between fragments of knowledge, multiple concepts to construct intellectual comprehension of the task to create and devise a structural layout plan for the bungalow house. The students are given full ownership of the bungalow house design, where they have to interpret the set of architectural drawings to draw conclusions on the architectural requirements.

Task's Brief:

In a group of 4, students are given a set of architectural drawings (Appendix A). The set of drawings is an architectural floor plan which helps to convey the architectural ideas and concepts of the architectural design. The first and second storey floor plan shows the arrangement of spaces, walls and its material, windows, types of door and its openings, and other features of that particular level of the bungalow house. The elevations view of the

bungalow house shows the profile of the side, the floor to ceiling height, wall height, staircase height, and design and other information not found on the floor plan. The students are required to design the structural elements of the house to meet the architecture, client, and authorities requirements. The task is split into three submissions, as shown in Appendix B. In this essay, only submission 1 will be used for discussion of rubrics.

CDIO Stages

For submission 1 (Conceive), the students are required to design and produce the structural floor plans for the bungalow house. They are required to submit both hardcopy and softcopy of their 2D drawings and Revit 3D-model for footing plan, 1st storey structural plan, 2nd storey structural plan, and structural roof plan. The main construct is house design, which is unpacked to the various criterion such as synchronizing architectural requirements in their structural floor plan, structural design, and compliance to authorities' requirements.

For submission 2 (Design & Implement), the students are required to exact information from their submission 1 in order to design and determine the sizes of the structural elements.
They are required to submit the structural design and detailed calculations for the structural elements which must comply with the Eurocode 2 and Singapore code of practices.

For submission 3 (Implement & Operate), the students are required to model their structures into smart 3D using a BIM tool. This allows them to identify structural clashes and unrealistic structural sizes. The 3D model also serves as a preliminary form of operation as it can show if the building is visually safe.

Physical Context

The task requires them to design a structural layout plan which complies with the regulatory requirements by Building Construction Authority (BCA), the architectural requirements, and the client. The high contextual fidelity of the task offer students plenty of opportunities to perform like a design engineer where they have to engage structural analyse tools, Revit modeling software to model the bungalow house in 3D, and referencing to Singapore code of practices. The time given for them to finish the task is about 3 weeks. As pointed out by Wiggins (1993), the constraints need to be realistic, and hence we sufficient time was allocated for the students to complete the task, and the duration should be close enough to simulate what the real-world duration is like.

The objective is to provide an educative experience (bungalow house design principles and concepts) inherently valuable to students because they can see the relevance to their future life as an engineer and the purpose in learning and how the knowledge gained in Polytechnic is transferred into solutions for the real-world problem. This objective answers one of the important issues of AA raised by Baker & O'Neil (1994), which is authentic to whom?

Social Context

In reality, design engineers do work as a team and sometimes as an individual depending on the scale of the project. For this task, the students will work as a group comprising of 4 members. The rationale of choosing group work over individual work is due to the high complexity of the task. The group work may provide more opportunity for in-depth work which mimic a more real-world experience compared to typical course work. (McCorkle, Reardon, Alexander, Kling, Harris, & Iyer, 1999). Students working in groups will also engage in

extended conversational exchanges with the lecturer or their peers about the subject matter in a way that builds an improved and shared understanding of ideas or topics (Newmann, 1996). Research by Johnson, Johnson & Smith (1998) and Springer & Donovan (1999) has also shown that collaborative learning improved learning relative to individual work for students in science, mathematics, engineering, and technology. Each group is required to meet the lecturer on a weekly basis for consultation – design review. In the real situation, the team of engineers usually are required to meet their professional engineer (PE) on a weekly or bi-weekly basis to review their design, which we termed as "design review" in the industry. During the consultation session, the lecturer will have to play multiple roles as "client" and "PE." The lecturers will only be providing his views, feedbacks, and needs as a client or as a PE and will not provide any answers and solutions to the students. The students are the designer of their learning, and the facilitator should not take power away from them. To further enhance the authenticity of a real consultation, an architect will be engaged to sit in the consultation sessions. The consultation session will also fit nicely with Wiggins's (1993) 6th criteria, where the interaction is important between the lecturer, architect, and the students. These consultation sessions serve as a platform for the assessee (students) to justify their choices with reasons and for the assessor (lecturer & architect) to ask questions and probe further to identify the student's depth of mastery and to enhance their learning.

Assessment Result or Form

The assessment result of the task consists of the four elements highlighted by Gulikers et al. (2004). The four elements are, (a) product and performance produced in real-life - the set of structural floor plans and the structural and architectural technical skills; (b) making valid inferences – the ability to do residential structural design; (c) a full array of tasks and multiple indicators of learning – students will demonstrate learning through the product of task and through inquiry during consultation sessions and (d) presentation of work – present set of structural floor plans to lecturer and architect through oral, 2D and 3D drawings.

Criteria and Standards

The major concern of authenticity is that nothing critical has been left out of the assessment of the focal construct (Messick, 1994). Therefore, the assessment has been designed with Messick's (1994) construct-driven approach to minimise construct-irrelevant variance and construct underrepresentation. The three criteria, synchronizing architectural requirement, structural design, and compliance of technical detailing for authority submission, are derived from the predominant construct, which is the structural design of a bungalow house. SOLO taxonomy has been adopted as an instrument to assess quality. As claimed by Biggs and Collis (1982), SOLO taxonomy is the only instrument that offered to assess quality in an objective and systematic manner. The levels are structured from concrete to abstract, which helps to assess the qualitative learning outcomes and is a good reflection of the complexity of learning. When compared to Bloom taxonomy, SOLO's ability to enable students to progress from uni structural to relational and abstract thinking is more suitable for assessing open-ended responses, and it is more accurate in making valid interference. On the other hand, Bloom taxonomy may be more suitable for setting questions rather than evaluating responses.

Table 1: Rubric for Submission 1 (15%)

Performance Criteria/Task	**1 (Unistructural)**	**2 (Multistructural)**	**3 (Relational)**	**4 (Extended Abstract)**
Synchronizing architectural requirement (30%)	• Did not consider and analyse client's and architectural requirements. • None of the architectural requirements have been synchronized into the structural plan.	• Consider and analyse some (limited) client's and architectural requirements • Some of the architectural requirements have been synchronized into the structural plan.	• Consider and analyse majority of client's and architectural requirements. • Majority of the architectural requirements have been synchronized into the structural plan.	• Consider and analyse majority of client's and architectural requirements. • All of the architectural requirements have been synchronized into the structural plan.
Structural Design (40%)	• Structural design shows basic logical structural layout without efficiency consideration resulting in not being a cost-effective design.	• Structural design shows an intermediate logical structural layout with some efficiency consideration resulting in being a minimal cost-effective design	• Structural design shows a good logical structural layout with good efficiency consideration resulting in being a cost-effective design.	• Structural design shows an excellent logical structural layout with excellent efficiency consideration resulting in being a very cost-effective design.
Compliance of technical detailing for authority submission (30%)	• Do not comply with BCA authority submission requirement • Incorrect technical format used. (e.g., incorrect line types, incorrect line weight, etc.) • No technical symbols used to communicate structural details	• Comply with some of BCA authority submission requirement • Some of the technical format used is correct. (e.g., correct line types, incorrect line weight, etc.) • Minimal technical symbols used to communicate structural details	• Comply with the majority of BCA authority submission requirement • Majority of the technical format used is correct. (e.g., correct line types, correct line weight, etc.) • Extensive use of technical symbols used to communicate a majority of structural details	• Comply with all of BCA authority submission requirement • All technical format used is correct. (e.g., correct block layer, correct font type used, correct lines types used, etc.) • Complete usage of technical symbols were used to communicate all structural details

DISCUSSION

Even though there are many benefits of AA for our civil engineering students and the push from industry to expose students to real-world problems, many lecturers are not comfortable in adopting AA as the lecturers are not ready to accept those open-ended responses. As highlighted by Hargreaves, Earl & Schmidt (2002), the predominant cultural perspective is one of the biggest challenges for AA. Can the lecturer be comfortable as collaborators in the student's learning? For the longest time, our engineering education has been adopting convergent assessment where exams and tests dominate. The lecturers hold power in decision making, and they feel safe and secure when armed with a solution script. The solution script seems to give them that extra boost of confidence and power over the students. However, in the form of AA, the lecturer may feel insecure without an absolute answer to safeguard their ego and authority, or they may feel powerless. It can also be a big challenge to their confidence level in relation to their depth of knowledge, skills, and competencies of that particular domain. Are the lecturers ready to accept alternative solutions and students challenging their opinions? Lecturers need to know that their roles will have to change when AA is adopted. They are collaborators of learning and not the sole provider of knowledge. They need to have the kind of openness and confidence to facilitate students and co-learn in an AA setting.

Another potential problem to the power struggle posed by Hargreaves et al. (2002) is that lecturer may intentionally craft an AA task to have only one possible solution or intentionally guide students to the solution he/she preferred which did not comply with what Newmann et al. (1996), Wiggins (1993) and Gulikers et al. (2004) have highlighted that an AA task is open-ended and ill-structured. This intention is to fend off any scrutiny from the students. When a task is open-ended, the strategy for assessment changes and assessment may move in multi-directions. Are our lecturers ready to receive feedback on their practice to make improvements and enhance learning?

One other key factor that plays a critical role in the success of AA is the facilitation skills of the lecturer. If lecturers perceive AA as "the window into learning" (Earl & Lemahieu, 1997; Wiggins & McTighe; 1998, Broadfoot, 1996), they make positive use of the consultation session to give constructive feedback and identifying professional trades in student's performance to track the depth of their learning and stimulate them to be critical thinkers. However, assessment is more often used to categorise them rather than for learning. Some lecturers may fear inflation of grades when they facilitate their learning. This is especially true if the AA project weighting is more than 50% of the module. Therefore, when the assessment is perceived to categorize them into different grades, the lecturer may hold back in giving constructive feedbacks, which may hinder their learning.

Interaction between the assessor and assessee is one of the key criteria for AA highlighted by Wiggin (1993) to provide opportunities for the assessor to probe and inquire student's responses and for the assessee to justify their responses. In order to facilitate these during the consultation sessions, the lecturers need to spend a substantial time (about 30 minutes) with each group, and the lecturer must ensure each member of the group is given sufficient attention and time to respond and justify. This requires good time and group management from the lecturer to prevent anyone from dominating the session and to ensure each student is given equal opportunities for learning.

AA has the potential to adequately assess all the capacities and outcomes we want to recognise and helps in student's learning. We should work towards minimising the impact of

the above-discussed problems because, at the polytechnic level, we have more valid reasons, resources, and support from the industry to drive AA.

CONCLUSION

The use of AA in the CDIO project in this module increases the richness of the context of the project, which allows students to dive deeper and explore beyond the superficial layer. The richness of the tasks enables the educator to play with the level of diversity and complexity. Instructions to the students should not be strict and complex as this will restrict exploration and promote spoon-feeding. Educators must encourage and accept various solutions. What educators usually overlook when designing the projects is that the project is too difficult, and the scope is too wide. Consider breaking up one big project into many goldilocks tasks. This will help to increase student's confidence because the tasks are attainable and not seem as impossible. During the enactment curriculum, the facilitators need to use inquiry-based techniques and avoid giving students the answers. To better facilitate, guide the students with guiding questions. Maybe some of our students may be frustrated because they only want the answers from us, but we give them a list of questions instead. Changing their mindset does take time; ultimately, they have been trained in the traditional education culture since their primary school days. Educators need to also take note of how to give effective feedback to the students during the consultation sessions, and feedbacks must also be given after each task has been assessed. This will help to minimise any missing gaps between students' learning. The consultation sessions are carried out in small groups; hence it will be more effective to be conducted during a three hours tutorial. The students thus far have been motivated because they are able to apply what they have learned to solve real-world problems. Educators can also explore the possibility of inviting external professionals to sit in the consultation sessions and give critique to their work. The next phase of the research could potentially study the effect of an external professional's critique on our student's motivation. In tertiary education, we are preparing students to be work-ready, and hence authentic learning approach can be one of the pedagogy to adopt to engage and motivate the students. Eventually, we are preparing them to be future engineers.

A survey has also been carried out at the end of the module to gather the student's feedback on the effectiveness of authentic learning implementation and their enjoyment level. Both quantitative & qualitative data were collected to analyse their experience on the use of AA in the CDIO project.

100% of the students have either agreed (25.8%) or strongly agreed (74.2%) that the project tasks have given them the opportunities to apply and integrate their prior knowledge rather than the reproduction of knowledge. Students are able to see the purpose of each module learned previously and how it can be applied to real-world problems.

100% of the students have either agreed (28.8%) or strongly agreed (71.2%) that the role they played as an engineer has allowed them to see the relevance with the industry. 97% of the students have either agreed (33.3%) or strongly agreed (63.7%) that the consultation session has helped to simulate a real-world working environment. 97% of the students have also either agreed (28.8%) or strongly agreed (68.2%) that the project tasks have prepared them for the industry and to be work-ready.

100% of the students have either agree (15.2%) or strongly agreed (84.8%) that the consultation session has provided them with effective support, guidance and have helped them

scaffold their tasks. 98.4% of the students have either agreed (24.2%) or strongly agreed (74.2%) that the way the module is being conducted allows them to see the relevance with the industry and appreciate civil engineering and the building profession. 100% of the students have also either agreed (22.7%) or strongly agreed (77.3%) that the tasks they did in this module are important and beneficial to them. The students are able to see the purposes of the tasks that are being assigned to them. All of the students have either agreed (30.3%) or strongly agreed (69.7%) that through consultation sessions, they have managed to gain technical knowledge as well as teamwork and communication skills. 98.4% of the students have either agreed (27.3%) or strongly agreed (71.1%) that the consultation sessions have trained them to ask the correct questions rather than reply to the lecturer. In order for the students to ask the correct questions, they have to think through the solutions process and identify any queries that they have. 92.4% of the students have also either agreed (42.4%) or strongly agreed (50%) that they have participated actively during the consultation sessions by asking questions. Only 7.6% of the students felt that they did not ask a lot of questions. This could be due to the organization of the group where they consolidated the questions and was asked by one person in the group, or this can also mean that the students have thought through the solutions process and clearly understood what is required to be done.

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BIOGRAPHICAL INFORMATION

Yina Chua is a Lecturer of Civil Engineering, School of Architecture & the Built Environment, Singapore Polytechnic. Her expertise covers structural design, green buildings, and sustainability. Yina is also a Young Leader under the Built Environment Young Leaders Programme set up by the Building and Construction Authority (BCA). She has had actively involved and contributed significantly as a nominated attendee for the Built Environment Cluster Sub-committee. Yina has also won various teaching awards awarded by Singapore Polytechnic. As part of the teaching team of Civil engineering, She has actively contributed to the curriculum design, pedagogy, and the adoption of CDIO in the curriculum.

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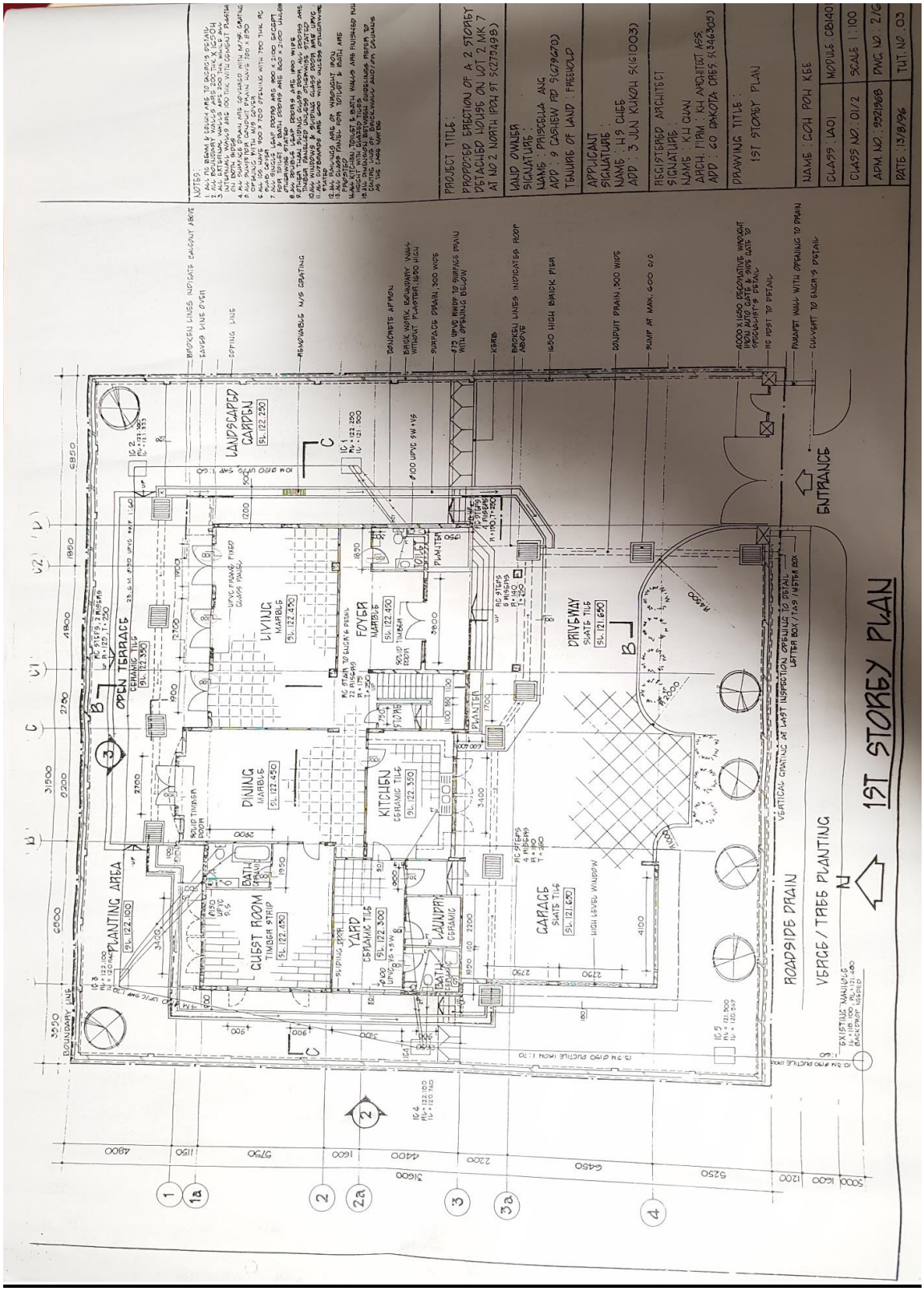
Appendix A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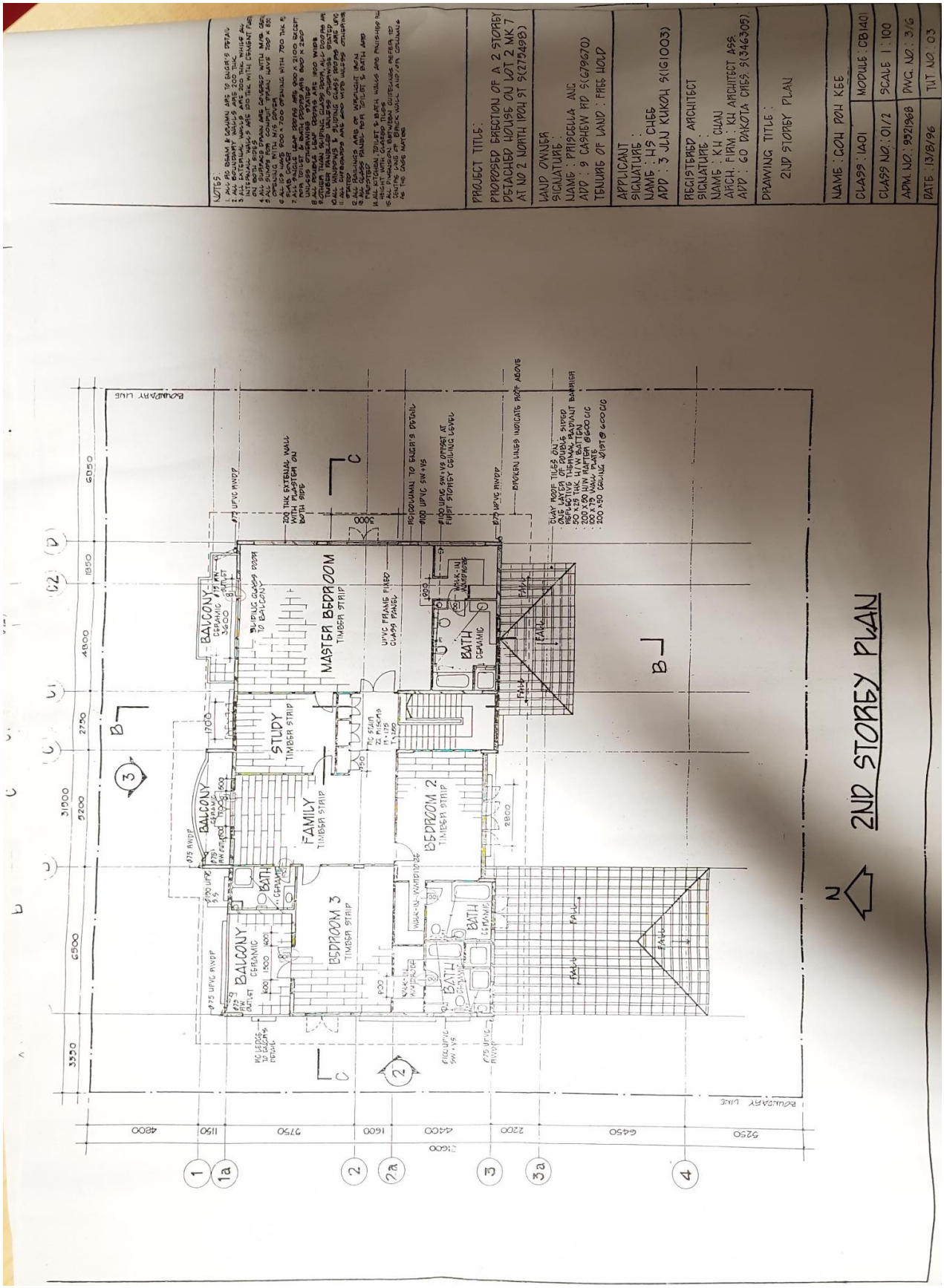
ADD : 9 CASHEW RD S(678470)
TENURE OF LAND : FREEHOLD
APPLICANT SIGNATURE :
NAME : H.S CHUE
ADD : 3 JUN KUKOH S(610003)
REGISTERED ARCHITECT SIGNATURE :
NAME : KH CHAN
ARCH. FIRM : KH ARCHITECT ARS
ADD : 60 DAKOTA CRES S(436305)
DRAWING TITLE :
1ST STOREY PLAN
NAME : CCH POH KEE
CLASS : LA01
MODULE CB1401
CLASS NO : 01/2
SCALE 1:100
ADM. NO : 9921968
DWG. NO : 2/G
DATE : 13/8/96
TUT. NO : 03
LANDSCAPED GARDEN
LIVING MARBLE
FOYER MARBLE
DINING MARBLE
KITCHEN CERAMIC TILE
GUEST ROOM TIMBER STRIP
YARD CERAMIC TILE
LAUNDRY CERAMIC
GARAGE SLATE TILE
DRIVEWAY SLATE TILE
OPEN TERRACE
PLANTING AREA
ENTRANCE
ROADSIDE DRAIN
VERGE / TREE PLANTING
BOUNDARY LINE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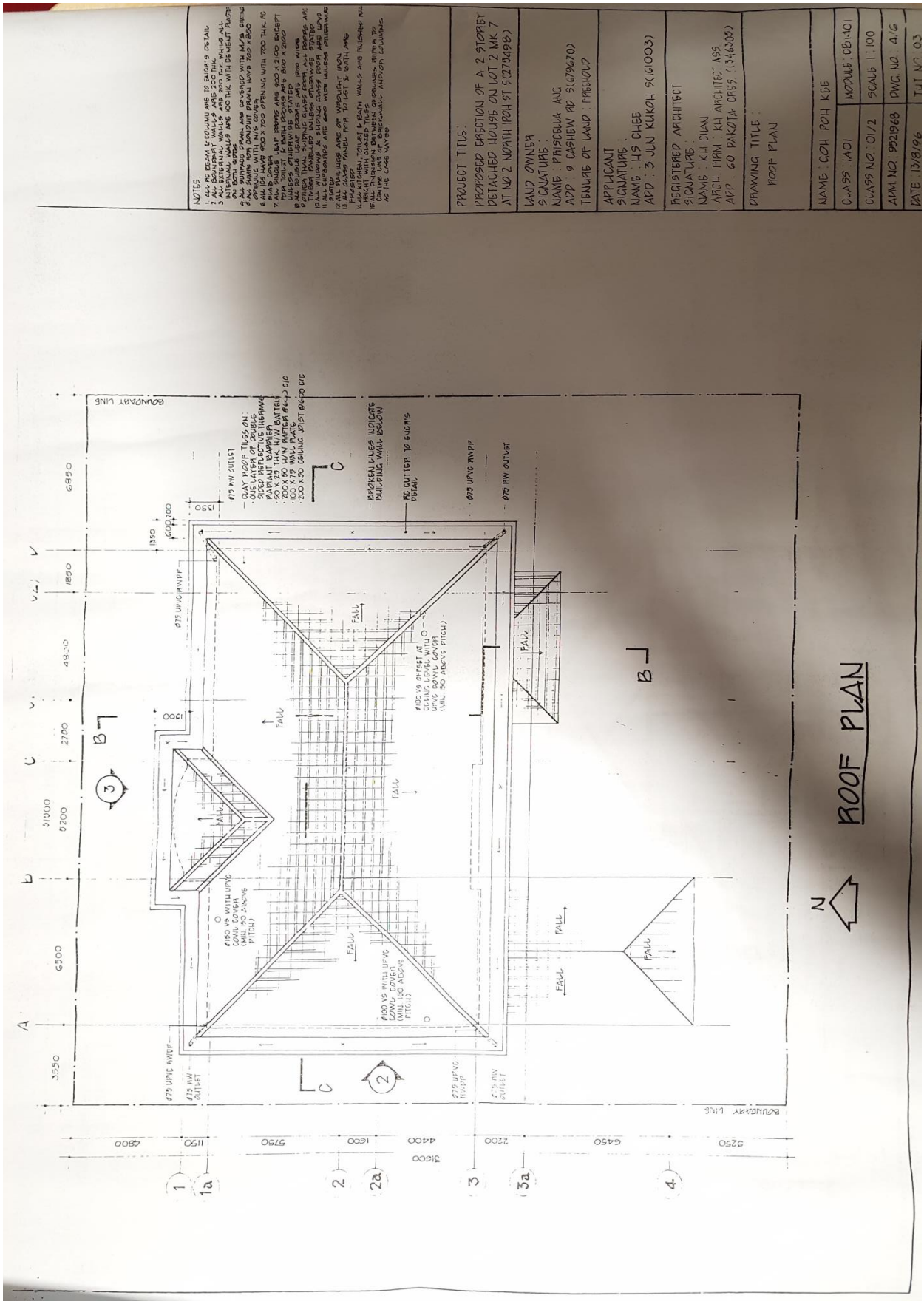
NAME : PRISCILLA ANG
ADD : 9 CASHEW RD S(679670)
TENURE OF LAND : FREE HOLD
APPLICANT SIGNATURE:
NAME : HS CHEE
ADD : 3 JLN KUKOH S(161003)
REGISTERED ARCHITECT SIGNATURE:
NAME : KH CHAN
ARCH. FIRM : KH ARCHITECT ASS.
ADD : 60 DAKOTA CRES. S(346305)
DRAWING TITLE:
2ND STOREY PLAN
NAME : COH POH KEE
CLASS : 1A01
MODULE : CB1401
CLASS NO : 01/2
SCALE 1 : 100
APM. NO : 952/968
DWG. NO : 3/6
DATE : 13/8/96
TUT NO 03
2ND STOREY PLAN
MASTER BEDROOM
TIMBER STRIP
STUDY
FAMILY
BEDROOM 2
BEDROOM 3
BALCONY
BATH
CERAMIC
WALK-IN WARDROBE
BOUNDARY LINE
N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TENURE OF LAND : FREEHOLD
APPLICANT
SIGNATURE :
NAME : HS CHEE
ADD : 3 JLN KUKOH S(610103)
REGISTERED ARCHITECT
SIGNATURE :
NAME : KH CHAN
ARCH FIRM : KH ARCHITECT ASS
ADD : 60 DAKOTA CRES (346203)
DRAWING TITLE :
ROOF PLAN
NAME : GOH POH KEE
CLASS : IA01
MODULE : CB1-101
CLASS NO : 01/2
SCALE 1 : 100
APM NO : 9921968
DWG NO : 4/6
DATE : 13/8/96
ROOF PLAN
N
BOUNDARY LINE
FALL
Ø75 UPVC RWDP
Ø75 RW OUTLET
Ø100 VS WITH UPVC CONVEX COVER (MIN 150 ABOVE PITCH)
Ø100 VS OFFSET AT CEILING LEVEL WITH UPVC CONVEX COVER (MIN 150 ABOVE PITCH)
RC GUTTER TO GUCMS DETAIL
IMPERVIOUS LINER INDICATE BUILDING WALL BELOW
CLAY ROOF TILES ON: ONE LAYER OF DOUBLE SIDED REFLECTIVE THERMAL RADIANT BARRIER
200 X 50 H/W RAFTER @600 C/C
100 X 75 WALL PLATE
200 X 50 CEILING JOIST @600 C/C
1550
4800
5750
1600
4400
2200
6450
3250
9600
1150
1350
600
1350
6850
1850
4850
2700
1300
6500
3550
6200
31000
A
B
C
D
E
F
1
1a
2
2a
3
3a
4

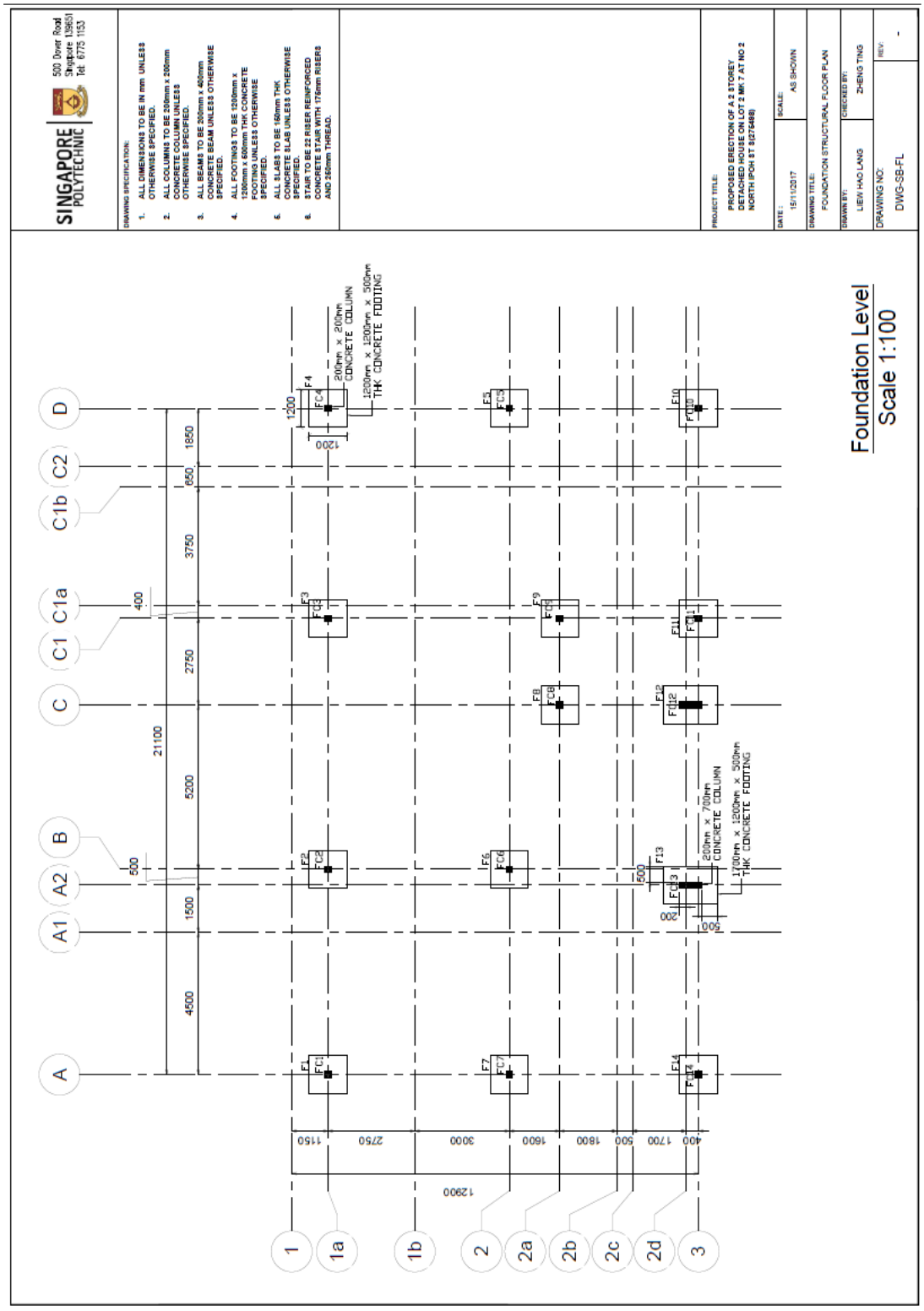
Appendix B

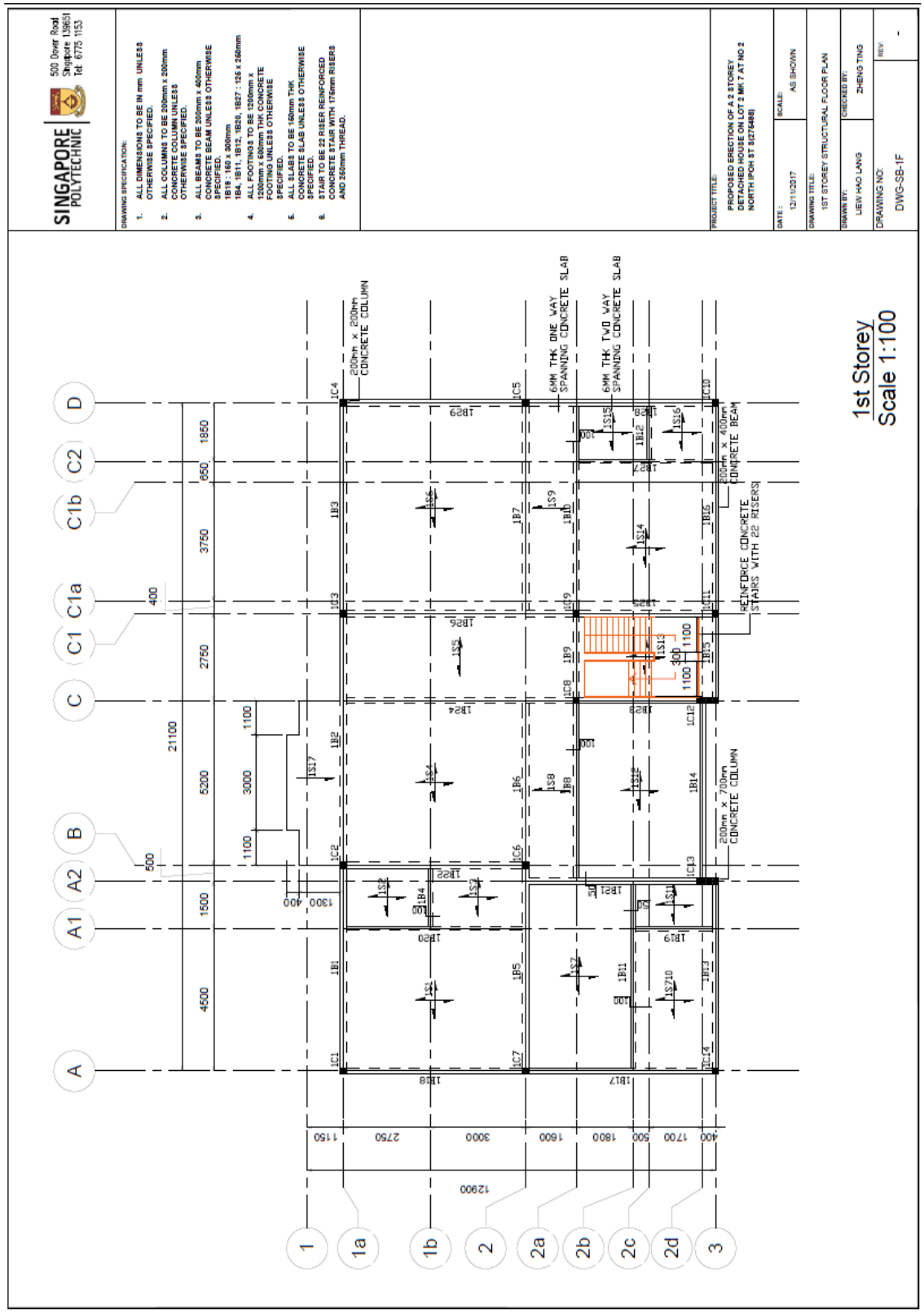
Project Tasks	Learning Outcomes	Learning Outcomes Rationale
Submission 1 (15%): Students are given a set of architectural drawings of a real bungalow house and are required to design and produce the structural floor plans for the bungalow house. They are required to submit both hardcopy and softcopy of their 2D drawings and Revit 3D-model : • Footing Plan, • 1st Storey structural plan • 2nd Storey structural plan • Roof structural plan	• To study the architectural drawing plan in order to understand what are the spaces used for and determine the position to place the structural elements such as columns and beams. • To configure the structural support system for their proposed structural plan.	• Students will have to view the tasks beyond their own discipline as a structural engineer. They must adopt different roles in order to think in cross-disciplines perspective. They must understand the perspective of an architect in order to ensure they meet the architect's requirements, and the structural elements do not pose any aesthetic issues. They must also understand the end-users needs of the bungalow. • Integrate prior knowledge and new resources and apply higher-order thinking by synthesising, hypothesising, and analysing to generate solutions.
Submission 2 (20%): Students are required to exact information from their submission 1 in order to design and determine the sizes of the structural elements. They are required to submit the structural design and calculations for: • Area method of load taking for 1 column • 1-way spanning span • 2-way spanning slab	• To analyse the structural floor plans submitted in submission 1 and to know what information to extract. • To design and determine the sizes and thickness of the structural elements and to ensure it meets all the requirements and code of practices for all relevant authorities.	• Students are required to apply and integrate knowledge gained in other modules from year 1 to year 3. • Students have to break down the task into sub-tasks before deriving the solutions.

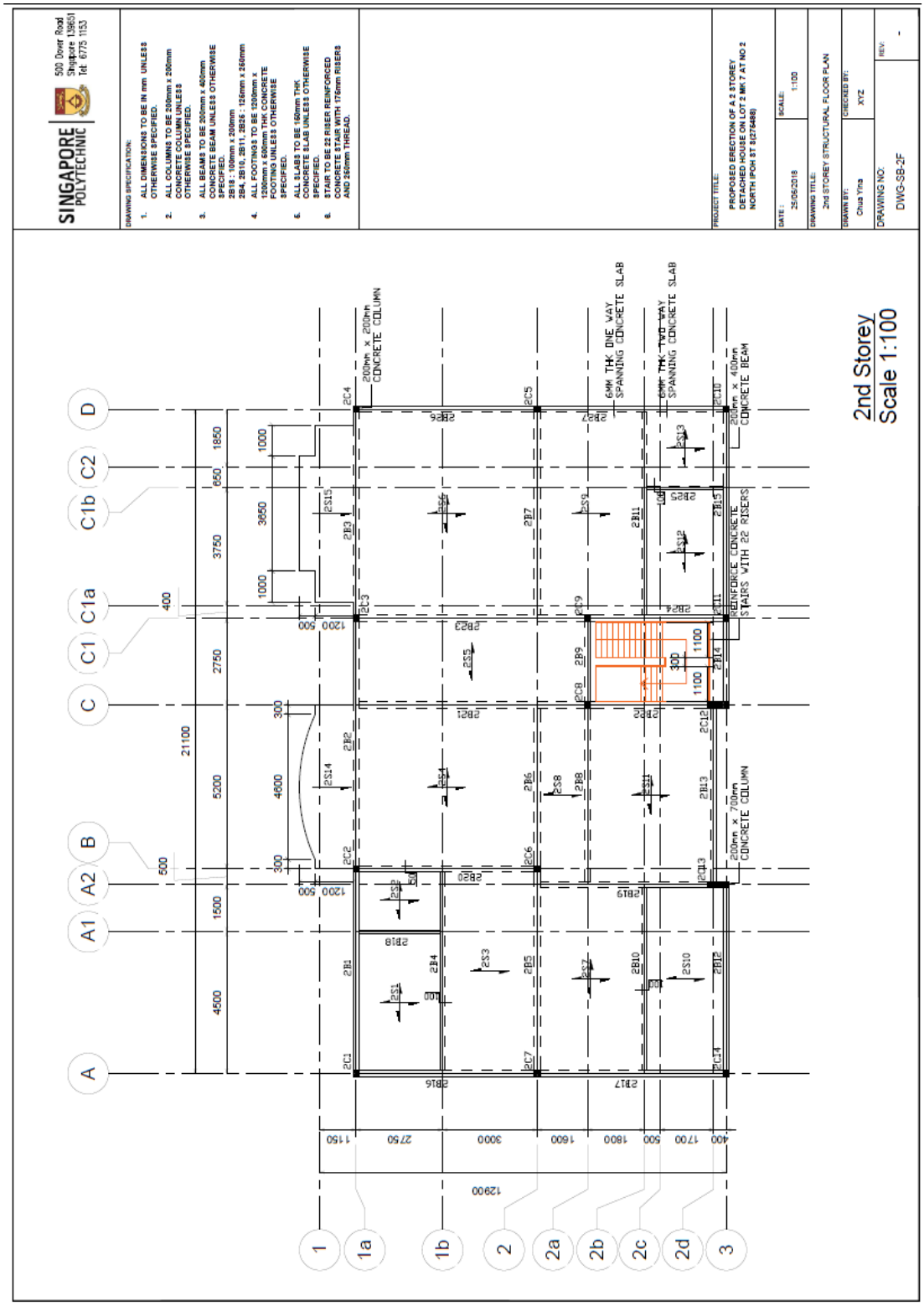
• staircase.		
Submission 3 (20%): Students are required to exact information from their submission 1 in order to design and determine the sizes of the structural elements. They are required to submit the structural design and calculations for: • Continuous beam • Single span beam • timber rafters • footing	Same as submission 2	Same as submission 2

Appendix C

Possible solutions




SINGAPORE POLYTECHNIC
500 Dover Road Singapore 139651 Tel 6775 1153
DRAWING SPECIFICATION:
1. ALL DIMENSIONS TO BE IN mm UNLESS OTHERWISE SPECIFIED.
2. ALL COLUMNS TO BE 200mm x 200mm CONCRETE COLUMN UNLESS OTHERWISE SPECIFIED.
3. ALL BEAMS TO BE 200mm x 400mm CONCRETE BEAM UNLESS OTHERWISE SPECIFIED.
1B19 : 150 x 300mm
1B4, 1B11, 1B12, 1B20, 1B27 : 125 x 250mm
4. ALL FOOTINGS TO BE 1200mm x 1200mm x 250mm THICK CONCRETE FOOTING UNLESS OTHERWISE SPECIFIED.
5. ALL SLABS TO BE 160mm THK CONCRETE SLAB UNLESS OTHERWISE SPECIFIED.
6. STAIR TO BE 22 RISER REINFORCED CONCRETE STAIR WITH 175mm RISERS AND 250mm THREAD.
PROJECT TITLE:
PROPOSED ERECTION OF A 2 STOREY DETACHED HOUSE ON LOT 2 MK 7 AT NO 2 NORTH IPOH ST 5(27/5488)
DATE : 12/11/2017
SCALE: AS SHOWN
DRAWING TITLE: 1ST STOREY STRUCTURAL FLOOR PLAN
DRAWN BY: LIEW HAO LANG
CHECKED BY: ZHENG TING
DRAWING NO: DWG-SB-1F
REV: -
200mm x 200mm CONCRETE COLUMN
6MM THK ONE WAY SPANNING CONCRETE SLAB
6MM THK TWO WAY SPANNING CONCRETE SLAB
200mm x 400mm CONCRETE BEAM
REINFORCE CONCRETE STAIRS WITH 22 RISERS
200mm x 700mm CONCRETE COLUMN
1st Storey
Scale 1:100


SINGAPORE POLYTECHNIC
500 Dover Road Singapore 139651 Tel: 6775 1153
DRAWING SPECIFICATION:
1. ALL DIMENSIONS TO BE IN mm UNLESS OTHERWISE SPECIFIED.
2. ALL COLUMNS TO BE 200mm x 200mm CONCRETE COLUMN UNLESS OTHERWISE SPECIFIED.
3. ALL BEAMS TO BE 200mm x 400mm CONCRETE BEAM UNLESS OTHERWISE SPECIFIED.
2SB1 : 150mm x 300mm
2B4, 2B10, 2B11, 2B26 : 125mm x 250mm
2B16, 2B17
4. ALL FOOTINGS TO BE 1000mm x 1200mm x 600mm THK CONCRETE FOOTING UNLESS OTHERWISE SPECIFIED.
5. ALL SLABS TO BE 150mm THK CONCRETE SLAB UNLESS OTHERWISE SPECIFIED.
6. STAIR TO BE 22 RISER REINFORCED CONCRETE STAIR WITH 176mm RISERS AND 250mm THREAD.
PROJECT TITLE:
PROPOSED ERECTION OF A 2 STOREY DETACHED HOUSE ON LOT 2 MK 7 AT NO 2 NORTH IPOH ST 8(275488)
DATE: 25/06/2018
SCALE: 1:100
DRAWING TITLE: 2nd STOREY STRUCTURAL FLOOR PLAN
DRAWN BY: Chua Yina
CHECKED BY: XYZ
DRAWING NO: DWG-SB-2F
REV: -
2nd Storey
Scale 1:100
200mm x 200mm CONCRETE COLUMN
6MM THK ONE WAY SPANNING CONCRETE SLAB
6MM THK TWO WAY SPANNING CONCRETE SLAB
200mm x 400mm CONCRETE BEAM
REINFORCE CONCRETE STAIRS WITH 22 RISERS
200mm x 700mm CONCRETE COLUMN
A
A1
A2
B
C
C1
C1a
C1b
C2
D
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1a
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2
2a
2b
2c
2d
3
12900
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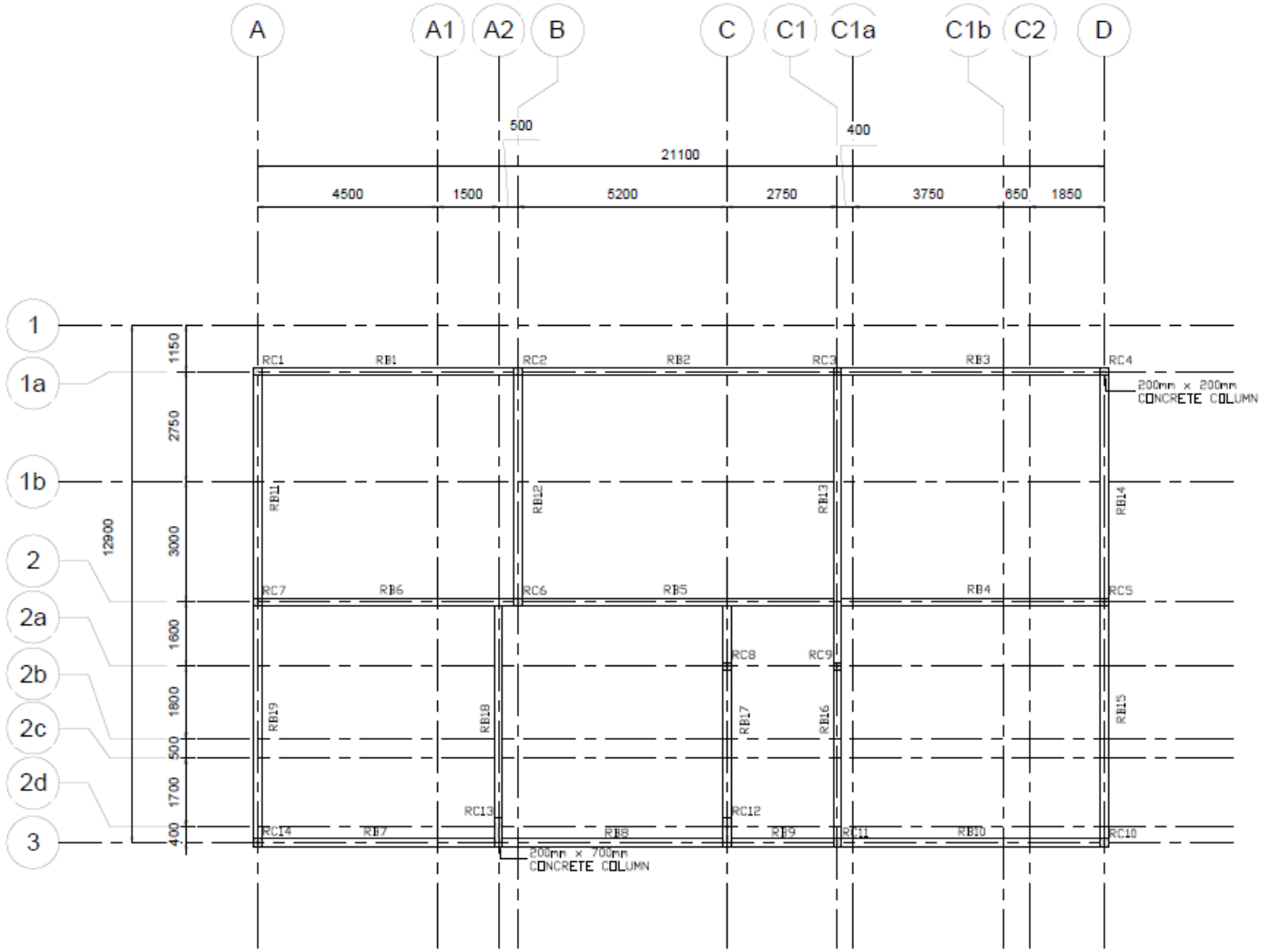

Roof Level
Scale 1:100

SINGAPORE POLYTECHNIC
500 Dover Road
Singapore 139651
Tel: 6775 1153

DRAWING SPECIFICATION:

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2. ALL COLUMNS TO BE 200mm x 200mm CONCRETE COLUMN UNLESS OTHERWISE SPECIFIED.
3. ALL BEAMS TO BE 200mm x 400mm CONCRETE BEAM UNLESS OTHERWISE SPECIFIED.
4. ALL FOOTINGS TO BE 1200mm x 1200mm x 600mm THK CONCRETE FOOTING UNLESS OTHERWISE SPECIFIED.
5. ALL SLABS TO BE 150mm THK CONCRETE SLAB UNLESS OTHERWISE SPECIFIED.
6. STAIR TO BE 22 RISER REINFORCED CONCRETE STAIR WITH 175mm RISERS AND 250mm THREAD.

PROJECT TITLE:
PROPOSED ERECTION OF A 2 STOREY DETACHED HOUSE ON LOT 2 MK 7 AT NO 2 NORTH IPOH ST 3(276488)

DATE :	SCALE:
25/06/2018	1:100

DRAWING TITLE:
ROOF STRUCTURAL FLOOR PLAN

DRAWN BY:	CHECKED BY:
Chua Ying	XYZ

DRAWING NO:	REV:
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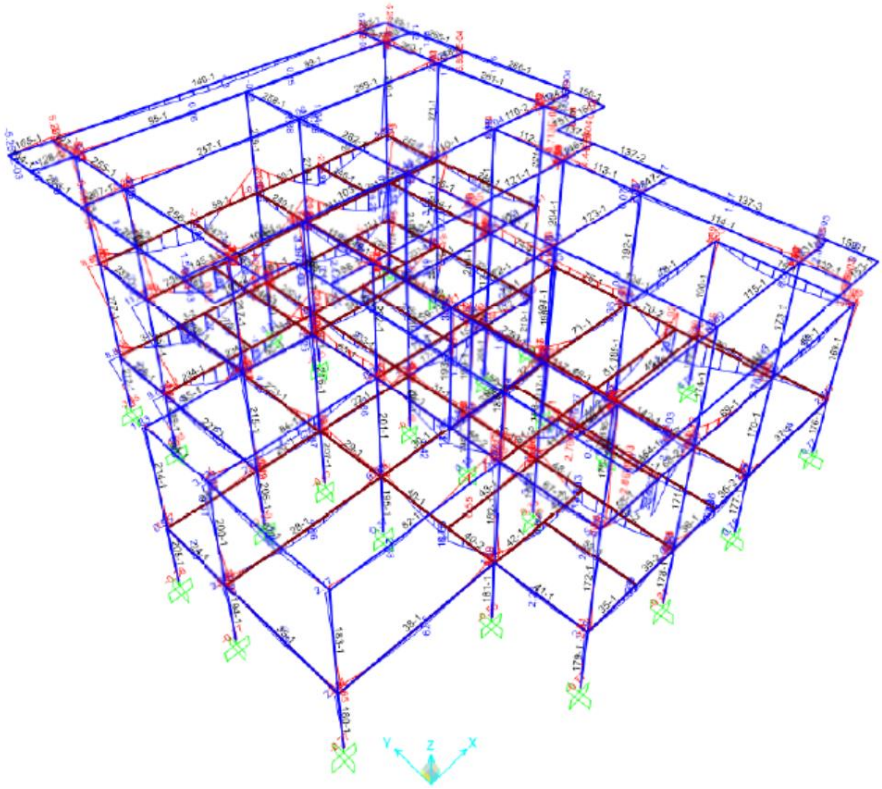
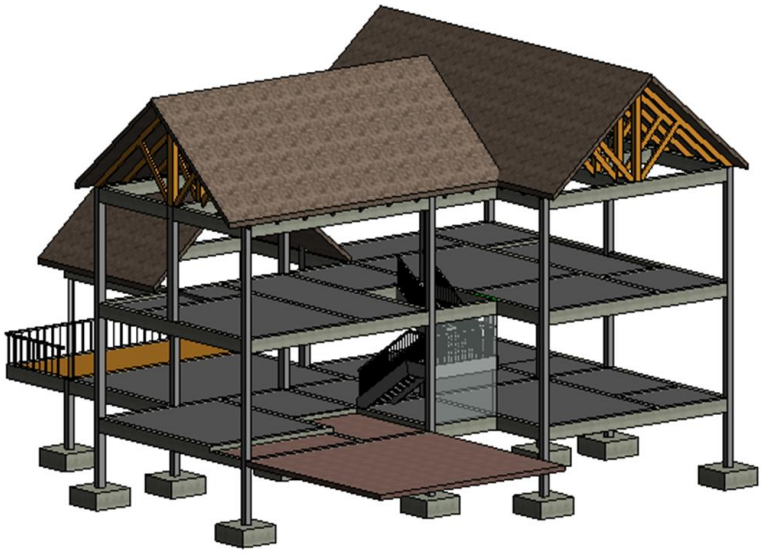


Submission 2: Bugalow Structural Analysis

Submission 3: Bungalow Revit Model with Architecture finishes



Submission 3: Bungalow structural Revit model

STUDENT PERCEPTIONS OF PROJECT-BASED LEARNING IN A SOFTWARE ENGINEERING COURSE

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ABSTRACT

This paper presents an overview of a second-year programming course in the department of software engineering at the University of Calgary. The course was recently restructured to include aspects of project-based learning (PBL) to help students meet graduate attributes and practice learning outcomes that a traditionally formatted course may not allow them to achieve. This restructuring centered around the implementation of a final term project that students completed in the final three weeks of the course. While this format does not necessarily follow the typical PBL approach, where a project is typically conducted throughout an entire semester while simultaneously acquiring disciplinary knowledge (often in other courses), it offers instructors a more accessible approach to PBL implementation that does not require restructuring at the department or faculty level. The project introduced to the course closely resembled a genuine industry project, and thus allowed students to experience what the software industry can be like, providing them with valuable experience. Data was collected in the form of a Likert-style survey that many of the students completed and supplemented with a descriptive questionnaire to which both the professor and handful students responded. This data was then analyzed using a theoretical framework based on relevant CDIO standards, and relevant findings are discussed alongside areas for improvement and further research. Students' response was generally quite positive, and the professor observed they benefited quite significantly from the implementation of PBL in the course.

KEYWORDS

Project-based learning, Software engineering, Hybrid PBL, Student perceptions, Standards 1, 2, 5, 7, 8

INTRODUCTION

The need for change in (software) engineering education

The field of engineering is ever-changing and, with it, the pressure on post-secondary institutions to develop and maintain a curriculum that can keep pace. Countless studies show that Canadian engineering graduates are not equipped with the skills and knowledge the industry demands of them (May & Strong, 2011). Similarly, graduate attributes published by different engineering accreditation boards are becoming more demanding. Specifically, the Canadian Engineering Accreditation Board expects students to not only have exceptional disciplinary knowledge and skills but also to develop their interpersonal skills, and be able to situate their work in the broader societal context in which they operate and to be lifelong learners ("CEAB Graduate Attributes, n.d.). Having a holistic skillset is incredibly important for engineers graduating today. In its Final Year Engineering Students 2017 Survey, with responses from 2,485 graduates from institutions across Canada, Engineers Canada found many students felt unprepared for or disconnected from the engineering industry, especially with respect to their coursework (most of the positive responses on the survey relating to industry preparedness was linked to students who completed work terms such as co-ops or internships) ("Final Year Engineering Students 2017 Survey - National Results", n.d.).

According to CDIO, the central issue in the problem of the discrepancy between engineering students' capabilities and industry demands is the tension between the need to develop students' technical knowledge with personal, interpersonal, and product, process, and system-building skills (Crawley, Malmqvist, Östlund, Brodeur, & Edström, 2014). While much of the engineering curriculum focuses on technical knowledge, these other skills are often overlooked, especially within the context of the traditional lecture learning format.

Software engineering, in particular, is a relatively new field compared to other engineering disciplines and is characterized by consistent, rapid technological development (Mead, 2009). As such, the demand for software engineering educators to adequately prepare their students for the industry is significant, and often software engineering programs fail to meet this demand (Shaw, 2000).

A potential solution: project-based learning

While resolving the rift between student capabilities and industry demands is a vast and complex issue, one solution many engineering educators are turning to is project-based learning (hereafter referred to as PBL). Countless case studies - several of these are reviewed in the following section - show the implementation of some form of PBL to be highly beneficial to students' learning, and encourages the development of many of the crucial skills that CDIO highlights. A review of research on active learning notes "extensive and credible evidence suggests that faculty consider a non-traditional model for promoting academic achievement and positive student attitudes." (Prince, 2004). PBL is an effective example of this kind of non-traditional learning methods.

Projects in software engineering can, when properly executed, provide an opportunity for students to practice the process of conceiving, designing, implementing, and operating an industry-relevant project, and help to facilitate the development of key skills and attributes (Crawley et al., 2014).

This paper will first summarize some of the relevant literature within the domains of project-based learning and (software) engineering education. It will then explain the methodology used to analyze student data, which involved selecting relevant CDIO standards and using them to examine a student survey and some comments. Interesting findings are then discussed, and finally, suggestions for improvements and future research are outlined.

BACKGROUND

There are countless instances of project-based learning being applied in engineering education. The majority of the literature suggests that PBL is both an effective and necessary strategy to engage engineering students, as well as to provide them with the opportunity to have a closer learning experience to what will actually be required of them in the future. In a twenty-year study conducted in Spain, professors found that by employing PBL, undergraduate engineering students consistently took greater responsibility for their own learning, actively immersed themselves in meaningful projects, and especially developed personal competencies including teamwork, motivation to learn, and creative problem solving (Ríos, Cazorla, Díaz-Puente, & Yagüe, 2010). This finding is reaffirmed by a study conducted at Massey University, which concluded that the implementation of PBL in their engineering courses resulted in increased student motivation, improved problem-solving skills, and a better understanding of the engineering design process (Shekar, 2014). Another study at the University of Adelaide of a final year honors project for mechanical engineering students found "student engagement […] increased only after the amalgamation made clear the links to authentic engineering practice." (Prime, Robertson, Cazzolato, Missingham, & Kestell, 2015). Another study done on a capstone project at Carleton University's Department of Systems and Computer Engineering came to a similar conclusion: that students were able to complete a project that closely resembled industry standards (Schramm & Chan, 2013). All of this points to the fact that PBL is an extremely effective strategy in bridging the gap between students' formal education and industry – this is crucial in such a career-oriented field of study.

Much of the research of PBL and alternate learning approaches has become even more relevant in the field of software engineering and computer science since it is a uniquely demanding field in terms of teaching strategies. A review of computer science projects found that in a PBL-based course, students were able to attain and apply disciplinary knowledge and skills while simultaneously developing teamwork and project management skills (Pucher & Lehner, 2011). Even when students received lower grades on projects in project-based courses, instructors determined they had attained higher learning outcomes. A similar case study at Oslo and Akershus University College of Applied Sciences found that so long as learning expectations were clear, student motivation was boosted by the inclusion of PBL in a programming course (Zouganeli, Tyssø, Feng, Arnesen, & Kapetanovic, 2014).

Essentially, in both general engineering education and specifically in software engineering education, PBL is an extremely effective method for getting students to apply their disciplinary knowledge, and at the same time, develop many of the disciplinary and interpersonal skills they will need in industry. This multifaceted approach has been a successful strategy for many educators in order to meet the ever-increasing demands for engineering graduates.

However, the typical PBL approach can be extremely demanding for instructors. (Stoicoiu & Cain, 2015) PBL restructuring often requires coordination with other courses so that students can learn the disciplinary knowledge required of them for their project in time. This can even require faculty-level reorganization, which is simply not viable for many instructors. As an

alternative, instructors can opt for a hybrid PBL approach, in which the earlier section of the course is taught more traditionally (using lectures, assignments, and labs), and only towards the end of the course are students given a PBL-style project. This project would have to be less extensive in scope, but can still result in many of the positive outcomes of the typical PBL approach, while also being accessible and practical at the individual course level.

ENSF 409: a case study in PBL in software engineering education

Software Engineering for Engineers (ENSF 409) is a core course for second-year students in software engineering at the University of Calgary. It covers topics including object-oriented programming and application of data structures and strategies for testing and debugging. In past years, the course was taught using a very traditional format, relying heavily on lectures and limited-scope assignments. However, the course was recently restructured to include a term project, modeled after the PBL paradigm, and introducing a new focus on software and coding best practices.

The term project is worth 10% of students' final grade and involves the development of a client-server application. It is completed towards the end of the semester and implements some aspects from previous assignments. The students are given the option to complete the project individually or in groups of up to three and the project is completed in four stages: a pre-project exercise that permits students to familiarize themselves with some programming strategies they will be employing later on, a design submission, and two implementation demonstrations.

Students are provided with the problem statement, but no other directions, in order to simulate an industry project, as well as to encourage them to research and design a solution without much guidance. The open-ended nature of the project also worked to encourage students' creativity, while still requiring them to apply their knowledge of object-oriented programming, client-server architecture, and software engineering best practices. Past iterations of the project have included an online learning platform for students and teachers to interact, a tool shop application, a course registration platform, and more.

METHODOLOGY

The Data

The data used to analyze student perceptions on the effectiveness of the recent implementation of PBL in ENSF 409 includes a student survey, which had a 33% response rate (43 out of 130). The survey included 30 questions on a 5-point Likert scale that asked students about the level of effort, course contributions to learning, course delivery, and content, and questions about the term project specifically. An additional questionnaire was also sent out to a handful of students to gather more specific comments on certain aspects of the project. Finally, the course instructor was also given a brief questionnaire, again used to gather additional details on the implementation and design of the project. Overall, the quantitative data from the in-class survey, combined with the qualitative data from the follow-up questionnaires, provided a rich source of data for analysis.

Theoretical Framework

To analyze students' data in a methodical fashion, a theoretical framework was used for the data analysis (Grant & Osanloo, 2014). The framework included five of the twelve CDIO standards. Because this paper only covers data from a single, core course, and due to the nature of the course itself, many of the CDIO standards were not relevant to our analysis. The rationales for the CDIO standards chosen are summarized in Table 1. We selected the CDIO standards as a means by which student success can be evaluated since the CDIO standards and syllabus are a direct response to the increasingly demanding expectations for graduating engineering students; research shows that experimentally, engineering programs modeled on a subset of the CDIO syllabus will likely achieve many, if not all of the CEAB graduate attributes (Cloutier, Hugo, & Sellens, 2012).

Table 1. CDIO Standards selected for use in the theoretical framework

Standard	***Reason for Inclusion***
Standard 1: The Context	The process of development, testing, and demonstrations of the project design align with the conceive-design-implement-operate model, as well as the product-process-system lifecycle. Thus, the term project is situated within the CDIO context.
Standard 2: Learning Outcomes	The majority of the learning outcomes set forth in Standard 2 can be found somewhere in the outcomes pursued in the project, and provide a useful framework with which the benefits of the project to students can be identified and evaluated.
Standard 5: Design-Implement Experiences*	The term project is an example of a design-implement experience for second-year software engineering students, and so the CDIO guidelines for a design-implement experience provide a helpful guide.
Standard 7: Integrated Learning Experiences*	Standard 7 can be seen as a method by which many of the learning outcomes from Standard 2 can be pursued, and will be treated as such in this paper.
Standard 8: Active Learning	As with Standard 5, the project acts as an example of an active learning experience, providing students with an engaging and self-guided opportunity to apply their skills and knowledge.

The five standards were mapped to relevant questions from the survey, as well as to questionnaire responses, in order to form a cohesive picture of the project's strengths and weaknesses within the context of the CDIO standards.

RESULTS

Survey Data

Table 2 shows each relevant question from the student survey and its average survey score. The survey followed a Likert scale, with 1-5 corresponding respectively to poor, fair, satisfactory, very good, and excellent for the first two categories, and to strongly disagree, disagree, neutral, agree, and strongly agree for the remaining four categories. The average response to all questions was 4.21, which we deemed a very positive overall response.

Table 2. Selected survey questions and corresponding CDIO standards

Category	**#**	**Question**	**CDIO Std.**	**Avg. Score**
Level Of Effort	1	Level of effort you put into the course	*	4.33
Contributions To Learning	2	Level of programming skill/knowledge at the start of course	2	3.14
	3	Level of programming skill/knowledge at the end of course	2, *	4.33
	4	Level of programming skill/knowledge required to complete the course	2	3.67
	5	Contribution to your skill/knowledge of programming	2, *	4.27
	6	Contribution to your understanding of best coding practices	1, 2, *	4.21
	7	Contribution to your understanding of software engineering best practices	1, 2, *	4.23
	8	Contribution of course to your understanding of object-oriented design	2	4.47
Course Delivery	9	Instructor stimulated student interest	7, 8	4.54
	10	Lectures effectively prepared me for assignments and the final project.	2, 7	4.24
Course Content	11	Learning objectives were clear	2	4.44
	12	Course organized to allow all students to participate fully	2, 8	4.49
Term Project	13	My understanding of technical concepts increased	2, 5, 7, 8	4.44
	14	My creative thinking was improved	1, 2, 5, 7, 8	4.24
	15	My interest in programming increased	1, 5, 7, 8	4.21
	16	Lectures effectively prepared me for the final project	2, 5, 7, 8	4.19
	17	I learn industry-relevant skills by completing the project	1, 2, 5, 7, 8	4.21
	18	Assignments and projects helped prepare me for the software industry	1, 2, 5, 7, 8	4.14

Student Perceptions	19	I enjoy computer programming	*	4.72
	20	I am interested in a career in software engineering	*	4.53
	21	I feel confident as a programmer	*	4.02

The use of averages above assumes Likert-scale data values are continuous - although this assumption is not widely accepted in descriptive statistics, we determined the use of average values helped to inform our conclusions and thus decided to include them.

In order to determine correlations between responses to each question on the survey, the Kendall Tau-B test was used since our data is ordinal and non-parametric (Cohen et al., 2018). Figure 1 shows the values of the correlations. Tau values greater than 0.3 are considered statistically significant (Puka, 2011).

Figure 1. Kendall Tau correlation values for questions that indicate general success

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	1.000	0.014	0.427	0.327	0.354	0.360	0.357	0.305	0.329	0.231	0.299	0.197	0.140	0.072	0.239	0.243	0.118	0.176	0.356	0.134	0.375
3			1.000	0.432	0.159	0.110	0.115	0.019	0.176	0.102	0.238	0.302	0.278	0.198	0.358	0.286	0.153	0.243	0.427	0.274	0.255
5					1.000	0.645	0.573	0.599	0.470	0.547	0.443	0.480	0.182	0.249	0.168	0.348	0.356	0.428	0.317	0.214	-0.008
6						1.000	0.784	0.704	0.469	0.548	0.464	0.496	0.317	0.265	0.215	0.296	0.314	0.352	0.322	0.431	-0.035
7							1.000	0.673	0.431	0.596	0.408	0.553	0.092	0.201	0.174	0.387	0.351	0.332	0.211	0.237	-0.068
19																			1.000	0.479	0.457
20																				1.000	0.111
21																					1.000

Legend
>0.3
>0.4
>0.5
>0.6
>0.7

DISCUSSION

Standard 1: The Context

The goal of Standard 1 in this course is to situate the course content within the greater context of the software industry, and so survey questions related to the industry, and best practices of the profession (6, 7, 14, 15, 17, 18) were mapped to Standard 1. Average response scores to these questions were quite close to the overall average response score of 4.21, and thus we concluded the project, as well as the course content, were fairly well situated within the context of the conceive-design-implement-operate model, as well as the product-process-system lifecycle. One student commented that "developing a larger piece of software with multiple people that actually did something was very interesting and enlightening to do," indicating that they benefited as a learner from completing an industry-relevant project.

Students and professor comments from the additional questionnaire indicated the project was, however, somewhat lacking in the final phase (operate) of the CDIO context. One student noted, the "Project was relevant to some extent as it was trying to emulate a server-client architecture which is commonly used in web development. I wish we had more time learning how to authenticate and run the application on two sets of machines." The professor emphasized that, since the course was indeed a software *development* course, the focus was on industry-relevant skills including iterative development, requirements analysis, and design, the use of tools such as IDEs and Git and emphasized good design, software engineering best practices (such as SOLID principles), and the client-server architecture. However, the latter stages of the product-process-system lifecycle are not the focus: the project did not include a testing phase. Additionally, system requirements were simplified in order to make the project manageable.

Standard 2: Learning Outcomes

Although not all CDIO learning outcomes were or even can be covered by a single software development course, the term project ensures many of them are (Crawley, Malmqvist, Lucas, & Brodeur, n.d.). Outcomes 1.1 and 1.2 are referred to in question 2, which was one of the lower-scoring questions. This indicates students did not feel as though they had quite enough knowledge going into the course as they might have liked to. However, questions 3, 5, 6, 7, and 8 all scored quite high, and these questions refer to outcomes 1.3, 2.1, and 2.2 since they cover a deeper level of knowledge and thinking that students acquire during the course.

The majority of the CDIO learning outcomes are covered through the term project (questions 13-18), in which they were encouraged to apply their disciplinary knowledge, problem-solving, system thinking, as well as work through at least the conceiving and designing aspects of the CDIO process. However, students were not only expected to code a fairly complex client-server application, but they also had to apply communication and presentation skills during demos and while communicating with their group members or instructors. As such, 'soft' skills were also required to successfully complete the project.

One student found that, with respect to group work, they had a fairly easy time with communication because they worked with friends. Another noted "when working in a group, it's good to have each person work on the individual classes/functions separately," indicating they gained some valuable insight on working with others. The professor commented on the differences he noticed between students who worked alone versus those who worked in groups, saying students who worked individually missed on the experience of teamwork and learning from their peers. The projects done in teams generally had more features, and were better designed." One drawback of teamwork, however, was "maintaining the balance of the work." Instructors worked to support students by discussing with groups and introducing best team practices - however, the distribution of group work is a very common problem, and it forces students to practice their interpersonal skills.

The main CDIO learning outcomes that were notably lacking in the course included 2.4 and 2.5 (attitudes, thought and learning, and ethics, equity, and other responsibilities) - though these could be argued to at least be touched upon for students who practiced best team practices - as well as 4.1 (external, societal, and environmental context), 4.5, and 4.6 (implementing and operating). These are most likely not covered in the course due to time and resource constraints.

Standard 5: Design-Implement Experiences and Standard 7: Integrated Learning Experiences

The term project acts as both a design-implement experience and an integrated learning experience, as they are defined by CDIO. As such, the survey questions about the project are used to evaluate both Standard 5 and Standard 7 jointly.

Many of the working parts of a successful design-implement and integrated learning experience are outlined in Standard 2. For example, the simultaneous development of both disciplinary and interpersonal skills developed through the completion of the project are key attributes of an integrated learning experience. Further, the CDIO process (learning outcomes 4.3-4.6) is an essential aspect of an effective design-implement experience.

Overall, students appeared to benefit quite significantly from the term project. The survey included two short answer questions at the end, asking students what aspects of the course they found useful and how they would improve the course. Of the 43 responses, six students said the term project was useful, and fifteen said the same about labs (concepts and code from labs were later reused and built upon in the project). Three students commented that they wanted more group work or a more involved final project, while only one said that they didn't like the project. These comments, along with high response scores for the questions about the term project, are all indicative that students benefited significantly from the introduction of an integrated, design-implement experience. Additionally, although we recognize that many factors can impact student course ratings, the professor noted that the course saw improved ratings after the redesign.

Standard 8: Active Learning

Active learning was an important and consistent theme across the duration of the course. Evidently, the term project is the aspect of the course that best reflects this theme, and was designed and implemented in order to employ the principle of active learning in a manner that would be manageable and set reasonable expectations for students. Students were presented with the challenge of applying the majority of the concepts and skills they had learned throughout the duration of the course but were not required to seek out *new* information in order to successfully complete the project. Two students mentioned having to do minor research on databases, but the third said they were able to complete the project without outside help, reaffirming the professor's assertion that the project was designed to be completed solely using the information from the course. The professor also provided a number of additional resources, including helpful links and instructional videos he created. Thus, while students were able to engage in active learning in the project, they were adequately supported and had all the resources they needed. Rather than the project being fully self-directed, students were guided into successfully completing it, thus keeping the scope of the project feasible for engineering students.

Beyond the project, lectures and labs were designed to encourage student participation. Questions 9 and 12 of the survey (instructor stimulated student interest and course organized to allow all students to participate fully) were among the highest-scoring questions.

CONCLUSIONS

Implications

Overall, we view the introduction and implementation of a term project as a success. Students benefited from the opportunity to develop a relatively industry-realistic client-server system by gaining (partial) experience in the conceive-design-implement-operate model. In addition, students engaged in the product-process-system lifecycle and worked towards many of the CDIO learning outcomes. Especially in the context of a single software development course, the term project successfully covered much of the relevant CDIO standards.

However, future iterations of the term project may benefit from a few changes. Firstly, because students who worked in groups developed their interpersonal skills far more than the students who chose to work individually, students should be encouraged, if not required, to work with others or at least complete part of the project in a team. Further, the project could benefit from being more precisely situated within the context of industry and especially the implement and

operate stages of the CDIO context. This would provide students a more true-to-real-life design experience, as well as to adhere more closely to CDIO standards.

In terms of changes to the delivery of the course, some of the responses to the survey indicated that there were certain aspects of the project that were not taught at a sufficient level of detail, while others noted that lectures could seem disorganized or unfocused. In future iterations of the course, course content and lectures could be structured to focus on teaching specific aspects of the project (for example, the GUI, working with databases, or class relationships).

Limitations and future research

The data used for this paper does have some limitations. Firstly, participation bias skews the results to be slightly more positive, and in particular, qualitative responses from the questionnaire are largely reflective of the opinions of strong students. Ideally, in the future we would be able to provide additional incentive to encourage more students to respond to the survey so would be able to hear more from students who are struggling, or who appear to be neutral to the structure of the course. Additionally, though the survey was anonymous, it would be beneficial for future iterations of the survey to be conducted by a neutral third party, so students would feel more comfortable responding openly.

Future research could include conducting an updated survey that more specifically targets CDIO standards and learning outcomes in order to monitor how student performance may change as the implementation of the project matures. This form of engineering education research, using relevant CDIO standards as a framework in order to analyze the effectiveness of different learning methods and projects, could be customized and applied to different engineering courses as well.

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Robyn Paul is a second-year Ph.D. student at the Schulich School of Engineering at the University of Calgary. Her work is looking at using best practices from ecofeminism to deconstruct the culture of engineering education and bring awareness to engineering's hidden curriculum. Robyn also has a master's degree in engineering education, where she studied engineering leadership education.

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STAKEHOLDERS' MANAGEMENT FOR TRULY IMMERSIVE CDIO EXPERIENCES IN BIOMEDICAL ENGINEERING

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ABSTRACT

When education is faced with a Project-Based Learning (PBL) approach, understanding and managing subjects considering project management principles help better achieving project objectives and hence improving the learning outcomes. Within the project management field, stakeholders' management has been considered a key element for project success. It is one of the main knowledge areas identified in the standards of the Project Management Institute (PMI), within PMBOK (Project Management Book Of Knowledge). Stakeholders' management is of great importance since it enables to improve benefits and probabilities of success of a project, by considering the impact and interest from different points of view and consequently defining an appropriate strategy. In this study, stakeholders' management approach is presented in a course devoted to the biomedical engineering field, namely "Bioengineering Design and Medtech", included in the Master's Degree in Industrial Engineering and in the Master's Degree in Engineering Management, both at the ETSI Industriales from Universidad Politécnica de Madrid. Students from the course collaborate in teams and live through the complete project life cycle of innovative medical devices. For stakeholders' management, different phases are carried out, such as stakeholders' identification, engagement planning, engagement managing, and monitoring. In this course, oriented to the biomedical field, participation and management of hospitals, patients, students, professors, innovation units, open innovation initiatives, potential users, associations, and health professionals, among others, are presented. Main results, difficulties, benefits, and conclusions of the experience are included in this work. The experience and its systematic assessment shows that students, feeling part of a whole system, by interacting with all key stakeholders, demonstrate higher commitment to achieve learning objectives and live through more realistic, complex, and transformative PBL-CDIO learning experiences. As a result, they become more professional engineers, which is one of the CDIO implementation benefits.

KEYWORDS
CDIO as Context, Project Based Learning, Project Management, Stakeholders' Management, Biomedical Engineering, Standards 2,3,4,7, 8

INTRODUCTION

In this study, a Project-Based Learning (PBL) approach following CDIO principles is applied to allow students to learn necessary Project Management (PM) and Biomedical Engineering competences. Students in this experience belong to two courses devoted to the biomedical engineering field, namely "Bioengineering Design" and "MedTech," included in the Master's Degree in Industrial Engineering and the Master's Degree in Engineering Management.

From the beginning of the courses, students are provided with specific knowledge, tools, and exercises to improve their capabilities for building strong teams and achieving their biomedical project goals. In this case, supported by the integration of the Stakeholders Management approach with a defined strategy, it has been possible to provide an effective learning experience for improving students' skills.

The learning approach, results, difficulties, lessons learned, and conclusions of this experience during the 2019-2020 course are presented in this paper.

LITERATURE REVIEW

Project-Based learning approach

Project-Based Learning (PBL) is a model in which learning opportunities are organized around projects. Projects are complex tasks that are based on challenging questions or subjects that involve the students in design, problem-solving, decision making, or investigative activities. In regard to students and Higher Education (HE), dealing with projects gives the former an opportunity to work relatively autonomously over extended periods. This culminates in the creation of realistic products or presentations (Thomas, 1999; Turner et al., 2002; van Rooij, 2009). In PBL, the project is the central teaching strategy. Students encounter and learn the fundamental concepts of the discipline by means of the project.

Some studies have shown that students retain minimal information in the traditional, didactic, teaching environment and frequently have trouble in transferring the acquired knowledge to new experiences (Schmidt, 1983). In contrast, PBL has proved to be an excellent method for developing new forms of competencies (Graaff and Kolmos, 2003; Kolmos and Kofoed, 2002). A PBL environment enables students to draw upon their prior knowledge and skills, brings a real-world context to the classroom, and reinforces the knowledge that they acquired by both independent and cooperative group work (Schmidt, 1993). To be considered an example of PBL a project should have centrality, a driving question, constructive investigation, autonomy, and realism (Thomas and Mergendoller, 2000). Projects should have characteristics that provide a feeling of authenticity to students. These characteristics can involve the topic, tasks, the roles that students play, context within which the work of the project is carried out, collaborators who work with students on the project, products that are produced, an audience for the project's products- or criteria by which the performance or products are judged.

Earlier studies suggested that project management skills are core to the leadership attributes of engineers (Hamilton, 2006; Wearne, 2004). Some interrelated research streams are available for an understanding of the challenges in teaching and learning both engineering (Zhou, 2012) and project management education (Ashleich et al., 2012; Louw and Rwelamila, 2012). Students' experiences have remained a major theme of interest to scholars, especially in the engineering and project management areas (Dietrich and Urban, 1998; Heer et al., 2003).

Stakeholders' Management

The importance that is attributed to the strategic role of project management in organizations has led in recent decades to the growing development of frameworks of international competencies and professional standards. Within normative project management literature (PMI, 2017), stakeholders management is proposed as a knowledge area to support project success.

Freeman (1984) defines stakeholders as "any group or individual who can affect or is affected by the achievement of the organization's objectives." Since then, the stakeholder concept has become a salient part of project management (Eskerod and Vaagaasar, 2014; Cleland, 1985; Crawford, 2005; Aaltonen, 2010). The main idea of project stakeholder management is that the project team can increase the possibility of project success by influencing stakeholders to define an appropriate strategy (PMI, 2017).

Savage et al. (1991) recommend that the project management team should be in charge of identifying and diagnosing the stakeholders in order to build a specific strategy for interacting with all of them (Eskerod and Vaagaasar, 2014). In line with Freeman (1984), it is suggested that the analysis should be based on each stakeholder's potential to cooperate with the organization and the stakeholder's potential to threaten the organization on a particular issue. This approach defines four different types of stakeholders' strategies: Supportive, Mixed Blessing, Nonsupportive, and Marginal (Table 1).

Table 1. Project stakeholder type framework. Source: Eskerod and Vaagaasar (2014).

		Stakeholders' potential for threatening the project (harm potential)	
		High	**Low**
Stakeholders' potential for cooperation with the projects (help potential)	**High**	Mixed Blessing *strategy*: *Collaborate*	Supportive strategy: *Involve*
	Low	Nonsupportive strategy*: Defend*	Marginal strategy: *Monitor*

Stakeholders' management is especially relevant in biomedical engineering since there is a wide variety of actors implied in decisions and technology development, considering the interconnected nature of the health field.

DESIGN OF THE LEARNING EXPERIENCE

Description of the course

Industriales Ingenia is a compulsory subject (12 ECTS) of the Master's Degree in Industrial Engineering and the Master's Degree in Engineering Management. There are 12 Industriales Ingenia different initiatives designed to cover most of the profiles of the Master's Degree in Industrial Engineering composed of approximately 300 students. 31 of these students selected "Bioengineering Design," which is the most demanding option. The students of the Master's Degree in Engineering Management are 41, and they could choose between three different tracks for studying Industriales Ingenia. "MedTech" was the first option for 13 of them, who

were all accepted. Therefore, a total number of 44 students are participating in these two subjects, working together in seven teams. These teams were formed with an average of 4-5 people from "Bioengineering Design" (technical profile) and two persons from "MedTech" (business and management profile). Although one project manager was required at the beginning of the course for every team, all the teams decided to work with a shared leadership for managing the project, giving an opportunity to a horizontal approach. Table 2 shows the characteristics of engineering students and their projects.

Table 2. Teams and projects participating in the experience.

Team members	**Logo and Name**	**Projects**
2 MT* + 4 BD*	Ingesapiens	Crutches with support meter
1 MT + 5 BD	Health Solutions	Radiology collaboration with a Hospital
2 MT + 5 BD	MedBeetle	Sock muscle treatment
2 MT + 5 BD	Sejmet	Device for Herniated Disc
2 MT + 4 BD	Hybmed	Redesigned Speculum
2 MT + 5 BD	L.I.F.E.	Arthrocentesis Device
2 MT + 4 BD	Dr. Gear	Multi-compartment refrigerator

*MT = MedTech; BD = Bioengineering Design

Lecture sessions, together with some specific conferences led by professionals of the Bioengineering arena, allow the teams to improve their capabilities and achieve their project goals. Furthermore, for three sessions, the teams were divided to deal in depth with prototype design, on the one hand, and into the marketing and entrepreneurship on the other hand. The rest of the sessions were shared and dealt with teamwork, project management, and sustainability. Based on the PM style, some deliverables are required for the teams along the course. PBL methodology and techniques used for reinforcing the PM and Bioengineering skills are the following:

- *Teamwork and team development:* Multidisciplinary teams, Team agreements, Personality assessment, Interviews, Organization charts, Competency assessment, Teambuilding activities.
- *Deliverables:* A set of deliverables is scheduled with deadlines. Some examples are CAD designs, Simulations, Prototyping, Usability, Business Plan, Team performance, Project Management Plan.

- *Oral presentations:* An interim presentation for assessing the progress and a final presentation is scheduled. They include technical, management, business, and sustainable aspects.
- *Complementary workshops:* Arduino-Matlab, Simulations, Sustainability, Biomechanics, Electronic design, Biomaterials, Leadership and communication skills, Entrepreneurship.

Description of stakeholders' management overall strategy

Professors, along with students, identified stakeholders regarding the projects proposed. Identification of stakeholders helps to define an appropriate strategy as well as gather useful information for ideas generations concerning bioengineering devices and business modeling.

Being aware of this, during the course, students and professors integrated different activities to manage stakeholders for the projects. Main activities and description are shown in Table 3:

Table 3. Stakeholders management activities

Stakeholders management activities	**Description**
Stakeholders' identification	Identification and diagnosis of stakeholders in order to build a specific strategy for interacting with all of them. Main stakeholders identified were: Universities Students; Hospitals; Patients; Innovation units; Open innovation initiatives; Potential users; Entrepreneurs; Spanish Agency of Medicines and Health Products; Business schools
Meetings	Several meetings were developed with stakeholders (practitioners, hospitals, clients, doctors, regulators, etc.); and Professors (by means of Mentoring activities). As an example, two professors went with one team to one of the principal hospitals in Madrid, in the radiology area to coordinate the activities of students and health professionals.
Interviews with professionals	Project teams were responsible for interviewing professionals from the field, depending on the medical device they were in charge of. Special emphasis was put on potential users, hospitals, and patients since they are relevant stakeholders in these projects.
Surveys	Some project teams considered the opportunity to develop a survey for different health professionals and potential users to better get the main requirements for medical devices design and business plan.
Round tables	Professors organized round tables with practitioners, university professors, hospitals, clients, doctors, regulators, students, entrepreneurs, etc. These sessions served to share different perspectives and allow project teams to understand principles and truly practice of biomedical engineering, open innovation initiatives, and business strategy.
Multiplier events	At the end of the course, several presentations were organized showing results with stakeholders and students from other PBL experiences in the school.

RESULTS AND LESSONS LEARNED DURING THE PROJECT

Some conceptual designs proposed by the students are shown in Figure 1. The first lesson learned is to afford the students to choose their project and to invite them to manage stakeholders from the beginning. It allows students to become more involved in their designs, results, understanding of the field, and definition of realistic objectives. In addition, it allowed them to choose a project that responds to a close need, often lived by a stakeholder. Then, the ability to obtain first-hand information also increases, and it is easier to align their entrepreneurship strategies with the stakeholders' needs. The skills related to the business and project management are developed at the same time as the technical skills, which remain essential for current and future engineers.

a)

b)

c)

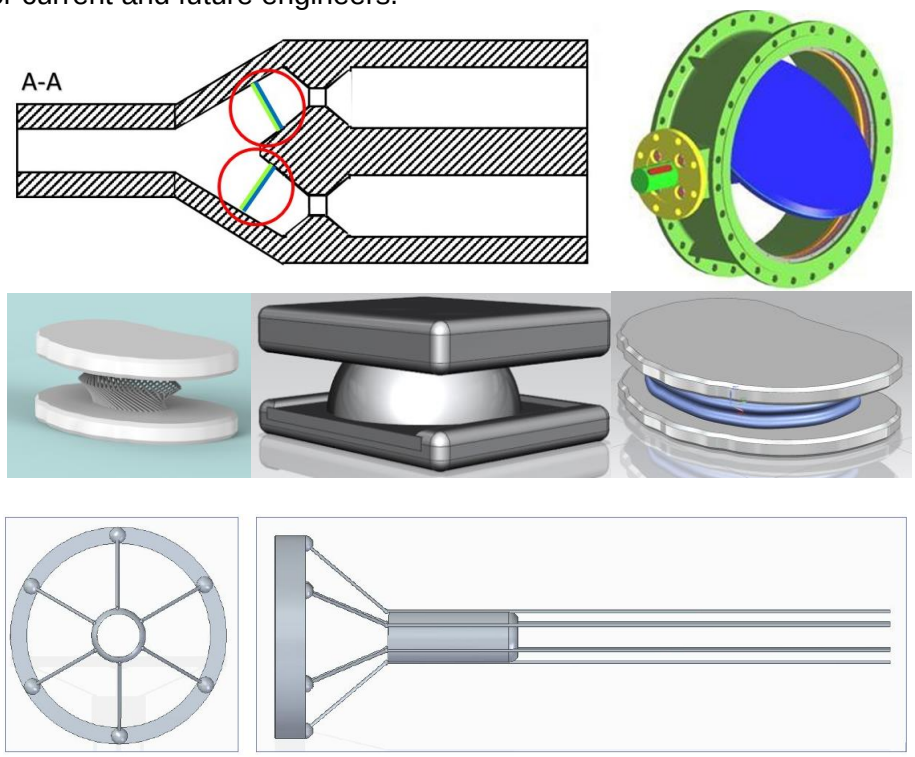

Figure 1. Examples of conceptual design proposals from different projects.
a) Arthrocentesis Device. b) Device for Herniated Disc. c) Redesigned Speculum.

The second learning is that working with this methodology allows the students to manage their time better and to share the tasks properly. With project and stakeholder management activities, students are really committed to the subject and motivated to achieve the objectives as a team. Professional competencies of engineers are implemented for the first time for most of the students. It brings them a little closer to the future work that awaits them once they finish their masters

The third lesson learned is that when an appropriate follow-up of stakeholders' management is done, the project trend is to advance itself progressively, without needing to pressure students. Probably, it is due to the natural way of working in a project that requires not only a team and a set of deliverables with deadlines but also the commitment to respond to stakeholders' needs. In the beginning, students were not much comfortable with the idea of interacting with different stakeholders, but during the course, they demonstrated an improvement in this area, becoming more confident and feeling professionals when doing it.

Personal competencies strengthening

For personal competencies strengthening, an interpersonal competencies questionnaire was implemented by the students during the learning experience. This helps to identify specific difficulties of students and focus on them in order to be improved. The main feedback received by students (n=41) during the course is shown in Table 4.

Table 4. Improvements areas and strengths of students during the course

Improvements areas	**Strengths**
Students have general difficulties for *time management, emotional management, and conflict management*. Main specific improvements areas detected by students were: • Stress management and patience • Delegation • Active listening • Shyness • Ambition • Empathy • Communication • Flexibility • Organization • Proactivity • Self-confidence	On the other hand, they generally feel they were very good at showing *professionalism and commitment* to the projects and the subject. Main specific strengths detected by them were: • Working capacity • Results orientation • Generosity • Team working • Respecting others • Loyalty • Perseverance • Innovation • Analytical thinking • Problem-solving • Responsibility

As an additional challenge during the second half of the course, students had the need to boost team working and collaborative engineering due to the COVID-19 scenario. They really made a rapid transition from normal classes to online working conditions by having more frequent meetings through MS Teams and with the support of the UBORA platform.

At the end of the course, students will give their feedback again to analyze differences and, therefore, the impact of this approach on students' performance, allowing identifying as well actions for the next courses.

CONCLUSIONS

The learning experience following the PBL approach and CDIO principles is showing to be effective for future engineers and professionals. In this case, when applying principles of project management, and specifically stakeholders' management function, project teams become committed, feeling professionals and being part of something bigger. Stakeholders' participation in this experience allows a better understanding of market needs, restrictions, and project threats. Project success is very linked to how the team manages stakeholders. Sometimes, as engineers, we tend to focus mainly on technical and design aspects of biomedical devices, which is essential, but not enough.

PBL and CDIO have demonstrated how to support students in competences strengthening and learning by doing. Now, the focus should be to identify good practices in order to become excellent in CDIO implementation.
The main difficulties that raised during the experience were in the first place the effort needed by professors to be well-coordinated, taking into account the participation of several stakeholders and the combination of two different master students in one project. As well, some difficulties have to do with the limitation in time and experience of the students, since they have several subjects with additional work and different agendas that make it difficult for them to work always together as a team.

Some limitations of this study have to do with competencies quantitative assessment since the course has not finished yet, and it was not possible to assess differences at two different moments (at the beginning and the end of the course). As well, the pandemic scenario (COVID-19) at the end of the course had an impact on prototyping and team working.

A new way of teaching future engineers is spreading in our university. If we focus on maintaining the spirit of CDIO initiative as well as continuous improvement of its implementation, we think we could be an example and a reference in our engineering school, leading the change of learning approaches for more subjects in several degrees.

ACKNOWLEDGMENT

This research was partially supported by the UBORA project, funded by the European Union's Horizon 2020 research and innovation program under grant agreement 731053.

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TABLET-AIDED LECTURING EFFECTIVENESS: CASE OF THE AUSTRALIAN COLLEGE OF KUWAIT

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ABSTRACT

Being frightened from becoming technologically outdated, higher educational institutions are nowadays competing to deploy the most advanced technologies in their teaching activities. With the exponential growth of technology, this becomes more challenging and resource-demanding; hence, the selection of a sustainable and effective technological solution that best supports the teaching, learning, sociological and pedagogical aspects within the institution becomes crucial. This paper investigates the effectiveness of tablet technology for in-class material delivery from the perspective of the students as well as two other learning tools that are provided by this technology which are: digital in-class written notes and video-recorded sessions. The study is conducted at the Australian College of Kuwait and involves three faculty members, four courses, and a total of 100 students from the Electrical Engineering department. The tablet device is a 2-in-1 stylus-enabled reversible laptop that can be used by the instructors for teaching, research, and other related activities. A quantitative methodology through the use of a questionnaire is then used to evaluate the intention to use, satisfaction, and effectiveness factors for each of the teaching and learning tools provided by tablets. The questionnaire results are finally analyzed through SPSS 25.0 software to draw a conclusion on each of these factors and their relationship with each of the analyzed teaching and learning tools.

KEYWORDS

Tablet, E-Learning, Student Satisfaction, Effectiveness, Standards 8, 9, 10

INTRODUCTION

With the dynamic technology evolution in the 21st century, various technologies have been studied by educational institutions to facilitate the teaching and learning experience for both students and faculty members. As a result, a blended learning environment that combines face to face learning, e-learning and/or online learning has massively emerged. For instance, among other computer-based software, mobile applications are nowadays designed to convert textbooks into interactive material in the form of videos and digital online learning material to benefit the students in case of an online learning environment or to create interactive exercises and problems that assist the students and the instructors in class in case of a blended teaching environment (Kadry et al., 2017), (Prasad et al., 2018). Specific online tools to address hands-on based aspects in engineering education were also suggested and evaluated in the context of distance learning (Krichene et al., 2017). Other digital tools such as the Learning

Management Systems (LMS) and their various features were used to create prediction variables that help in evaluating and predicting students' performance (Conijn el al., 2017). Other studies focused on the barriers confronting the implementation of new technologies in teaching and learning from the perspectives of the teachers (Opeyemi el al., 2019) and recommended adopting changes to the curricula to support digital literacy and promoting digital literacy training for the teachers. Nevertheless, the majority of these studies focused on implementing the new technology without evaluating it quantitatively or qualitatively and without comparing it with alternative solutions that may produce similar outcomes.

Focusing on tablet technology, Hecht et al. (2018) studied the impact of using tablets in a Project-Based Learning (PBL) environment over one semester on engineering courses. The study focused on identifying the required knowledge and skills, defining the problem/project, identifying project criteria, developing knowledge, testing, and evaluating the solutions and refining designs. Although analysis and reflection on the effect of using tablet technology were presented, the study lacked any comparison with results in case tablets were not used. Furthermore, the study was limited to PBL courses and thus restricted the results into this context.

In this paper, in alignment with CDIO standard 10 and particularly the need of faculty members to teach and assess in new ways, the usage of tablets by instructors in a face-to-face traditional learning environment to support teaching and learning in the form of various e-learning tools and resources and create a blended learning environment is suggested. The study is conducted at the Australian College of Kuwait and involved three faculty members, four courses, and a total of 100 students from the Electrical Engineering department. The tablet device is a 2-in-1 stylus-enabled reversible laptop that can be used by the instructors for teaching, research, and other related activities. In class, the instructor uses solely the tablet, its stylus, and other supporting software to deliver the class digitally. This includes writing all in-class notes digitally, playing videos, interacting, or sharing other supporting material with the students. While the instructor explains the lesson, the students visualize a duplicate display of the instructor's tablet's screen via an overhead projector. Simultaneously, the tablet's display, along with the voice of the instructor are video-recorded then shared with the students as supporting online material on the course homepage in the learning management system. Similarly, all in-class notes written digitally by the instructor (e.g., illustrations, diagrams, solutions, etc.) are also saved and shared as documents with the students.

As per CDIO standard 8, focusing on active learning and particularly, on the importance of collecting feedback from students about what they are learning, the effectiveness of implementing tablet technology and various e-learning resources/tools it provides is then evaluated quantitively from the perspective of the involved students in the form of a questionnaire that is based on DeLone and McLane user satisfaction model which was developed in 1992 and revised in 2003 (DeLone et al., 2003) and other similar models and studies (Davis et al., 1989), (Piccoli et al., 2001), (Aldaihani et al., 2018). The results are then analyzed, and a conclusion is drawn.

STUDY DESCRIPTION

The courses involved in this study are four compulsory courses from the Diploma of Electrical and Electronics Engineering program offered at the Electrical Engineering Department at the School of Engineering at the Australian College of Kuwait (ACK) that are delivered by three

instructors from the same department. The courses involved in this study are listed in Table 3 below along with the number of students enrolled in each.

Table 3. Courses Involved in the Study

Course Code	Course Title	Semester	Enrolled Students
15FELE120	Electrical Circuit Analysis II	2	27
15FELE123	Introduction to Computer Programming	2	32
15FELE210	Semiconductor Devices and Circuits	3	23
15FELE212	Digital Logic	3	19

An HP EliteBook X360 2-in-1 G4 laptop, hereafter referred to as "tablet", was used by each of the three instructors engaged in this study. This laptop has the advantage of being used as a normal laptop or converted to a tablet if needed. It is a highly performant tablet that can potentially replace the offices' computers of faculty members. The device pictures are shown in Figure 1, and a summary of its main specifications are listed in Table 4. This tablet was selected after thorough research in order to facilitate e-learning in three forms: e-Class, e-Lecture, and e-Note. It has a relatively low weight and small screen size for the sake of ease of mobility between instructors' offices and classes. It is equipped with a bundled rechargeable stylus, which eliminates any incompatibility issue with separately purchased active pens and battery replacements. It has a built-in full HDMI interface to enable the simple use of the in-class HDMI cable. It is fully compatible with the IT hardware, software, and network infrastructure at ACK.

(a) Laptop Mode (b) Tablet Mode

Figure 3. HP Elitebook X360 2-in-1 G4: Laptop Modes

Table 4. HP EliteBook x360 2-in-1 G4: Notebook Specification

Operating system	Windows 10 Pro 64
Processor Name	Intel® Core™ i7-8565U (1.8 GHz base frequency, up to 4.6 GHz with Intel® Turbo Boost Technology, 8 MB cache, 4 cores)
Memory	16GB DDR4 2666 RAM
Hard drive	512GB PCIe® NVMe™ SSD
Display	(13.3) diagonal FHD IPS anti-glare WLED-backlit
Graphics	Intel® UHD Graphics 620
Wireless	Intel® AX200 Wi-Fi 6 (2x2) and Bluetooth® 5 Combo, vPro™
Stylus	HP Active Pen
Weight	Starting at 1.27 kg

METHODOLOGY

The study is conducted during the Fall 2019 semester, which consists of 17 weeks, 13 weeks of which were teaching, and four weeks were dedicated to midterm/final exams. All involved courses are delivered in class as 3 hours of lectures and 2 hours lab per week. During the first 5 weeks of study, the instructors used the traditional delivery method using ink-based whiteboards. Tablets were used by the instructors afterward until the end of the semester to allow the same sample of students/instructors to be involved for the sake of comparing the two methods of delivery. All lectures are presented in class using an overhead projector that is directly connected to the in-class laptop in case of the traditional delivery method (i.e., during the first 5 weeks) or directly to the tablet via HDMI cable during the remaining of the course. The study presented in this paper investigates the efficiency of three e-learning features/resources provided by the tablet technology: “e-Class”; “e-Lecture,”; and “e-Note.”

e-Class

“e-Class” denotes a face-to-face class during which the instructor uses the tablet as the main electronic tool to conduct the class. For instance, all notes, illustrations, graphs, detailed explanations, exercises, solutions, etc. are written/drawn on the tablet screen using its stylus and various Microsoft software such as Microsoft OneNote, Microsoft PowerPoint, and Microsoft Whiteboard, while the tablet’s display is projected to the students on a large screen. Figure *4* shows an example of using Microsoft OneNote to write a solution for an exercise and draw a diagram.

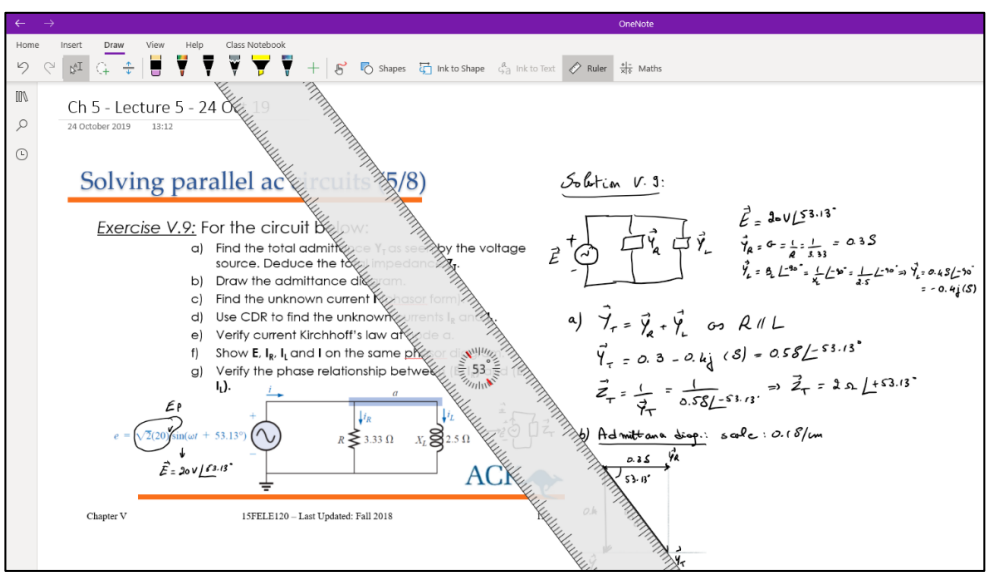

Figure 4. e-Class: Tablet based class delivery using Microsoft OneNote

e-Lecture

"e-Lecture" denotes a video recorded version of a lecture that is shared with the students electronically. Indeed, during an e-Class, the tablet's display and the audio it is capturing are recorded using "Open Broadcast Software" (OBS) freeware software, which is very simple to use and offers the possibility to pause recordings and many other features. The output provided by this software is a video record of everything displayed to the students and the

discussions that occurred in class. This video is then shared with the students using either access-restricted YouTube channels, Dropbox or Google Drive.

Figure 3 shows the "YouTube studio," (i.e., the environment facilitated by YouTube website to upload videos) of one of the instructors with sample videos of recorded lectures for the course 15FELE120 along with the views count of each. Also, Figure 4 shows Google drive Instructor interface used to share videos with students for the course 15FELE210. Simple trimming/merging of video files may also be applied prior to uploading the videos if needed using the simple "Photos" application that is available in Windows 10 operating systems.

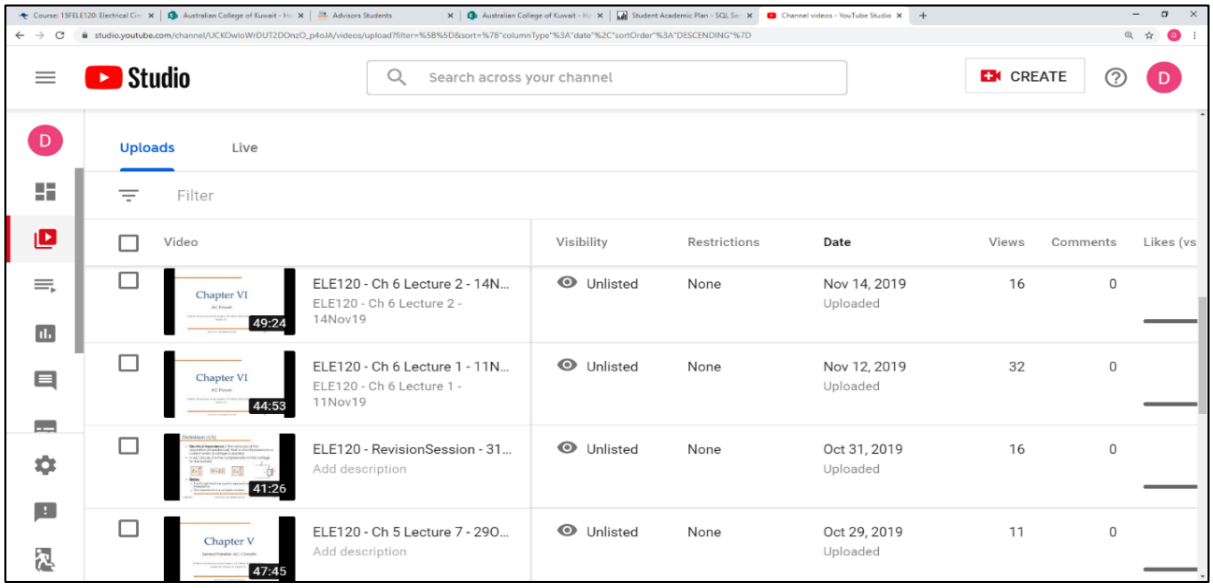

Figure 5. e-Lectures: YouTube Channel of an Instructor (Course: 15FELE120)

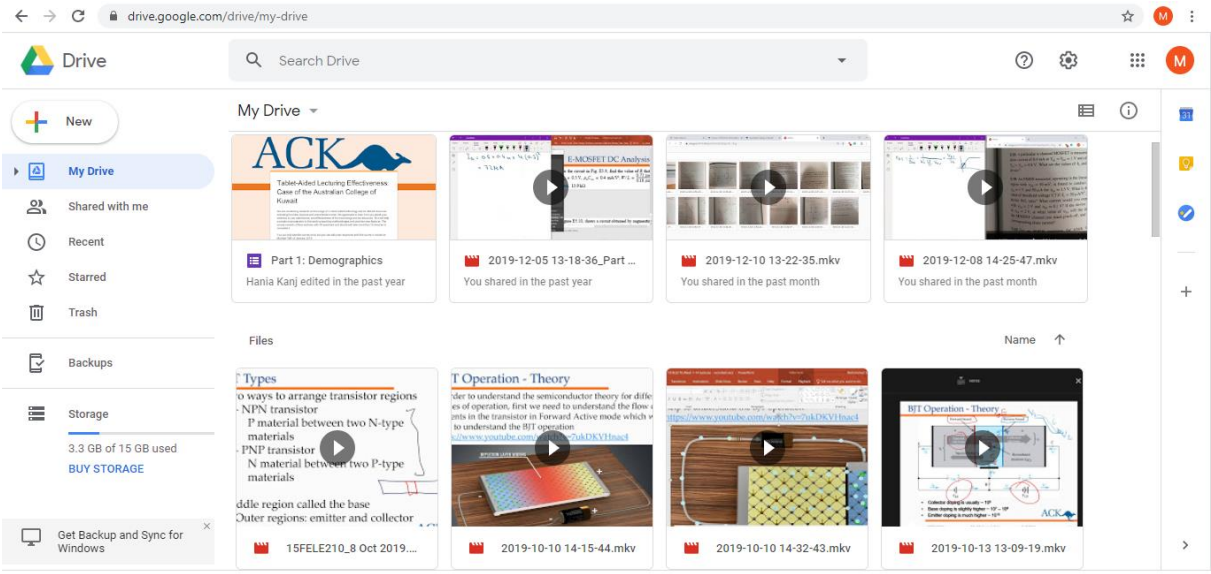

Figure 6. e-Lectures in Google Drive instructor's account (Course: 15FELE210)

As illustrated in Figure 5, whatever the video-sharing platform is, the link to reach the video is shared with the students electronically via each course homepage on ACK's Learning Management System (LMS) and is accessible by the enrolled students only.

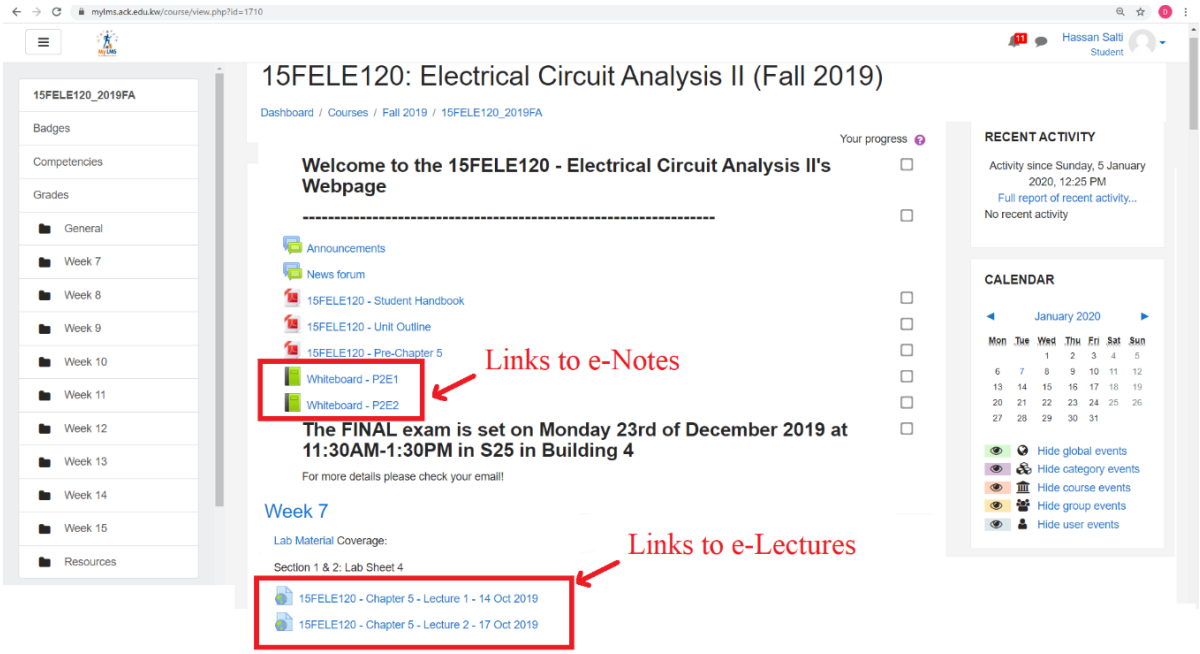

Figure 7. Sharing e-Lectures Links on the LMS (Course: 15FELE120)

e-Note

"e-Note" denotes the soft copy of all the notes written by the instructor during an e-Class and shared electronically with the students. Indeed, whether the instructor is using Microsoft OneNote or Microsoft Whiteboard to write his/her in-class notes on the tablet screen, these notes are saved as an "OneNote" file or a simple "jpeg" image and shared with the students on the course home page on the LMS.

Figure 7 shows a snapshot of the links created to access e-Notes on the course home page on the LMS that are uploaded in the form of an e-portfolio, and
Figure 8 shows a sample part of an e-Note.

STUDENTS' SURVEY

In order to evaluate the overall students' satisfaction, their intention to use the e-learning features/resources provided by the tablet, and accordingly comment on the effectiveness of this technology in the four candidate courses, a pragmatic approach is used through the implementation of quantitative methods.

Instrument Definition

The instrument used is a student survey questionnaire consisting of 69 questions. The questionnaire included two main parts. The first part is dedicated to collect demographic data such as age, gender, nationality, GPA, and semester level of the survey respondents. The

second part consisted of three sections. Each section involved questions related to the three constructs of the conceptual model: (1) Intention To Use, (2) Satisfaction, and (3) Effectiveness. Moreover, each construct has been studied across three factors: (1) e-Class, (2) e-Lecture, and (3) e-Note, which were explained earlier. Table 5 lists all the variables, factors, the subscale variables, and the corresponding codes that are addressed in this case study.

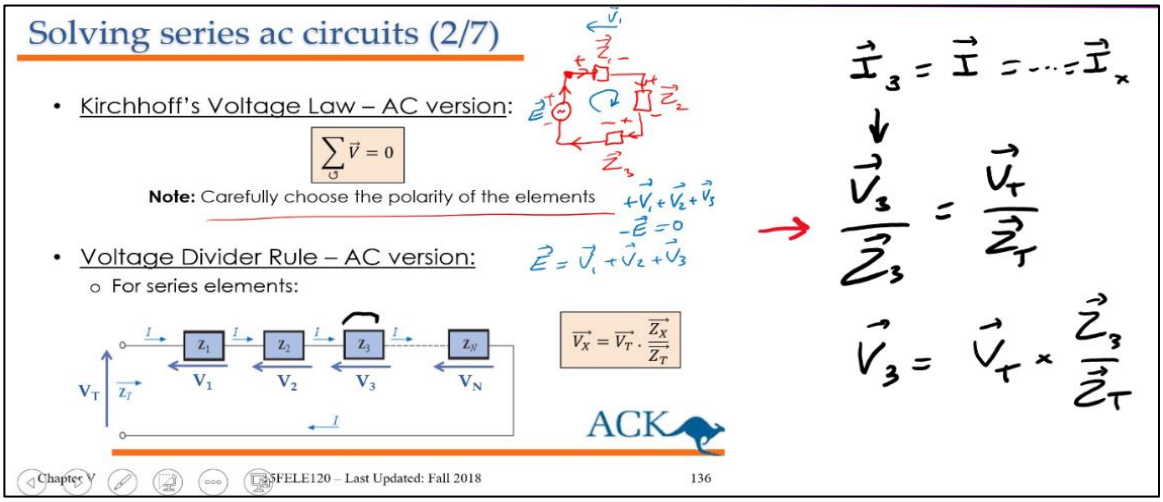

Figure 8. e-Notes: An example

Table 5. Summary of Variables and Sub-Scale Variables

Variable	*Factor*	*Sub-scale Variable*	*Code*
Intention	e-Class	**S**tudent **I**ntention to attend e-**C**lasses	SIC
	e-Lecture	**S**tudent **I**ntention to use e-**L**ectures	SIL
	e-Note	**S**tudent **I**ntention to use e-**N**otes	SIN
Satisfaction	e-Class	**S**tudent **S**atisfaction with e-**C**lasses	SSC
	e-Lecture	**S**tudent **S**atisfaction with e-**L**ectures	SSL
	e-Note	**S**tudent **S**atisfaction with e-**N**otes	SSN
Effectiveness	e-Class	**E**ffectiveness of e-**C**lasses	EC
	e-Lecture	**E**ffectiveness of e-**L**ectures	EL
	e-Note	**E**ffectiveness of e-**N**otes	EN

For each factor, five to eight questions were allocated in the questionnaire, and negative questions were added to flag responses that are filled without carefully reading the corresponding questions and eliminate them accordingly. These measures were taken to ensure higher reliability and validity of the results. All questions were based on five points Likert scale where 1 denotes "Strongly Disagree," 2 denotes "Disagree," 3 denotes "Neutral," 4 denotes "Agree," and 5 denotes "Strongly Agree." As all respondents are diploma level students, the questions were carefully structured to make sure it is clear and understandable by the students. Moreover, a pilot test for the questionnaire was conducted on eight students to collect feedback about the clarity of the questions and adequacy of their level. The feedback was then addressed in the survey questionnaire. The questionnaire was anonymously implemented online using the ACK MyLMS tools and was posted on the course homepage of each of the four candidate courses.

Data Collection

The survey is launched, and data is collected during weeks 15 and 16 (the last two teaching weeks of the Fall 2019 semester), and the data is analyzed afterward using IBM SPSS 25.0 software. Incomplete responses were excluded from the survey due to missing data. As a result, out of the 101 students registered in the four courses, 80 students participated in the questionnaire, which gives an approximate response rate of 79%.

The demographics analysis of the results shows that from the respondents, 53.8% aged between 20-22, 66.3% are males, 83.8% are Kuwaitis, 62.5% have a Grade Point Average (GPA) less than 2.6, and 51.2% are studying in Semester 3. Table 6 illustrates the respondents' demographics.

Table 6. Respondents Demographics

Demographic Item	Category	Frequency	Percentage
Age	Less than 19	16	20.0%
	20-22	43	53.8%
	23-25	9	11.3%
	More than 25	12	15.0%
Gender	Male	53	66.3%
	Female	27	33.8%
Nationality	Kuwaiti	67	83.8%
	Non-Kuwaiti	13	16.3%
GPA	Less than 2.6	50	62.5%
	2.6-3.0	12	15.0%
	3.1-3.5	3	3.8%
	More than 3.5	15	18.8%
Semester Level	Semester 1	1	1.3%
	Semester 2	33	41.3%
	Semester 3	41	51.2%
	Semester 4	5	6.3%

DESCRIPTIVE RESULTS

Descriptive statistics that are used to describe the Intention To Use, Satisfaction, and Effectiveness of e-Classes, e-Lectures and e-Notes are displayed in Table 7 in the form of the mean, median, mode, standard deviation, and variance of each sub-scale variable previously defined in Table 5. These values are obtained after inverting the results of all negative response questions and eliminating invalid responses using SPSS software.

Table 7. Descriptive Results

	SIC	***SIL***	***SIN***	***SSC***	***SSL***	***SSN***	***EC***	***EL***	***EN***
Mean	4.238	4.350	4.444	4.438	4.413	4.500	4.3500	4.413	4.444
Median	4.00	4.00	5.00	5.00	5.00	5.00	4.00	5.00	5.00
Mode	4.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Std. Deviation	.716	.731	.70479	.726	.774	.70711	.731	.741	.61570
Variance	.513	.534	.497	.528	.600	.500	.534	.549	.379

At the questions' level, the results could also be analyzed to extract useful information. For instance, some questions in the students' questionnaire were designed to demonstrate the students' satisfaction with this teaching methodology compared to the traditional way of teaching, a sample question with the corresponding students' responses are shown in Figure 7. Indeed, students' responses to this particular question prove that students preferred the new teaching methodology compared to the traditional one. Similarly, other questions addressed the effectiveness of this methodology in terms of students' understanding from the perspective of the students themselves (c.f. Figure 8).

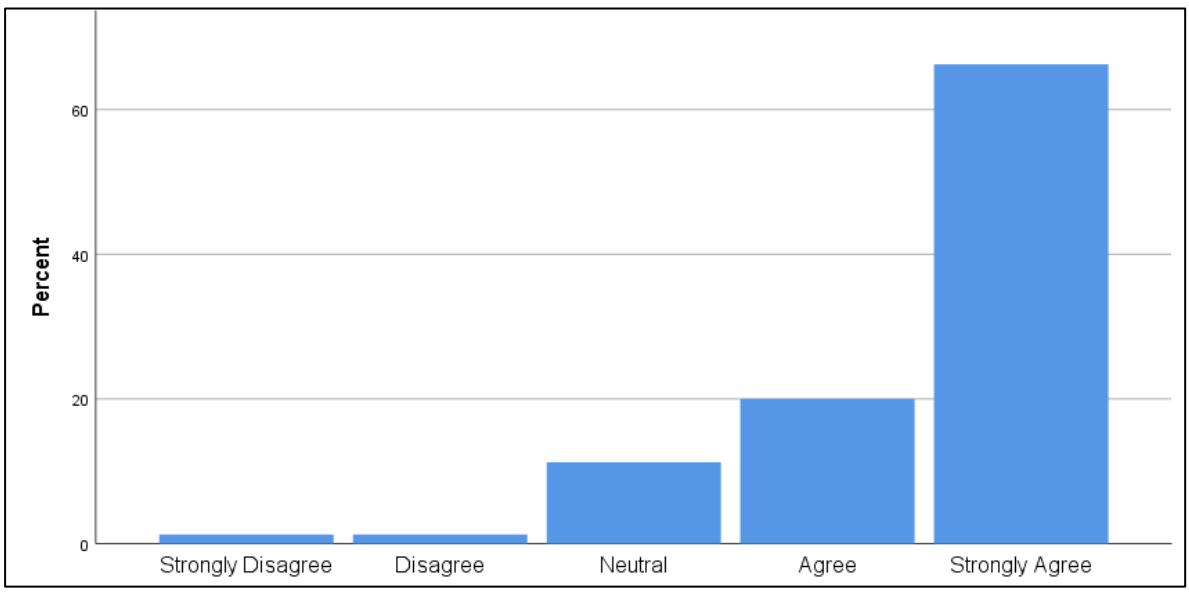

Figure 9. Statistics of question SST4, "I wish other instructors use in-class tablet technology in the units they teach."

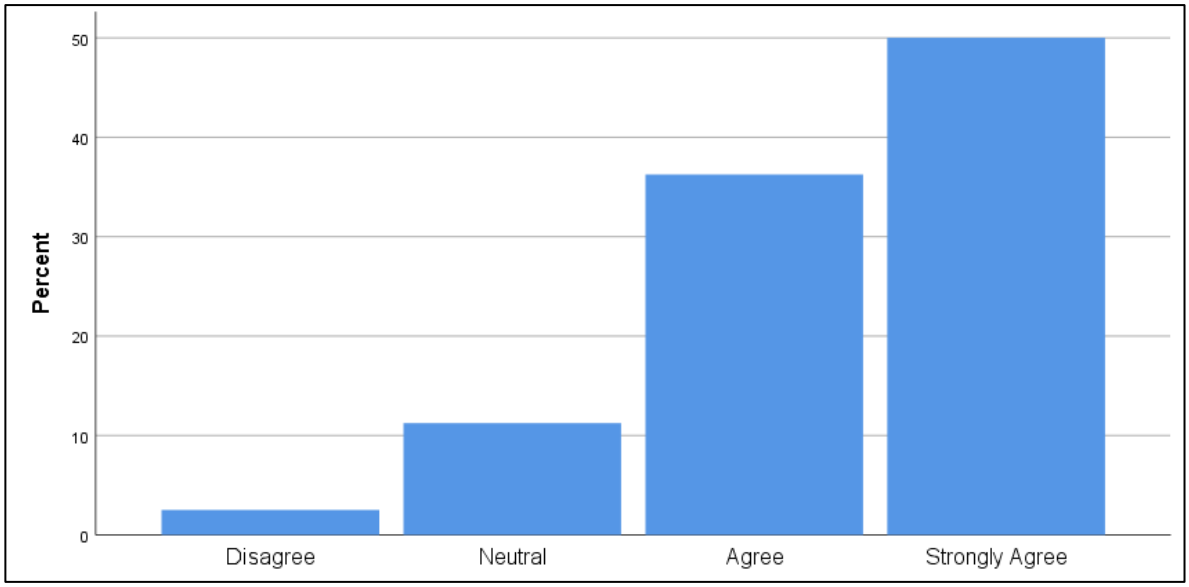

Figure 10. Statistics of question SET5, "The usage of in-class tablet technology by my instructor, improved my understanding of the unit."

DISCUSSION

The results show that the means of all factors are above 4.00 which indicates that the majority of the students responded to the questions with an average of "Agree" to "Strongly Agree." Moreover, the distribution of the responses over the Likert Scale for all sub-variables is positively skewed towards "Strongly Agree." This indicates a high overall intention, satisfaction, and effectiveness for the three e-learning features/resources facilitated by tablets (i.e., e-Class, e-Lecture, and e-Note). The highest mean values were scored by the "e-Lecture" followed by "e-Note" and then "e-Class," which implicitly indicates that e-Lecture is the most effective e-learning resource for the students followed by the e-notes then the e-Class.

CONCLUSION

This paper investigated the effectiveness of using tablets to conduct digitally face-to-face classes and two of the immediate online resources this technology facilitates, which are: shared soft copy of in-class instructor written notes and shared video recorded lectures. This was achieved via a survey questionnaire that is based on previously well-established models to evaluate the intention to use and user satisfaction and comment on the overall effectiveness of this technology. The results show that the use of this technology in class and to provide additional online resources is highly accepted by the students who prove its effectiveness. Future studies will focus on extending the study to cover more courses from various engineering disciplines. Moreover, the correlation between this study results and students' grades after and before technology adaptation will be investigated to support the effectiveness of such a methodology. Furthermore, investigating the intention to use, satisfaction, and effectiveness of the tablet usage from the perspective of faculty members can be explored as well to validate the usefulness of such technology from all stakeholders' points of view.

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BIOGRAPHICAL INFORMATION

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STUDENTS' STRESS AND SATISFACTION IN CDIO EXPERIENCES: FINDING THE BALANCE

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ABSTRACT

The Conceive-Design-Implement-Operate (CDIO) educational framework has been revolutionizing the world of engineering education since its inception at the beginning of this century. Its approach to business reality, encouraging comprehensive and contextualized project-based learning, has been the subject of numerous praises in recent years. However, working within CDIO initiatives requires maturity on the part of the students, who go from working individually to being part of a team, with the management of conflicts that this transition entails. This new way of working, together with the imposition of delivery dates and the fact of facing new design challenges, which students tend to approach in too many cases through a trial and error strategy, can lead to a higher workload and relevant doses of stress. This workload stress needs to be compensated by the levels of students' satisfaction, especially as regards their understanding of the learning process and gained outcomes so that the experience can be considered successful in terms of its positive impact on students. This study seeks to assess students' satisfaction and their relationship with the workload they face. The assessment is done in a set of interwoven courses (Bioengineering Design and MedTech) related to the development and delivery of technological solutions for health challenges. These courses are respectively included in the Master's Degree in Industrial Engineering and the Master's Degree in Engineering Management at the ETSI Industriales from the Universidad Politécnica de Madrid. The results show that if students feel supported by the group of professors participating in the subjects, their level of satisfaction is very high, regardless of the workload stress, which is not perceived so high. The CDIO methodology is thus reinforced, establishing itself as a set of practices that bring the future engineers closer to their next steps in professional life through a satisfactory process.

KEYWORDS

CDIO as Context, workload stress, students' satisfaction, Project Based Learning, Biomedical Engineering, Standards 7, 8, 11, 12

INTRODUCTION

The Conceive-Design-Implement-Operate (CDIO) educational framework is an international initiative in revolutionizing and reforming the previous world of engineering education. This framework, based on Project-Based Learning (PBL), is aligned to the current business reality. Nevertheless, the business world is a riddle of difficulties, and to work with engineering projects requires coping with stress, as previous studies have shown (Anantatmula, 2015; Ballesteros et al., 2019). Are the engineering students prepared to deal with these stressful and, sometimes, overloading the role of pretending to be professionals? And, most important, do they value the role-play experience as satisfactory?

This research aims to discover the self-perception of the work overload and satisfaction by asking the students of the "Bioengineering Design" and "Medtech" courses. These courses are part of the *Industriales Ingenia*, a compulsory course for master's students that born as part of the CDIO initiatives, and they are included in the first year of the Master's Degree in Industrial Engineering, and the Master's Degree in Engineering Management, respectively. The students from both courses work together during the whole year in seven teams under the CDIO framework and with the PBL methodology. This particularity of mixing students from different Masters is something unique in the ETSI Industriales from the Universidad Politécnica de Madrid, and it is interesting to discover if it causes more stress or satisfaction in the students.

LITERATURE REVIEW

Work-life balance

The idea of work-life balance emerged at the 1970s coinciding with the incorporation of the women into paid employment (Dizaho et al., 2017) but has gone beyond women in the last decades, and it has been particularly noticeable in recent generations as millennials, the great advocates of working to live and not living to work.

Although the definition of work-life balance is still not clear in the literature due to some authors link this concept to the care of dependent relatives while others open it to enjoy the free time (Gregory et al., 2013), it can be understood as the compromise between work and non-work activities. There are numerous studies that show that when there are mismatches in that balance, symptoms such as lower levels of job satisfaction and work performance, absenteeism, stress increase, and burnout, begin to appear (Beauregard & Henry, 2009; Chatrakul Na Ayudhya et al., 2017). These symptoms have been studied in detail in professional environments, especially in the healthcare area in the recent years (Holland et al., 2019; Yehya et al., 2020), probably because previous research pointed to healthcare workers as more stressed than people in other professions (Theorell et al., 1990).

Nevertheless, work-life balance has been scarcely studied in the higher education environment, with some exceptions focused on academic staff (Catano et al., 2019; Fontinha et al., 2019) where the high levels of stress have gone increasing over the last years, turning a motivational work by a demanding combination of excel at teaching as well as research.

Stress and satisfaction at the university

The effects of stress suffered by professors in some way are also transmitted to the students, who face the increasingly demanding educational systems from an awkward position since they are not used to cope with stressful situations (Amirkhan et al., 2019).

The tendency to bridge the educational methodologies with the professional reality requires maturity and coping by the students, defining coping as the cognitive and behavioral efforts to deal with stressful situations (Folkman & Lazarus, 1985). Some of these situations are the overload of credits in the semester, the number of tasks to develop in different teams, and conflict management in the working groups. Despite these situations, there are also a few studies about how stress influences the students (Karakas, 2015; Weidner et al., 1996).

Something similar happens around the satisfaction levels at university; there is little published about how students and professors are having their expectations fulfilled. Concerning professors, the study of Fontinha et al. (2019), reveals that although academic life provides flexibility, the higher number of extra hours causes dissatisfaction in the academic community. Regarding the students, despite the stress of facing new challenges, some students show dissatisfaction related to a large number of educational activities and the scarce linkage between the conceptual issue - taught at university - and the experiential learning - demanding by the labor market - (Cavallone et al., 2020). Moreover, work in teams uses to be appreciated by students, but the research of Backlund & Garvare (2019) shown they feel more comfortable with an individual assessment within the group.

METHODOLOGY

To contribute to the scarce literature on stress and satisfaction in students, this research aims to assess both levels in a course conceived under the CDIO standards.

The method consisted of the design and distribution of a questionnaire to discover the opinion of the master's students attending to the Bioengineering Design and MedTech course, developed entirely under the CDIO practices.

The questionnaire had two sections. The first section collected information about the gender, country, the program they are coursing, and their previous formation. The second section had two different parts based on the level of agreement of the students about the causes of the stress level (first part) and the reasons for the satisfaction level (second part). The level of agreement was measured by a 1-7 Likert-scale (fully agree to fully disagree).

The section dedicated to the stress levels has partially followed the items designed by Spielberg (1994) in his *Job Stress Survey* (JSS) (Spielberger & Reheiser, 1994), adapting the stressors to the academic context. The JSS assesses the levels of stress measuring the severity and frequency of each of the 30 stress items.

The session devoted to the satisfaction levels includes items that have also been adapted from the study about job satisfaction of nurses, designed by Kekana et al. (2007).

The total number of students attending the course is 44 (31 from Bioengineering Design and 13 from MedTech), and the number of responses is 14 (10 from Bioengineering Design and 4 from MedTech). It is a reduced number, but it has the responses of two persons from every

team, to homogenize the levels of stress and satisfaction of all the teams. These two persons act as representatives of their teams. Table 1 shows the main characteristics of the sample.

The analysis of the responses from the questionnaire has been made with the assistance of IBM SPSS software. Stress and satisfaction levels were analyzed by means of a descriptive statistic. The descriptive statistic was completed with the correlation matrix. To keep the simplicity of the descriptive analysis, the most usual Pearson's coefficient was used. Correlation coefficients were obtained in three stages: firstly, the correlation matrix for the stress variables, secondly, the correlations between the satisfaction variables, and finally, the cross-correlations between the stress and satisfaction variables. Although the number of observations is very small (14), many significant coefficients have been obtained. These are indicated in the corresponding tables with a double asterisk.

Table 1. Profile of the respondents

Gender		Master		Country of previous studies		
Male	Female	Industrial Engineering.	Engineering Management	Spain	France	Perú
11	3	10	4	12	1	1

Table 2. Descriptive of the Stress level

		Mean	S. D.	Median
SS1	Team members not doing their job	1,642	,744	1,5
SS2	Inadequate support by professors	1,785	,699	2
SS3	Insufficient team members to handle assignment	1,571	,513	2
SS4	Lack of recognition for good work	1,571	,937	1
SS5	Frequent Interruptions in the course development	2,500	1,160	2
SS6	Dealing with crisis situations within the team	1,785	,801	2
SS7	Inappropriate behavior by my team colleagues	1,142	,534	1
SS8	Inappropriate behavior by professors	1,428	,937	1
SS9	Poorly motivated other teams in the course	2,214	1,050	2
SS10	Poorly motivated team colleagues	2,714	1,138	2
SS11	Lack participation in the course decisions	2,642	1,499	2
SS12	Difficulty getting along with professors	1,642	,928	1
SS13	Assignment of disagreeable duties	1,928	1,328	2
SS14	Inadequate quality equipment for doing the duties	2,357	1,392	2
SS15	Excessive paperwork of the assignments	2,642	1,549	2
SS16	Very tight delivery times	2,642	1,691	2
SS17	Assignment of increased responsability	2,571	1,504	2
SS18	Assignment of new or unfamiliar duties	3,785	2,006	4
SS19	Frequent changes in the assignments	2,928	1,859	2
SS20	Periods of inactivity	3,071	1,899	2,5
SS21	Working overtime	2,642	1,336	3
	TOTAL STRESS LEVEL	2,247		

RESULTS

Table 2 and Table 3 show the self-perception of the students about the stress and satisfaction level, respectively).

Regarding the stress analysis (Table 2), a low-stress level is appreciated (mean of 2,247 over 7), highlighting as the more stressful the *assignment of new or unfamiliar duties* (3,785), the *periods of inactivity* during the course due to breaks for exams or holidays (3,071), and the *frequent changes in the* assignments (2,928). On the other hand, the *inappropriate behaviors of their team colleagues* (1,142)*, or professors* (1,428), and the *lack of recognition for good work* (1,571), are hardly perceived as stress variables.

Table 3. Descriptive of the Satisfaction level

		Mean	S. D.	Median
ST1	Previous university studies	5,071	1,141	5
ST2	University contributing to my life	4,785	1,050	5
ST3	Mission and vision of this university	4,357	,841	4
ST4	The opportunity to have a variety in this course	5,142	1,657	5
ST5	The workload of this master's first year	4,285	1,637	4
ST6	The workload of this course	4,000	1,467	4
ST7	The help of the professors	5,642	1,598	6
ST8	The help of the team colleagues	6,071	,730	6
ST9	The sense of belonging to a team	5,357	1,215	6
ST10	The materials/equipment available in the course	3,928	1,730	4
ST11	The option of doing my favorite tasks in the team	5,428	,851	6
ST12	The cooperation within the team	5,571	,937	6
ST13	The professional ethics perceived in the course	5,500	,940	5,5
ST14	The interest in the projects developed	4,928	1,639	5
ST15	The ability to improve the methods used	5,285	,825	5
ST16	The possibility to discuss about the assignments	5,642	,633	6
ST17	My opinion is considered	5,928	,828	6
ST18	The attitudes of my team colleagues	5,714	1,204	6
ST19	The interaction with healthcare professionals	5,571	1,157	6
ST20	The commitment to the quality in the course	5,285	,825	5,5
ST21	Self- motivation for the good work	5,571	,851	6
ST22	The support of the professors	5,928	,997	6
ST23	The possibility of helping other colleagues	5,285	1,138	5,5
	TOTAL SATISFACTION LEVEL	5,229		

Analyzing the data of satisfaction (Table 3), it is possible to appreciate a high satisfaction level according to the values obtained (mean of 5,229 over 7). Between all these values, stand out

as causes of more satisfaction with the *help of the team colleagues* (6,071), the feeling of *personal opinion is considered* (5,928), and the *support of the professors* (5,928). By contrast, the *materials/equipment* available for the course (3,928), the *workload of the course* (4,000), or *the workload of the whole master* (4,285) were chosen as the causes of major dissatisfaction.

Table 4 and Table 5 show the correlation matrix between the stress variables and the satisfaction variables, respectively. Both matrixes have been simplified, showing the rows or columns exclusively where appeared a high statistically significant level.

Table 4. Correlations between the Stress variables

	SS4	SS5	SS6	SS10	SS11	SS12	SS13	SS14	SS17	SS19	SS20	SS21
SS1	0,315	0,489	,764**	,596*	0,359	0,469	0,205	0,132	0,059	0,091	0,019	0,017
SS2	,670**	,616*	0,323	,690**	,802**	,702**	,562*	,717**	0,272	0,461	0,186	0,323
SS4	1	,707**	0,073	,669**	,649*	,782**	,653*	,774**	0,241	0,467	0,148	0,114
SS5	,707**	1	0,455	0,466	,730**	,750**	0,374	,785**	0,485	,624*	0,506	,620*
SS8	-0,12	0,495	,643*	-0,16	0,336	0,366	0,026	0,227	0,358	0,24	0,413	,684**
SS11	,649*	,730**	0,251	,566*	1	,785**	,566*	,692**	0,234	0,377	0,172	0,507
SS12	,782**	,750**	0,406	0,478	,785**	1	,726**	,641*	0,322	0,43	0,103	0,261
SS16	0,526	0,411	-0,06	0,143	0,158	0,5	0,501	0,385	,751**	,676**	0,511	0,075
SS17	0,241	0,485	0,046	0,148	0,234	0,322	0,099	0,336	1	,868**	,819**	0,454
SS18	,561*	0,512	-0,17	0,409	,637*	0,492	0,34	,607*	,655*	,779**	0,489	0,457
SS19	0,467	,624*	0,144	0,353	0,377	0,43	0,06	,575*	,868**	1	,698**	0,484
SS20	0,148	0,506	0,112	0,117	0,172	0,103	0,063	0,484	,819**	,698**	1	,677**
SS21	0,114	,620*	0,282	0,079	0,507	0,261	0,028	,611*	0,454	0,484	,677**	1

** Statistically significant at the 0,01 (bilateral) level. * Statistically significant at the 0,05 (bilateral) level.

Table 5. Correlations between the Satisfaction variables

	ST4	ST12	ST14	ST15	ST16	ST17	ST18	ST19	ST20	ST21	ST22
ST2	,681**	,056	,839**	,076	,338	,069	-,052	,614*	,342	-,196	,058
ST4	1	,141	,684**	,418	,712**	,400	,138	,756**	,699**	,210	,193
ST7	,166	-,213	,019	,258	,320	,676**	,063	,119	,258	,105	,369
ST9	,240	,752**	,477	,274	,078	,256	,863**	,281	,350	,308	,530
ST10	,433	,217	,595*	,069	,326	-,004	,100	,751**	,339	-,179	-,092
ST12	,141	1	,479	,071	-,019	-,240	,837**	,314	,170	,041	,129
ST13	,345	,349	,324	,694**	,323	,345	,340	,565*	,793**	,672**	,779**
ST19	,756**	,314	,712**	,299	,614*	,286	,126	1	,782**	,267	,305
ST20	,699**	,170	,414	,548*	,652*	,482	,166	,782**	1	,735**	,681**
ST21	,210	,041	-,189	,516	,407	,498	,171	,267	,735**	1	,776**

** Statistically significant at the 0,01 (bilateral) level. * Statistically significant at the 0,05 (bilateral) level.

Between the correlations of both, the Stress variables (Table 4) and the Satisfaction variables (Table 5), it is possible to appreciate the great number of positive and highly significative correlations.

Attending to the results achieved in Table 4, some interesting relations can be highlighted, as the link between *the support of the professors* (SS2) and the *participation of the students in the course decision* (SS11), or how the *assumptions of responsibilities* by the students (SS17) make them see with critical eyes the *periods of inactivity* (S20) or the *frequent changes in the assignments* (S19).

Attending to the results achieved in Table 5 and with the focus on the highest correlations, it is possible to appreciate how students feel satisfaction when *university contributes to their lives* (ST2) in the sense of being able to *develop projects of interest* (ST14). Also, they feel satisfied with working in a team, when the *attitudes of the team members* are positive (ST18), as they strengthen the *sense of team membership* (ST9) and the *cooperation* principles (ST12).

Finally, this research has checked the correlations between stress and satisfaction levels (Table 6). This analysis has allowed identifying which variables can balance the relationship between stress and satisfaction. On this occasion, and as expected, most of the correlations are negative.

Table 6. Correlations between the stress and the Satisfaction variables

	ST2	ST12	ST13	ST14	ST19	ST20	ST21	ST22	ST23
SS1	-,204	-,677**	-,384	-,463	-,459	-,197	-,017	-,244	-,324
SS2	-,591*	-,151	-,526	-,618*	-,692**	-,685**	-,295	-,575*	-,593*
SS5	-,410	-,141	-,529	-,425	-,515	-,562*	-,467	-,698**	-,466
SS7	-,215	-,789**	,153	-,514	-,142	,249	,483	,309	-,072
SS8	,100	-,300	-,523	,021	-,455	-,568*	-,716**	-,458	-,124
SS9	,254	,022	-,428	,278	,018	-,342	-,663**	-,718**	-,055
SS10	-,505	-,412	-,503	-,754**	-,508	-,398	,102	-,358	-,703**
SS11	-,296	-,227	-,791**	-,387	-,538*	-,782**	-,671**	-,842**	-,657*
SS12	-,084	-,101	-,572*	-,170	-,296	-,559*	-,597*	-,860**	-,260
SS13	,098	-,088	-,400	-,073	-,071	-,261	-,301	-,701**	,015
SS18	-,498	,152	-,550*	-,403	-,340	-,657*	-,463	-,700**	-,510
SS19	-,678**	,158	-,330	-,481	-,444	-,537*	-,264	-,459	-,389
SS21	-,223	-,009	-,581*	-,188	-,604*	-,737**	-,618*	-,482	-,484

** Statistically significant at the 0,01 (bilateral) level. * Statistically significant at the 0,05 (bilateral) level.

Table 6 shows the reduced correlation matrix where it is possible to highlight the important role of the *support of the professors* (ST22) to counter the effects of the stress in the students, *encouraging their incorporation into decision-making* about the course (SS11), and *facilitating interaction with them* (SS12).

DISCUSSION

Despite the low-stress level perceived by the students, variables linked to ambiguity or uncertainty (*assignment of unfamiliar duties* or *changes in assignments*) are appreciated as stressors. This result match with previous studies where ambiguity had an important role in stress and dissatisfaction levels (Yehya et al., 2020). To minimize the stress levels, this study reveals that the *appropriate behavior of the team and professors*, and the *recognition for good work* are good allies.

The satisfaction analysis proves that the students need to feel valued and cared for by the ecosystem integrated by supervisors and colleagues to reach their satisfaction, and how if it happens, other aspects as the scarcity of *materials/equipment* or the *workload* become relegated to the second place.

The correlations between the stress variables demonstrate that when students feel confidents and supported by professors, they assume responsibilities and demand more commitment from everyone, even themselves, taking ownership of their projects.

In the same line, the correlations between the satisfaction variables show that students are pleased with Higher Education Institutions when they learn by doing exciting projects, and the teamwork is made in a cooperative environment. These results confirm the idea of designing collaborative spaces for millennials established by Karakas et al. (2015).

Finally, as the cross-correlations between stress and satisfaction variables demonstrate, the support of the professors takes an active role in balancing these variables. Professors are called to help to design an atmosphere of trust during the course where students can interact and participate in the decision process.

CONCLUSIONS

It has been shown that a low level of stress and a high level of satisfaction is perceived by the students in this course developed under the CDIO methodologies. These results encourage further work under CDIO practices, supporting teamwork and the students' participation in making decisions about their assigned projects. The analysis also demonstrates the need for more significant commitment from professors, whose support for the teams has been shown to be essential to balance the stress and satisfaction levels.

Despite these favorable results for the CDIO practices, it is necessary to mention that this study has been made in the middle of the semester, and the designs of the products were in an early phase. An increment of the stress level is foreseen during the last days of the course when the students must present their final prototypes.

Likewise, to be able to generalize the conclusions drawn, it would be necessary to carry out this research with a larger sample and incorporating students from other courses under the CDIO methodologies to complement the study contrasting through an analysis of variance.

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IMPROVING THE IMPLEMENTATION OF A FIRST-SEMESTER PROGRAMMING COURSE

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ABSTRACT

The flipped classroom (FC) is a form of active learning in which in-class and out-of-class activities are flipped: students are expected to study a specific material outside the class and then be able to apply the knowledge to complete various activities related to the material during class under the guidance of an instructor. FC is often used together with team-based learning (TBL), where students work in teams to apply their knowledge as opposed to working individually on activities. During that last two years (2018 and 2019), the Department of Computer Science at Reykjavik University has experimented with applying FC and TBL in the first-semester programming course. In previous publications, we have described our experience using FC and TBL during the first experimental year (2018), i.e., the motivation for restructuring the course, the implementation, the results of two student surveys, and the outcome of several exams. In this paper, we describe the improvements made during the second experimental year (2019), both with regards to the online learning material and the course assessment. Furthermore, we compare the outcome of student surveys between the two years as well as students' performance on various exams. The results of a student survey given in the second year show that students' attitudes towards the FC approach were much more positive compared to the previous year. We argue that this is due to the specific changes made to the online material and the assessment of programming projects in class. Finally, it is interesting that the failure rates in the course in 2019 are much lower than the failure rates in 2018.

KEYWORDS

Flipped classroom, team-based learning, first programming course, Standards 7, 8

INTRODUCTION

When teachers move from traditional lecturing to a more active learning environment, they have many different pedagogic options to study, customize, and implement. The aim of redesigning a course, maybe to increase students' interest in their study, their engagement, activity, knowledge, and skills needed for them to be successful in their search for further

educational development. Flipped classroom (FC) is one way of activating students in the learning process with its learner-centered focus, where direct instruction is replaced with effective out-of-class work and different learning activities in the classroom with the teacher as the facilitator. The learning activities that used to happen outside the classroom are now inside the classroom and vice versa.

Mclaughlin, Roth, Glatt, Gharkholonarehe, et al. (2014) recommend FC as an achievable and essential educational model when educating a large group of students. There seems to be no single model for the FC, but we can identify three main parts in the model: the out-of-class/before class activity, usually supporting individual learning, the learner-centered classroom activity often with group work, and the assessment and evaluation of the learning.

A thoughtful design of pre-class learning activities is needed for FC, where students have an opportunity to gain information and knowledge before the class activity. Today, the course material can be in a diverse format, e.g., traditional textbooks/papers or more modern e-textbooks/papers and videos for the students to explore and develop new skills and ideas from, on their own or with peers. Research has shown that students claim they do not use the textbook as expected to prepare for class, but videos are highly regarded and considered useful to prepare for class and gain an understanding of the subject (Matthíasdóttir and Loftsson, 2019). Nevertheless, a study by Cheah, Sale, and Lees (2017) revealed that watching videos before class can be boring. Research has also shown that "it's not the instructional videos on their own, but how they are integrated into an overall approach, that makes the difference" (Tucker, 2012, p. 82). Watching educational videos corresponds to Bloom's taxonomy lowest levels of remembering and understanding (Slavensky, 2019), but can be at higher levels if followed by complementary activities.

It is important to connect out-of-class activities to in-class activities and organize the students' work well. In the classroom, use of team-based learning (TBL) is a known way to organise a FC, in which students work in groups on projects and other applied activities. Number of interactive activities can be used with both individual and collaborative actions, e.g. project work, case studies, active discussions, presentations and quizzes. Group work can support cooperation and build a learning community where students can learn from each other. All this is to support active learning and knowledge application (O'Flaherty and Phillips, 2015) and reach higher levels of Bloom's taxonomy.

Evaluating student-learning outcomes is important, and the assessment methods have to be consistent with the teaching and learning methods. Some studies of FC have revealed that the pass rates have not improved at first when using FC (Gommer, Hermsen & Zwier, 2016; Loftsson and Matthíasdóttir, 2019), but others have shown higher course grades (Wilson, 2013; Mason, Shuman, and Cook, 2013).

Finelli et al. (2018) point out that concerns about students' resistance, defined as "negative behavioral responses to active learning," is one of the barriers faced by teachers when adopting active learning methods. Other barriers mentioned are, for example, the efficacy of the methods, teacher preparation time, and the ability of the teacher to cover the course syllabus. Deslauries et al. (2019) identify an inherent student bias against active learning that can limit its effectiveness and may hinder the wide adoption of these methods. They show that students in active classes perceived that they learned less, compared with students in traditional lectures, while in reality, they learned more.

During that last two years, the Department of Computer Science (DCS) at Reykjavik University (RU) has experimented with applying FC and TBL in the first-semester programming course. In previous publications (Matthíasdóttir and Loftsson, 2019; Loftsson and Matthíasdóttir, 2019), we have described our experience using FC and TBL during the first year (fall 2018), i.e., the motivation for restructuring the course, the implementation, the results of two student surveys, and the outcome of several exams. In this paper, we describe the improvements made during the second year (fall 2019), both with regards to the online learning material and the course assessment. Moreover, we compare the outcome of student surveys between the two years as well as students' performance on various exams. The improvements made to the course during the second year were influenced by the experience of the students and the teachers during the first year, and the authors' research (Matthíasdóttir and Loftsson, 2019; Loftsson and Matthíasdóttir, 2019).

COURSE IMPLEMENTATION

In this section, we describe the implementation and the assessment in the 12-week first-semester programming course in the DCS at RU in the fall semester 2019. In the last two years, Python has been used, whereas previously, C++ had been used for many years. At the start of the course in the second experimental year (fall 2019), 390 students were registered. The students were divided into seven sections and then into groups of 5-6 students within each section, which met in class twice a week for 4*45 minutes. Each class had one teacher and one teaching assistant as facilitators and tutors.

The course implementation in the first experimental year (fall 2018) has been previously described in Loftsson and Matthíasdóttir (2019), on which the implementation in fall 2019 is based. In what follows, we repeat some of the individual items from that paper, but we specifically note the changes made during this second experimental year:

- In advance of most of the classes, students were expected to read a given chapter of the textbook (Punch and Enbody, 2017). Results from surveys in 2018 had shown that a large proportion (45%) of the students never or seldom read the textbook (see section RESULTS). This result was consistent with the fact that the teachers felt that many of the students did not come sufficiently prepared for classes. Therefore, this year the teachers specifically emphasized the importance of reading the textbook before coming to class.

- At the beginning of each class, a video (15-25 minutes) was shown in each of the sections. The purpose of the videos, made by the main instructor, was to be supplementary material for the given textbook chapters. In the previous experimental year, the students were expected to watch short videos (5-10 minutes each) before coming to class. These videos were a selection from YouTube made by various people (but not the main instructor). The reason for this change in 2019, i.e., showing a video made by the instructor at the beginning of each class, as opposed to expecting students to watch a short video before coming to class, was that our surveys in 2018 (see section RESULTS) showed that many students wanted some traditional lecturing in the course, specifically from the main instructor.

- After the video had been played, students were given a short quiz (in most of the classes), containing ten multiple-choice questions, which were directly linked to the given textbook material and the video. After this individual quiz, students discussed the same quiz in groups and handed in the groups' answers.

- For the remainder of the class, students were given several short programming assignments for practicing the specific concepts. Students worked on these assignments in groups, but each student needed to submit his/her solution at the end of class. These programming assignments were automatically graded using test cases. In fall 2018, each student received a programming grade at the end of each class, which was then accumulated over the whole semester as the overall class programming grade for the student. In contrast, in fall 2019, students only needed to obtain 50% "green tests" over the whole semester to receive full marks for the programming part of the class. The reason for making this change is that in 2018 many students felt that there was too much pressure on submitting the solutions to the programming assignments in class and that they were always competing against the clock in order to submit before the class finished. By only demanding that students fulfilled 50% of test cases over the whole semester, this pressure disappeared, and students were able to concentrate better on the assignments without having to worry about the time running out.

- In addition to the short programming assignments given in class, students were given larger programming projects each week to work on at home, optionally in a group of two students.

- In addition to the video shown at the beginning of each class, in fall 2019 (but not in 2018), the main instructor made several videos, for the student to watch at home, that demonstrated how to break a problem description into individual tasks and implement functions for those tasks (i.e., apply functional decomposition).

- In the first experimental year (2018), two midterm exams, a final exam, and a retake exam were given in the course. In the second year (2019), the third midterm exam was added. All the exams were "open book," i.e., students were allowed to use the textbook, slides, notes, and solutions to assignments in the exam. Grades are given on a 0–10 scale, and a grade below 5 is a fail. In 2019, two best out of three midterm exams counted towards the final grade, compared to the better ones out of two in 2018. The learning material (see Loftsson and Matthíasdótttir, 2019) for the first two midterm exams, as well as the final exam, was similar between years.

The course assessment in 2019 was the following: 1) Quizzes (individual and group) in class: 10%; 2) short programming assignments in class: 10%; 3) homework programming projects: 20%; 4) three midterm exams (two best counted): 20%; and 5) final exam: 40%.

Canvas (www.canvalms.com) is RU's learning management system (LMS), Piazza (www.piazza.com) was used for questions and answers in the course, and Mimir Classroom (www.mimirht.com) for administrating quizzes, assignments, projects, and exams.

METHOD

A survey was conducted in fall 2019, based on a survey from the previous year (Matthíasdóttir and Loftsson, 2019; Loftsson, Matthíasdóttir, 2019) with some minor changes of wording.

Participants

The participants were the 390 registered students, out of which 251 (64.4%) answered, 159 (63.3%) males and 92 (36.7%) females. The average age was 23.7 years, ranging between 18 and 47 years. Most students, or 185 (73.7%), were first-semester students, 103 (41.0%)

students rated their programming skills prior to the course very little or little, and 45 (17.9%) students rated it as great or very great.

Measures

The online survey consisted of 26 questions, out of which 22 were from the previous year's survey (described in Matthíasdóttir and Loftsson, 2019). The background questions were the same; about gender, age and semester, and one about computer skills. Four new questions were added to obtain better information and understanding of the students' attitudes: "*I like FC in this course," "I like the organization of the programming assignments in class (50% submission)", Programming assignments in class are consistent with the class material",* and "*Weekly homework programming projects are consistent with the class material".* All the questions were rated on a five-point Likert scale, ranging between "Totally disagree" and" Totally agree."

Procedure

The system Free Online Surveys (https://freeonlinesurveys.com) was used to put the survey online and a link sent to the students by e-mail in the 10th week of the course. Excel and the Statistical Package for the Social Sciences (SPSS) were used for data analysis.

RESULTS

In this section, we present the results of the individual questions from the two surveys conducted in the first (2018) and the second (2019) experimental year. Furthermore, we present students' performance on various exams for two years.

Surveys 2018 and 2019

Table 1 shows the results of the questions administered in both 2018 and 2019. The first column lists the individual questions, and the second and third columns show statistics for 2018 and 2019, respectively. To see the development in the participants' answers, an independent t-test was used to compare the means from the two surveys. Table 1 shows that the difference was significant for ten questions.

As Table 1 shows, the main difference between the two years seems to be regarding the use of the textbook (see questions no. 3 and 4). Both questions indicate more use of the textbook in the second year.

Table 2 shows the participants' answers to the four new questions. For all the questions, the majority of the students agreed with the corresponding statement.

Exams

The results of all the exams conducted in both years are shown in Table 3. The "Students" column shows the number and the ratio of students (the number of students that showed up divided by the number of registered students) that showed up for the given exam.

Table 8: Results of survey questions presented in both experimental years, 2018 and 2019.

	2018	2019	
Questions	**Mean (SD) (N)**	**Mean (SD) (N)**	**t-value**
The organization of the course is good	3.2 (1.2) (179)	3.6 (1.0) (244)	-3.94***
The class hours each week are useful to me	3.3 (1.3) (178)	3.6 (1.2) (248)	-2.08*
The book of the course helped me in my study	2.6 (1.3) (179)	3.4 (1.2) (245)	-5.97***
I usually read the book before class	2.8 (1.4) (179)	3.4 (1.5) (247)	-4.23***
The videos in the course helped me in my study	3.6 (1.2) (178)	3.5 (1.2) (248)	0.59
I watch the video that I should watch before or after the class	4.1 (1.2) (179)	3.9 (1.2) (251)	1.51
I miss traditional lecturing in the course (minor changes)	3.4 (1.5) (179)	3.1 (1.5) (248)	2.32*
I like the organization of the short exams at the beginning of class (take the exam alone and then with others)	3.2 (1.3) (179)	3.3 (1.3) (259)	0.70
I like the arrangements of the midterm exams (two out of three are graded)	4.4 (0.9) (179)	4.4 (0.9) (249)	-0.14
To discuss with fellow students in class helped me to study	3.6 (1.3) (179)	4.0 (1.1) (249)	-3.58***
To discuss with fellow students outside the class hours helped me study	3.7 (1.3) (179)	3.9 (1.1) (249)	-1.64
I like to work in a group with fellow students	3.6 (1.3) (178)	3.9 (1.2) (252)	-2.14*
Communications with teachers in class help me to study	3.7 (1.2) (179)	3.6 (1.3) (252)	1.26
I liked to use Canvas in my study	4.0 (1.0) (179)	4.0 (1.0) (249)	-0.32
I liked to use Piazza in my study	3.6 (1.2) (179)	3.8 (1.2) (252)	-1.45
I like to use Mimir in my study	3.9 (1.1) (179)	4.3 (1.0) (252)	-3.69***
This course is overall a good learning experience	3.5 (1.3) (179)	3.8 (1.2) (250)	-2.43*
I have done well in this course	3.3 (1.3) (179)	3.7 (1.2) (251)	-2.89**

*p<0.05, **p<0.01, ***p<0.001

Table 9 Answers to the four new questions

	Totally disagree and disagree N (%)	**Neutral N (%)**	**Totally agree and agree N (%)**
I like FC in this course	55 (22)	61 (24)	134 (53)
I like the organisation of the programming assignments in class (50% submission)	31 (12)	39 (16)	180 (72)
Programming assignments in class are consistent with the learning material	43 (17)	35 (14)	174 (69)
Weekly return assignments are consistent with the class material	70 (28)	50 (20)	130 (52)

Table 10: Results from all exams in 2018 and 2019

Exam	Students	Average grade	Failure rate
Midterm 1			
2018	281 (86.5%)	7.1	19.9%
2019	346 (88.7%)	8.5	8.1%
Midterm 2			
2018	227 (69.8%)	6.3	36.1%
2019	323 (82.8%)	6.0	39.6%
Midterm 3			
2019	263 (67.4%)	5.6	41.8%
Final			
2018	279 (85.8%)	4.4	55.6%
2019	304 (77.9%)	5.9	33.9%
Retake			
2018	133 (40.9%)	5.4	41.3%
2019	91 (23.3%)	4.0	51.6%

DISCUSSION

Surveys

In what follows, we discuss the ten questions from Table 1, for which the difference in means was statistically significant.

- *"The organization of the course is good" and "This course is overall a good learning experience":* The results of these two questions show that students were more positive towards the organization and the teaching methods of the course in 2019, in comparison with 2018. We believe that this is due to the main changes made to the course in 2019:

    1. The videos made by the main instructor, both the ones that were shown at the beginning of each class, and the ones about functional decomposition to be watched at home.
    2. The change in submissions of class programming assignments (50% green tests).
    3. Making two best midterms out of three counts towards the final grade, as opposed to the better one out of two.

- *"The class hours each week are useful to me:"* The students in 2019 felt that the class hours were more useful to them compared to the students in 2018. This may be explained by the videos shown at the start of each class in 2019, and a possible reduced submission pressure of class programming assignments.

- *"The book of the course helped me in my study "and "I usually read the book before class":* It is evident from the answers to these two questions (and the t-values) that the students responded well to the emphasis that the teachers made in 2019, regarding the importance of reading given chapters of the textbook before coming to class.

- *"I miss traditional lecturing in the course":* Almost half of the students agreed on this question in 2018 (Matthíasdóttir and Loftsson, 2019). Consequently, we decided to introduce videos, made by the main instructor, at the beginning of each class in 2019. In the strict sense, these videos do not constitute traditional lecturing (because the videos were recorded in a studio, but not in a lecture hall with students present). Nevertheless, by making the videos the students were at least able to see how the main instructor presented the learning material. The mean of students' answers to this question is significantly lower in 2019 compared to 2018, which indicates that these recorded videos can, at least partly, replace traditional lecturing

- *"To discuss with fellow students in class helped me to study" and "I like to work in a group with fellow students":* Evidently, the students in 2019 agreed to a larger extent to these questions than the students in 2018. It is difficult to explain the reason for this change, but it is possible that the students in 2019 felt more at ease in class because of the change in the submission of the class programming assignments.

- *"I like to use Mimir in my study":* Mimir is the web-based solution that we use for administrating and grading quizzes, assignments, projects, and exams. There is a very significant change in the positive attitudes of the students between the two years in using Mimir. We do not have a specific explanation for this.

- *"I have done well in this course":* On average, the students in 2019 felt that they had done better in the course compared to the students in 2018. It thus seems that there is a correlation between the increased positive attitudes in the course and how well the students feel that they are performing. In the section on Exams below, we also see that the failure rate decreased significantly between the two years.

The results from the four new questions (presented in Table 2) show that the majority of the students (53%) liked the FC in the course. A large majority of the students (72%) liked the organization of the programming assignments in class and felt that the assignments/projects were consistent with the learning material (69%). Although 52% of the students felt that the weekly homework assignments were consistent with the learning material, still 28% of the students disagreed. FC is a new method for most if not all students in this course, and our experience, surveys, and exam results indicate that we are on the right track with FC.

Exams

A discussion about the exam results in 2018 has been presented in Loftsson and Matthíasdóttir, (2019). Here, we discuss the main differences in the results between the two years.

- First, the average grade in the first midterm in 2019 (8.5) is significantly higher than in the previous year (7.1), and the failure rate in 2019 significantly lower than in 2018. We believe that this is due to the fact that one of the assignments on the first midterm in 2019 was mistakenly made too easy, compared to a corresponding assignment on the same midterm in 2018.

- Second, the ratio of students showing up for the second midterm in 2018 (69.8%) is much lower than the corresponding rate in 2019 (82.8%). This can be explained by the fact that in 2018, two midterms were given and the higher one counted towards the overall midterm grade. Thus, many students that scored high on the first midterm exam decided not to show up on the second exam. In contrast, in 2019, three midterm exams were given, of

which the two highest counted. This also explains why the ratio of students showing up in the third midterm exam in 2019 (67.4%) is low compared to the corresponding ratios in the first and second midterm exams in 2019 (88.7% and 82.8%, respectively).

- Third, the most striking difference is in failure rates on the final exam between the two years. In 2019, the failure rate was 33.9%, whereas in 2018, it was 55.6%. In Loftsson and Matthíasdóttir (2019), the authors argued that the main reason for the exceptionally high failure rate in 2018 was the inability of many students to apply functional decomposition, i.e. break a problem description into individual tasks and implement functions for those tasks. Therefore, during the running of the course in 2019, a larger emphasis (compared to the previous year) was made on practicing this skill. In particular, the main instructor made several demonstrative videos in 2019 that showed how to apply functional decomposition. Another important factor, which explains much lower failure rates on the final exam in 2019, is that in 2018 the students were not given any practice exams. In 2018, the Python programming language was used for the first time in the first-semester programming course in the DCS at RU. Therefore, no previous Python programming exams at RU were available for the students to use as preparation material. On the other hand, in 2019, students were able to use both the final exam and the retake exams from 2018 in their preparation for the final. Additionally, two other practice exams, which were made for the students that needed to take the retake exam in 2018, were available for the students that took the final exam in 2019. Thus, four exams in total were available for the students before the final in 2019 compared to none for the students in 2018. Finally, much lower ratio of students needed to take the retake exam in 2019 (23.3%) compared to the ratio in 2018 (40.9). This is due to the fact that the failure rate on the final exam in 2018 was much higher than in 2019.

CONCLUSION

Engineering and computer science education is shifting away from traditional teacher-based format to a more learner-based format using different pedagogical approaches (Mason, Shuman, and Cook, 2013) that we could even call a more modern method. FC is one of the options because it offers the opportunity to emphasize an integrated learning experience and active, experiential learning methods in line with CDIO standards 7 and 8. The question educators are asking is how to organize FC in our environment? In this paper, we have discussed an experiment over two years in applying FC in a first-semester programming course where the development of the organization of the teaching and learning has taken in account the students' views and attitudes. The survey conducted in the second year the FC was used, after the improvements of the implementation of the course, does support the work that has been carried out and encourages the faculty to continue with developing the FC further.

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BIOGRAPHICAL INFORMATION

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STUDENT´S JOURNEY AND PERSONAL DEVELOPMENT IN AN ENGINEERING PROGRAM

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ABSTRACT

Student's journey through the engineering educational program is academically demanding, and along the way, the student is required to develop professional interpersonal skills. To promote student's positive journey, the engineering program at Reykjavik University (RU) implemented an intense two-day event called Disaster Days, normally occurring in the fourth or fifth week into the first semester. In this event, students are challenged with a simulated disastrous situation where they have to face a sudden complex event that must be tackled in a single day. In this study, we used semi-structured interviews to ascertain to what extent the event affected the student´s journey through the engineering program. Emerging clearly from these interviews with 15 students is that the students like this brief shift from the traditional individualistic learning environment, they value being confronted with group work with new people and that the event opens doors for a lasting social network. In particular, this experiential learning event has proved fruitful for developing the student's appreciation for group work. These interviews show that we can confidently conclude that this immersive short event provides a good start for the student's journey throughout the engineering program at RU and is arguably an important part of the curriculum to enhance interpersonal skills.

KEYWORDS

Student's journey, experiential learning, interpersonal skills, group work, integrated learning, student's well-being, networking, Standards 7, 8

INTRODUCTION

In the OECD framework for measuring well-being, education, skills, and social connections are part of eleven dimensions of well-being (OECD, 2015). This should guide educational work with the aim of offering students an environment that supports their well-being by emphasizing studying that offers time for socialization. Student's well-being is affected by many factors in the learning environment, such as the pedagogy employed, projects, learning material, and the structure of the study program. The social aspect of learning, like cooperation and relations with both teachers and fellow students, is also of importance. It has been well documented

that the first-year student experience is important for student´s success, and in particular, students that develop a social network are more likely to succeed in their studies (Wilson, 2009; Kavanagh, Clark-Murphy and Wood, 2011).

In an effort to implement certain interpersonal development and improve student's well-being, the engineering program at RU has run a two-day intensive event early in the first semester of the program, called Disaster Days. The event is described to some extent later in this paper. The objective of our study is to ascertain if and then to what extent the two-day Disaster Days affects the student's journey through the engineering program, including teamwork, social network, and well-being. This was done by taking semi-structured interviews with students that had participated in the event, i.e., earlier in the same semester, one year earlier and two years earlier. Information obtained in this study can guide the faculty in developing Disaster Days further and strengthen the focus on students' well-being.

Experiential Learning

Pedagogically the authors place the event Disaster Days in the domain of experiential learning theory (ELT) were the student is educated by stimulating his intelligence based on learning by experience and reflection (Dewey, 1938). Another important driver for our implementation and development of Disaster Days is the CDIO learning model. The CDIO engineering education model emphasizes that students learn in the form of organic connection between active application and course participation. It emphasizes "learning by doing" with the whole process of the project life cycle as the carrier. Moreover, this learning model is intended to cultivate students' engineering ability, personal, professional morality, academic knowledge and the ability to use knowledge to solve problems by nurturing interpersonal skills (CDIO, 2019). It is necessary to emphasize group work and teamwork in engineering education as it is seen as a crucial ability at the company level as employers emphasize that engineers need good communication skills and be able to work well with co-workers (Lingard and Barkataki, 2011; Borrego, Karlin, McNair and Beddoes, 2013; Bergman et al., 2017). According to Duhigg (2016), it is not easy to find the best recipe for a "good" group, and he states, "In the best teams, members listen to one another and show sensitivity to feelings and needs." (Duhigg, np, 2016). In schools, good and successful work cannot be taken for granted, as there are many factors that influence the group work, e.g., transfer of knowledge, social support, attachment, and individual characteristics (Lavy, 2017). Experiential learning is part of the paradigm that shapes the education of engineering students in some universities. A noteworthy example is the participation of the authors in the Erasmus+ project Dahoy were several universities collaborate to establish a learning framework based on the experiential learning approach (Gaultier Le Bris et al., 2017).

Disaster Days

Disaster Days have been part of the engineering programs at Reykjavik University (RU) since 2011, now implemented as a two-day intensive course early in the first semester (Saemundsdottir, Matthiasdottir, Audunsson and Sævarsdottir, 2012; Audunsson, Fridgeirsson and Saemundsdottir, 2018). The purpose of the event has been to break up a long semester, enhance interpersonal skills, and provide an early opportunity for students to become acquainted with students in the same field of study. In this event, students are challenged with an unexpected simulated disastrous situation that must be tackled within teams and in a single day. The event is designed in such a way that the scenario awakens the students'´ interest, and teamwork appears as a natural way to tackle the situation.

Four or five weeks into the first semester, Disaster Days start on Wednesday afternoon with an hour of short lectures on teamwork and on the importance of being able to do back-of-the-envelope calculations. The same day students are put in groups, typically six students in each and from the same engineering discipline. Faculty members are involved, such that each one is a mentor for about five or six groups. Early on Thursday morning, all students gather in an auditorium, and the unexpected disaster is introduced as a dramatic short news bulletin video made in cooperation with a local TV station. This kick-off event gives the disaster and the task at hand a more realistic flavor and urgency. The scenario unfolds throughout the morning with several fresh news text bulletins to keep up the volatile and agile atmosphere. All Thursday, students work in teams, and at the end of the day, there is a short lecture on presentation methods. On Friday morning, the teams work on summarizing results and prepare for presenting their results to fellow students in the early afternoon. The presentations are run in often five parallel sessions, about seven teams in each, and take in total one hour. When the presentations are completed, the event is over. A more detailed description of Disaster Days can be found in Audunsson et al. (2018). Figure 1 shows one team in action.

The scenario presented to the students at the beginning of Disaster Days in fall 2019 was as follows: Breaking news - a very contiguous pandemic started out simultaneously in several of the world´s largest cities, it spreads fast and has a very high fatality rate. The task was to design the first reaction in Iceland, how to isolate the island from the pandemic, possibly divide the country into several quarantine areas, and estimate if and how the nation could survive in isolation for possibly a few months. In the previous two years, 2017 and 2018, the events focused on sudden local volcanic eruptions.

Figure 1. One of the teams working during Disaster Days fall of 2017.

METHOD

A qualitative research approach was chosen, with semi-structured interviews and open questions. A qualitative research approach strives to explore and understand the meaning individuals or groups ascribe to a social or human problem. This method was believed to provide better insight and understating of student perceptions and experience of Disaster Days.

Participants

Interviews were conducted with engineering students that had taken part in Disaster Days. The students were selected randomly by asking them to participate when they were in class, so they are a convenience sampling drawn from the population that was close to hand. A total of 15 students participated, six males and nine females, and they were in their first, second, and third year of study for BSc in engineering (5 from each year).

Measures

Four open questions were used to guide the interview, but students were encouraged to describe their experience with their own words. We asked them to reflect on the event, and we left it completely up to them how and what they preferred to talk about. The questions were:

1. How did you experience Disaster Days? Not how the event was conducted, but more how it affected you.
2. Did you find Disaster Days affected your vision of engineering as a subject and on engineering work?
3. Tell me if your stay in RU changed after the event, e.g., social life, friends, cooperation, or well-being.
4. Anything else you would like to mention about the Disaster Days?

Procedure

The interview started with a short introduction to the purpose of the interview and asking for permission to record the audio of the interview. The students were asked to state their names, study lines, and a semester at the beginning of the recordings. Each interview lasted 5 to 10 minutes and took place in a quiet room provided by the authors. Two of the authors were present in all of the interviews, and the same person asked the questions in the same manner in all the interviews.

RESULTS AND DISCUSSION

Analyzing the perception and experiences of these students provided information that can guide both further development of engineering education at RU and be valuable to others who plan to implement the concept. Three themes emerged from the analysis of the interviews, as discussed in the following sections: 1) the enjoyment of breaking up the normal agenda, 2) the importance of teamwork, and 3) the benefit and pleasure of meeting and working with new people.

The Enjoyment of Breaking up the Normal Agenda

The first-year semester in university can be a tough learning experience, and as shown by Baker et al. (2007), this experience influences their decision to become engineers and Balakrishnan and Low (2016) emphasize the importance of providing students positive learning environment as it influences whether students will complete their study or not.

Almost every student stated early in the interview that participating in the event was truly enjoyable. The reason we emphasize truly is that the students iterated this one way or another during the interview and explained why. In addition, many students mentioned that solving the

open-ended assignment of Disaster Days and using their creativity was a welcome change from the normal course of study. They felt a bit of a relief to break up the normal course of study, sitting in lectures and the like, and have the opportunity to do something very different, and they were much more engaged in what they were doing. This is revealed in the following comments from three students:

“I found it very enjoyable, it's nice to do something else than just read books, and things like that”

"Yes, I here ... I felt this a nice change from here ... the first semester is kind of difficult, kind of a lot of stress at every stage. Good to break up that week and everyone was in a good mood…. just satisfied”

“These two days I was one hundred percent engaged, totally different from normal lectures when I dropped out soon after the lecture started”

These comments by the students are in line with results from Murphy et al. (2006), that short icebreaker immersive events at the beginning of an introduction to engineering course were most popular among students, for their duration and that the students were removed from their usual learning environment.

The Importance of Teamwork

It was clear from the students’ answers that they generally had a positive experience of teamwork and valued the experience of being confronted with working with new people. Several students mentioned that this was in contrast with their earlier experience in high school when they were used to work with their familiar classmates and friends. It was unexpected how often they mention how lucky they felt with the group members as if they had won the lottery and the benefit of friendly group members that would discuss and work well together from the first moment. Although experienced as a challenge by the students, this was considered a good learning experience and even the highlight of Disaster Days as these two students said:

"It was really fun to work in a group like this, and this was really the first time I worked with someone else, not just the one you chose but you were put in a group with someone you didn't know, and so on.”

“ ...this was something different, got you to work in a group, chat together and ... but it also was difficult, you had to agree without necessarily agreeing, being able to reason without being dissatisfied. "

Group work is not always easy and can put a strain on the members, especially if they are not all motivated and ready for hard work. This was reflected also in students comments although most of them were satisfied they were not all happy with the experience of the group work as this student said:

“I sometimes have difficulty working in a group …. But I wanted to do this well, is just that, conscientious, but it wasn't necessarily a lot of interest in the group… they saw it more as an opportunity to have fun.

The students had preconceived notions of what engineering is about and they were quite confident that their study lays the groundwork for future professional life. Therefore, they considered it of great importance to be prepared for teamwork and be ready to work with people you do not know. This notion is stated in these comments:

“in the future you work in groups and you just have to learn and train for it”

“It's kind of weird at first to have to work with strangers, but it prepares you for what is to come, needs to be ready to work with everyone and to get started right away."

Although students believe they know what engineers do, they did often mention that Disaster Days strengthened and confirmed their idea of how engineers work, gave them better insight and they were quite happy to have the opportunity to train skills such as reasoning, debate and draw conclusions from the discussion within the team. Connection to real life is important, and Disaster Days are an opportunity for the students to work with open-ended projects that do not have one final solution like this comment presents:

“And also very nice that this was not too clear task, you had to decide for yourself how to do this ... we are just so used to getting an example to calculate, and know exactly how to do it, but this was kind of more open, and we got more to use our imagination”

The Benefit and Pleasure of Meeting and Working with New People

The students appreciated the opportunity to get to know new people, and they mentioned several reasons for this. One is that this was a splendid opportunity to meet students in their own field of study, that they made new friends that they were able to sit next to in lectures and greet them in the hallway. They also mentioned that the team would become a kind of support base, both socially and in their study, and formed an integral part of their study network. Also, having worked so personally with members of the team, somehow, they felt more comfortable in the study program. Students that did not know anyone when they started the program at RU stated that this event and the teamwork was very beneficial for them.

The students did not only get to know new people in their working group, but they also established a friendship during Disaster Days that lasted after the project finished, or as these students said:

“There I met 6 new people I can chat with and greet in the corridors. You made new friends and things like that. "

“And yet to this day we are good friends, it was fun getting to know more people in the course ... I greet all these people today, and I did not know them … This was a great choice for me, it was the first group work project in college, but in high school, it was good for friends to work together in a group. So it was really fun to ... throw you in the deep pool and work with people you haven't worked with before. "

The event in Disaster Days is selected, and its unfolding is designed in such a way that it hopefully entices the students to get actively involved and that teamwork appears natural in solving the open-ended task, in part done by the urgency and relevance. Experiential learning, as used here, appears to be appropriate in learning and appreciating teamwork, and based on the interviews, the students may even reflect on their teamwork with fellow students long after the event. Although we chose to use the term Disaster Days for this event, some sort of VUCA-

type (Elkington, van der Steege and Moss Breen, 2017) of an event may work as well (Audunsson et al, 2018), something with urgency and which automatically leads to teamwork.

CONCLUSION

This event, Disaster Days, is in the spirit of CDIO's emphasis on integrated learning, different learning styles, and engagement. Although the event is only two days, the students were introduced to a relevant engineering task, which is designed such that it is best approached through teamwork.

The interviews with 15 students analyzed in this study were designed to probe the long term effect of Disaster Days, from two months to two years, including teamwork, companionship and well-being, and the student´s journey in the engineering program.

Direct remarks in the interviews show clearly that the students value in particular the experience of teamwork. Although some of them mentioned that working in a group with new people was challenging, they felt it prepared them well for professional work. Secondly, the individuals they worked with so intensively in their teams frequently became, to some extent, their support base at school, both socially and as part of their study web, and hence the event helped most of the students to either build or enhance their social network. Thirdly, the enjoyment of breaking up the agenda of normal learning routine during the first semester and taking part in something new and unexpected, in this case, tackling a disaster as an engineering task, was mentioned by almost all the interviewed students. Reflecting on the event in the interviews almost always brought back some positive remarks. Based on these three themes, we are confident to conclude that the event provided a good start for the students' journey in the engineering program.

It is interesting to note that the students gave the same impression independent of if they had participated in the event only two months earlier, one year or two years. If this is significant and to what extent Disaster Days affect students in the long term, like after graduation, it is of interest and may call for further studies. It must be noted that although this study and several end-of-course evaluations by students seem to consolidate that Disaster Days have a positive impact, the results have not been tested for cognitive biases.

In short, placing a short, two-days, an event like Disaster Days early in the first semester in the engineering program provides a positive start for the students' journey for the upcoming years in their study, both for academic advancement and for interpersonal development and well-being.

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VERIFICATION OF EDUCATIONAL EFFECT FOR INNOVATION PRACTICE ON ELECTRICAL TECHNOLOGY

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ABSTRACT

There is a need to develop human resources who can play an active role in the intense competition of international society. We created a practice in which students acquire fundamental competency by working on electrical technologies in a virtual company. By starting a mock company on their own, the first aim for students is to learn basic company management, the second aim is for them to acquire the skills required as a member of society, and the third aim is for them to gain knowledge about the latest technology in the field of electrical technology. Students learn about company management systems through participation in administrative procedures such as manufacturing, sales, personnel and accounting practices. In order to establish a company related to electrical technology, it is necessary to analyze cutting-edge technologies in each field (electric power, electronics, robots, AI, IoT, entertainment, etc.), and second-year students can begin their investigation, which is the same as learning about research backgrounds previously conducted primarily in graduation research. The mock company requires a collection of capital and performs all costs related to the business using a virtual currency called ANET Coins. Teachers make investments as shareholders or request proposals from the students' company as virtual currency holders. All information related to this practice is managed on the LMS (Learning Management System). This practice is a chance to recognize and act in various situations and will become an opportunity for reflection. The results of the student surveys regarding the improvement of competency, which working adults are required to have, showed that this practice is more effective than any prior experiences. In this paper, we show the contents of the innovation practice on electrical technologies and describe the verification of the educational effect from student surveys. This practice can be widely applied in the field of Education.

KEYWORDS

Virtual company, electrical technologies, practice, virtual currency, Learning Management System, Standards 2, 3, 7, 8

INTRODUCTION

Currently, higher education institutions are required to develop human resources who can play an active role in a modern society where international competition is intensifying. Therefore, in addition to the knowledge and skills of the past, it is necessary to have competencies such as

basic skills for working adults [Ministry of Economy, 2018], bachelor's ability [Education, 2012], and cross-disciplinary abilities [Technology, 2017]. In addition, from the viewpoint of new Education that fosters the ability to play an active role in a global society, the OECD's international learning achievement test called PISA is based on the investigation of emotional abilities at PISA2018 and meta-competency at PISA2021 [Research, 2019]. According to the survey in PISA, the age of competency evaluation is progressing, and efforts to develop competency through active learning in elementary and (American Psychological Association, 2018) junior high schools have begun [Shigeo Kawamura, 2016]. It is important in the education field to create more opportunities to acquire the necessary skills to create useful human resources in society [Sadayuki Shimoda, 2016]. In order to develop such competency, each school has been promoting the active learning of regular lectures and has introduced problem-solving learning and student-participation learning.

The authors show that if students can experience competencies that can be acquired for the first time by experiencing everything from job hunting to work, we will improve our students' abilities if we can experience them in our studies at technical colleges. We have created an electrical technology innovation practice (hereafter, this practice) in which students work as virtual members of society. In April 2018, it was introduced as one theme of electrical and electronic engineering experiments in the electrical course [Minoru Komatsu, 2019].

In this paper, we construct an innovation practice for electrical technology that is conscious of working people, shows the contents and state of activities, and verifies the effectiveness of the practice. This practice is for the second to fifth-year students of the electrical course. Therefore, we have established a company based on electrical Technology, but since various applications are possible, it is a practical training that can be adopted widely not only in a technical college but also from high school to university. In addition, there will basically be one teacher in charge of this training.

PRACTICE PURPOSE

In this practice of starting a mock company, the first thing students learn is basic company management, secondly, to acquire the skills required as a member of society, and thirdly to become familiar with cutting-edge electrical Technology. The purpose is to make connections that exceed their grade-level in the course, respectively, in the fourth grade.

By being involved in company management, students are able to learn from experience how to carry out administrative procedures such as manufacturing, sales, personnel, and accounting, and acquire basic skills required for working people from various social experiences, including ordering from other companies and conducting personnel exchange.

This practice will be a chance to recognize and act in various situations, and it will be an opportunity for students to reflect on their experiences. Failure in this practice is not a problem at all, and the experience of failure is connected to what comes next, as well as self-reflection and the growth cycle by PDCA, which is originally required and all of which are established by students themselves.

In this practice, students will also learn about financial Education by the introduction of an on-campus virtual currency (ANET coins) and by conducting all exchanges (salary, purchase costs, facility management expenses, etc.) in this virtual currency. This virtual currency exists only on the Cloud Education Support System. It is a historical credit record of the exchange of

virtual currency between the teacher and the student. The introduction of virtual currencies not only enables more realistic transactions but also increases student motivation.

In order to establish a company related to electrical technology, it is necessary to analyze the cutting-edge technologies of each field (electric power, electronics, robots, AI, IoT, entertainment), and second-year students can begin their investigations of the research background that was previously conducted only in graduation research. Figure 1 shows the innovation practice of electrical Technology. In this practice, students from each grade make up one company, so that students can connect not only in class but also across grade levels. In the past, there has been a connection in the class, but the connection beyond the school year has been thin, so this practice includes elements of club activities, which are extracurricular activities.

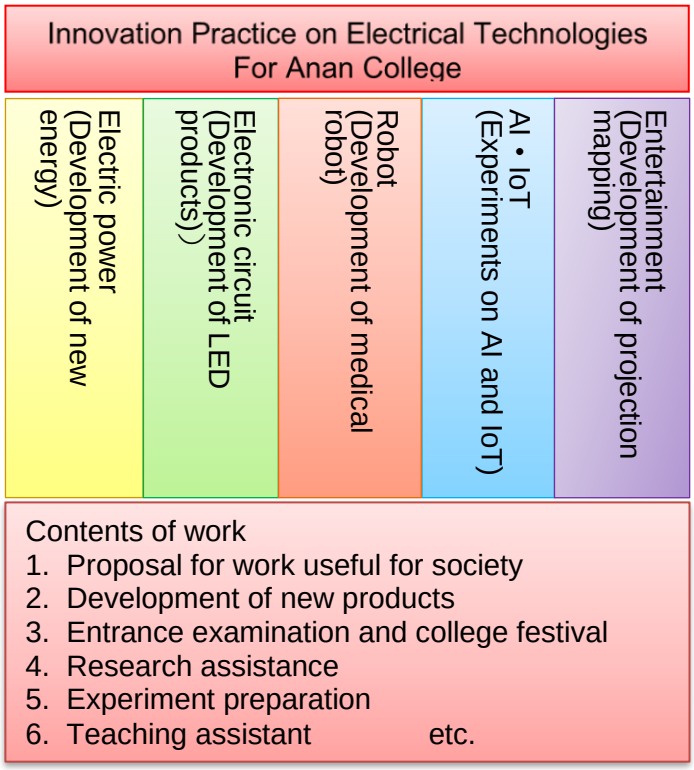

Figure 1. Overview of innovation practice on electrical Technology

PRACTICE CONTENTS

This practice is put forth as one of the electrical and electronic engineering experiments for third-grade students as well as from the second to fourth grades. Electrical and electronic engineering experiments are conducted on 8 to 12 themes in each grade and will be incorporated as an additional theme. The first group is held every other week in which the second group conducts this practice on the day for experimenting with other themes. Since the experimental date is different for each grade and there is no opportunity for the entire company to gather, we set up an electrical and electronic engineering experiment supplement each week on a timetable and use it for internal meetings. The fifth-grade students are

cryptocurrency holders who work on creative engineering exercises, graduation research, and invest in companies.

As for the start-up method, the teacher selects ten presidents from amongst the fourth-grade students after an examination of their business plans, and fourth-grade students conduct interviews with other students and determine the place of employment for all fourth-grade students. It is possible for anyone to start an independent business in the middle of the year. Students who wish to become independent can submit a new business plan and start a business if students can acquire ANET Coins for the necessary funds to be included in the business plan through the ANET capital-acquisition presentation. Second- and third-year students go job hunting among the companies the fourth-year students started, deciding where to find a job. After their employment, students can set up an independent company after a certain period.

As a company organization, about ten students can be hired with additional people as necessary. The company shall start by raising capital and performing all expenses related to the business in virtual currency (ANET Coins). The evaluation of this practice shall be based on the business report submitted by each individual, and the evaluation of the first theme of the experiment.

All information related to this practice, such as work requests and report submissions, shall be provided using the LMS cloud education support system. Figure 2 shows the LMS.

As a cryptocurrency holder, the faculty will make a business request after receiving investment or a student's proposal. Teachers and technical staff may participate as counselors, and if students consult with each other, students will pay a consultation fee and carry out the consultation.

The company's business hours shall be only four hours per week (3 hours for experiments and 1 hour for supplementary lectures) and will be held every other week in relation to other experimental themes. The one-hour experimental course, which is common to students in all grades, will be used for internal meetings, etc., and the purpose of the following tasks and the reports from everyone will be carried out to improve the quality of the company's business.

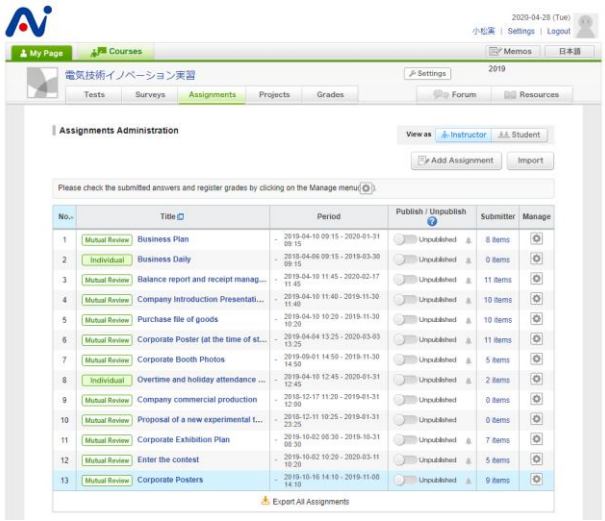

Figure 2. LMS (Cloud Education Support System)

ACTIVITIES

Figure 3 shows the company briefing for third-year students conducted in April. Five companies held joint-briefings, and the fourth-year students prepared the company introduction in advance with projectors and handouts and explained in detail to the third-year students. The fourth-years who explained their companies began with the president's self-introduction and then the appeal of the company from various perspectives, such as the corporate atmosphere, corporate philosophy, corporate culture, and what kind of work students would like to do based on the theme that is the axis. The third-year students who were job hunting took part in briefings with nervous faces and took notes and chose the company seriously. In the interview, the fourth-year students prepared to ask questions on their own and consulted with them about what kind of employees the company wanted. Third-year students were observed to be so nervous that their hands which held resumes trembled. Figure 4 shows the interview at the employment examinations.

Figure 3. Picture of the company briefing

Figure 4. Picture of the interview

Figure 5. Picture of the flow of planning a project and the meeting for the entire company

Figure 6. Picture of an e-sports tournament as an activity

Each task is carried out by planning out the flow of a project, discussing it at an internal meeting, and then working on it. After it is over, a reflection meeting is held. Figure 5 shows the planning of the flow of a project and the meeting of the entire company. Figure 6 shows an e-sports tournament as an activity. E-sports is an event in which the event management company operates the tournament and participates in a variety of students.

QUESTIONNARIRE RESULTS

Questions 1 and 2 were directed at students in the second and third years who were looking for a job. Questions 3 and 4 focused on third and fourth-year students.

(1) Were you nervous about the interview?
(2) Was this company interview experience meaningful?
(3) What kind of character of student could you grasp at the interview?
(4) After you experienced being an interviewer, has your attitude changed in the future?

Choose an answer from the following five: 5: Many, 4: Little, 3: Neither, 2: Not so much, 1: Not at all. Figure 7 shows the results of a questionnaire in job hunting. As shown in Figure 7, 5 and 4 answers to each question were more than 80%, and the results were valid.

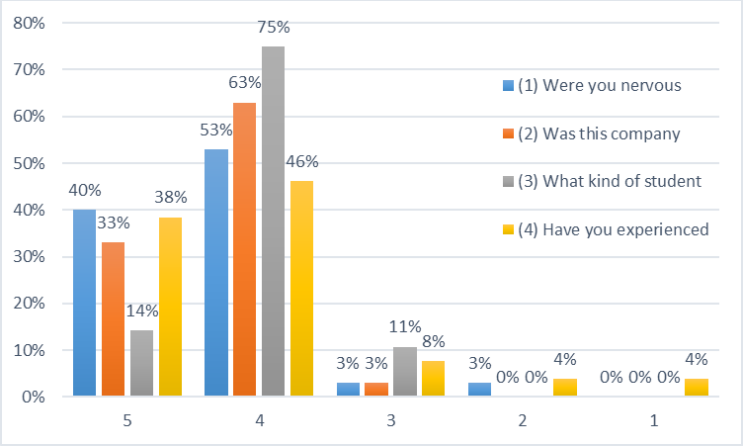

Figure 7. Results of a questionnaire in job hunting

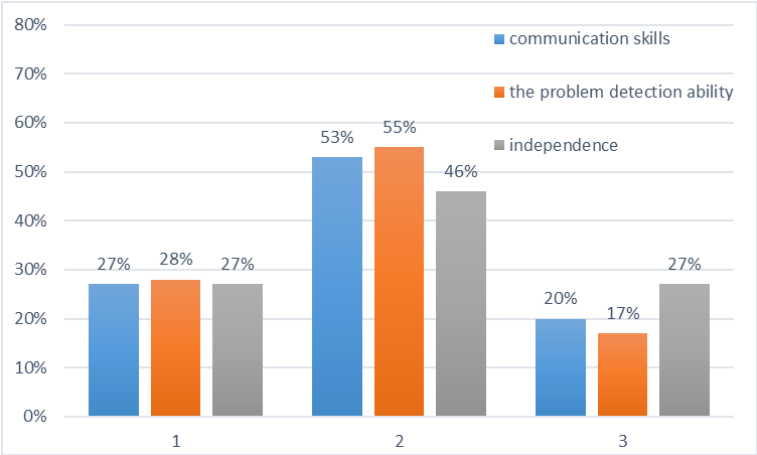

Figure 8. Results of communication skills, problem detection ability, and independence

Figure 8 shows the results of communication skills, problem-solving skills, and subjectivity. The results of the survey show that between 70% and 90% of respondents in 1 and 2 have helped to improve their skills.

This is a question about communication skills.
1. You can express your opinion.
2. Actively exchange opinions.
3. You can communicate your opinion, convincingly.

This is a question about the ability of problem detection.
1. You can mention yourself or your group's challenges.
2. You can set up specific action scans that you or your group should take.
3. It is possible to determine effective action proposals to achieve the issues that you and your group should achieve.

This is a question about independence.
1. You understand the roles and actions required of you.
2. You understand the content and meaning of the roles and actions required of you.
3. You can think for yourself about your roles and actions.

These surveys are in the first year, and the effectiveness of this practice can be verified by continuing the investigation. From the next year, we plan to devise a way to confirm the growth of competency due to differences in the way of engaging in practical training.

CONCLUSION

In this paper, we develop and describe the contents of an electrical technology innovation practice in which students become virtual members of society. Students followed the basic rules of working as members of society and worked with a sense of motivation. In this practice, the introduction of cryptocurrency was very effective, and we focused on sales and development so as not to bankrupt the companies.

This practice is conducted in the second year, and although the first year and second year have not been compared, it is seen as beneficial for the student's growth from various viewpoints. There are new proposals from students one after another because there is an opportunity to do what students want to do in this practice. Students often try new things without fear of failure. Guidance for passive students is also progressing, and there is an initiative that is conscious of competency from the lower grades, such as changing jobs and holding self-development seminars.

In the future, we plan to verify the effect every year and continue to evolve this practice with a focus on further competency development by incorporating new collaboration between companies. We hope that students who have experienced this practice will bring about new innovations in society.

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THE USE OF EDUSCRUM METHODOLOGY IN THE SOCIALLY-ORIENTED PROJECTS

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ABSTRACT

For the Bachelor's degree in engineering, field project activities are the key component of the curriculum. Incorporation of project activities facilitates an increase in the effectiveness of mastering the educational program. The Project-Based-Learning (PBL) provides a means for faster adaptation of students to future professional activities. We have discovered, that involving students in the realization of IT-technological socially-oriented projects allows high effectiveness in the realization of all four CDIO initiative provisions – Conceive, Design, Implement, Operate. It was brought to light that when realizing socially-oriented projects, if the project team consists of not only IT-developing students but also humanitarian fields' students, project activity's effectiveness and quality of the final product substantially increase. Approbation of interdisciplinary socially-oriented projects' realization was carried out. Achievable positive effects of their realization were established. The creation of the «PetSearch» system that helps find lost pets was one of the most successful projects. The effectiveness of the influence of project activities on the increase in motivation and academic performance was evaluated.

KEYWORDS

Team project activities, EduScrum, Socially-oriented projects, Standards 1, 3, 5, 7

INTRODUCTION

One of the main provisions of the CDIO initiative is the intensive use of project-based learning (Crawley E. F., Malmqvist J., Östlund S., Brodeur D. R., & Edström K., 2014). The emphasis is put on team project activities. In accordance with Standards 1, 3, 5, and 7 of the CDIO initiative Surgut State University has incorporated intensive use of project-based learning into the educational programs.

The involvement of students in the implementation of socially-oriented projects in the field of IT technologies ensures high effectiveness for the realization of the CDIO initiative's all four stages - Conceive Design Implement Operate. In any average IT project, the first three stages are successfully implemented. The fourth is often poorly implemented. But solving socially-oriented problems significantly increase the motivation of students to operate and maintain the product. Thus, it becomes possible to fully implement the fourth stage.

ORGANIZATION OF PROJECT-BASED LEARNING

Project-based learning is the core component of the curriculum and is carried out throughout all eight semesters of the Bachelor's degree program. Implementation of project activities promotes an increase in the effectiveness of mastering the educational program. For students, the Project-Based-Learning (PBL) lays the foundation of system approach in Education and further professional activities (Rebrin O, Sholina I., & Berestova S., 2014). Effectiveness of students' motivation to learn the subject field by involvement in the project activities is supported by real experience (Siong, G., & Thow, V. S., 2017), (Nguyen-Xuan, H., & Sato, K., 2018).

In Surgut State University, for students studying in the field of "Software Engineering," the organization of project activities based on the EduScrum methodology is practiced. The provisions of EduScrum are detailed in the literature(Delhij, A., van Solingen, R., & Wijnands, W., 2015), (Wijnands W., & Stolze A., 2019). This methodology is a further development of Scrum (Sutherland, 2014), adapted for the education system. A positive experience of using Scrum and EduScrum in a number of universities - members of the CDIO initiative was noted (Ferreira, E. P, & Martins, A., 2016), (Paul, R., & Behjat, L., 2019).

Independently students organize teams consisting of 3-6 people and set a theme for the project in creating a certain socially valuable software product. Students are not restricted in the choice of theme, but there is a condition, that as the result of the project, there should be working socially beneficial software product. This circumstance provides freedom in choosing the theme and the team members. There is no aim to integrate programming results of various teams into one system. A prerequisite is the completion of the project within one semester. The semester time interval is divided into four sprints. Each sprint corresponds to one of the stages of the CDIO project activity (Standard°1). The duration of sprints varies from 2 weeks to 1.5 months.

Sprint «Conceive»

Within the stage of project activities' initiation, the primary distribution of roles is made. Role - Scrum Master is assigned to a teacher, who is the project supervisor. It was brought to light that when realizing socially-oriented projects, if the project team consists of not only IT-developing students but also humanitarian and socio-economical fields' students, project activity's effectiveness and quality of the final product substantially increase (Standard°7). They are more familiar with areas requiring the support of IT-technologies. They are involved as problem analysts or marketers. At the Conceive stage, this combination allows us to quickly identify urgent tasks for creating socially-oriented IT systems.

Sprint «Design»

At the Design stage, the final formation of Scrum teams takes place. The Product Owner role is assigned to the student leader of the team. As a rule, this is an IT field student. Remaining team members are assigned the necessary functional roles. Teams independently choose the means and technologies for project task implementation. Team members responsible for the "psychological" and communicative component of the project establish requirements and restrictions for the informational and technical parts of the project. IT field students offer options for implementing the set tasks. At the same time, they are focused on the maximum use of advanced IT technologies.

Sprint «Implement»

Within this sprint, the concepts developed at the previous stage are implemented. The coding of the software components is carried out. At weekly team meetings, the effectiveness of the work performed is analyzed. The achieved functionality, usability, and user-friendliness of the interface are evaluated. Assembly of project components is carried out. The assembled components are tested periodically. Significant attention is paid to the implementation of man-machine interaction. The result of this sprint is a fully functional system prototype.

Sprint «Operate»

A significant advantage of socially-oriented IT projects is the possibility of testing them in operation. As part of the Operate phase, at least the test operation of the resulting project solution is performed. The project team has the ability to receive feedback from the real system users. The information collected allows for making adjustments to the project. In some cases, there is a need to critically rethink project decisions or concepts. The task of maintaining an IT system can be set independently.

Projects in the IT industry have an extremely broad focus. Modern industrial enterprises and businesses are implementing a lot of industrially focused IT projects. They allow optimization of technological and information processes. They also allow the creation of analytical and forecasting systems. At the same time, the quantity of another group of projects is large, and it includes socially-oriented IT applications. Due to specific requirements and implementation features, projects of the industrially oriented group are difficult for students. Involving students into socially-oriented projects' implementation allows more efficient construction of the learning process. Projects of this orientation are well limited in time and permit passing through all the CDIO stages.

EXAMPLE OF TESTING OF SOCIALLY-ORIENTED PROJECTS

The above-mentioned approach to the project activities organization was successfully tested. The "PetSearch" Pet Registration, Search, and Tracking System was one of the most successful projects. The problem of finding lost pets is very relevant around the world. The loss of a pet leads to the significant emotional stress of both owners and lost animals.

At the Conceive stage, a project team was formed. It includes five second-year students. One student is enrolled in the "Management" program, and four other students are enrolled in the "Software Engineering" program. At this stage, the team conducts pre-design studies. In the course of the research, analysis of the demand for this system was performed. As a result, the project mission was presented, as shown in Figure 1.

During the Design stage, team members assigned roles. The leader of the team, Product owner, has been assigned the DevOps consultant functionality. Team members received roles:

- Marketer;
- JS developer;
- PHP developer;
- Designer;
- Layout designer.

Figure 1. The project mission.

The Marketing Specialist role was assigned to the student enrolled in the "Management" program. The remaining roles were distributed among students in the field of "Software Engineering." Students chose approaches and technologies for project implementation. The marketer determined the target consumer. The most friendly format of communication with the consumer was proposed. IT field students considered various options for implementing the system. The team thought through and developed the ideology of the system. A system architecture consisting of four components was proposed:

- Controller - main system component. He is engaged in processing user requests, referring to Model to get data from Database (DB), and to view, for graphical presentation of content to the user.
- Model - is a set of methods that allow you to "communicate" with Database: request and receive the result based on the parameters transmitted by Controller.
- View - based on the data transmitted by Controller and received through Model, it forms a graphical representation of the content that will be presented to the user.
- Database – data storage about the owners and their pets.

Database management system was selected. Formats of interaction between components and applications are presented. Exchange protocols were proposed. User interface was developed. The accepted version of the architecture for the WEB application is presented in Figure 2.

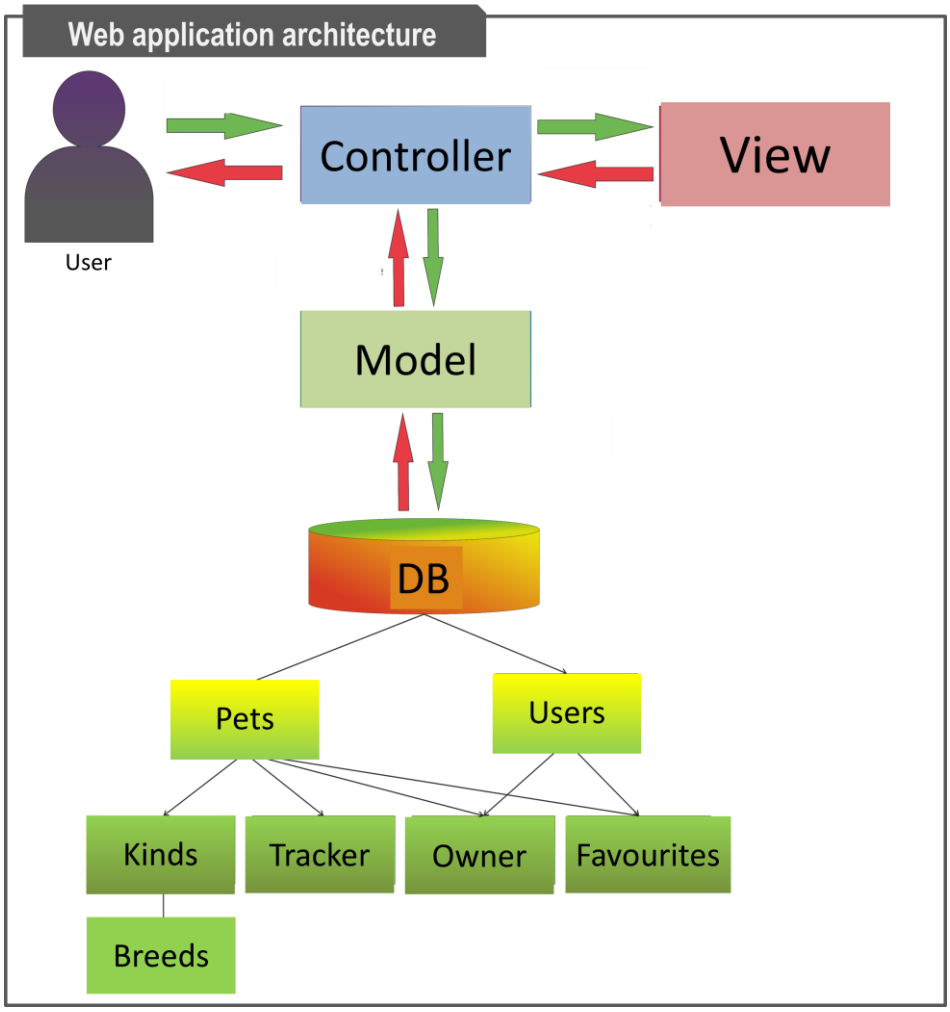

Figure 2. The Web application architecture.

During the **Implement** phase, the code of the software components was written. The installation of the project components was carried out. During the installation, regular testing of components' operational integrity of was held. Fragments of the prototype system's user interface are presented in Figure 3.

As part of the Sprint **Operate**, the whole system was tested. Team members registered 10 test users and their pets in the system. Ten carriers of the QR code were made for them. The QR code tablets were delivered to various areas of the city and scanned. The search engine has successfully discovered all the scanning processes.

The successful testing experience allowed putting the system into test operation mode. Pet owners are encouraged to register with PetSearch and purchase collars with a unique QR code. Currently, more than 20 pets and their owners are registered in the system. Anybody who meets a pet with such a collar just needs to scan a QR code and send it to the system. The project team is able to receive feedback from real system users. The task of maintaining an IT system can be set independently.

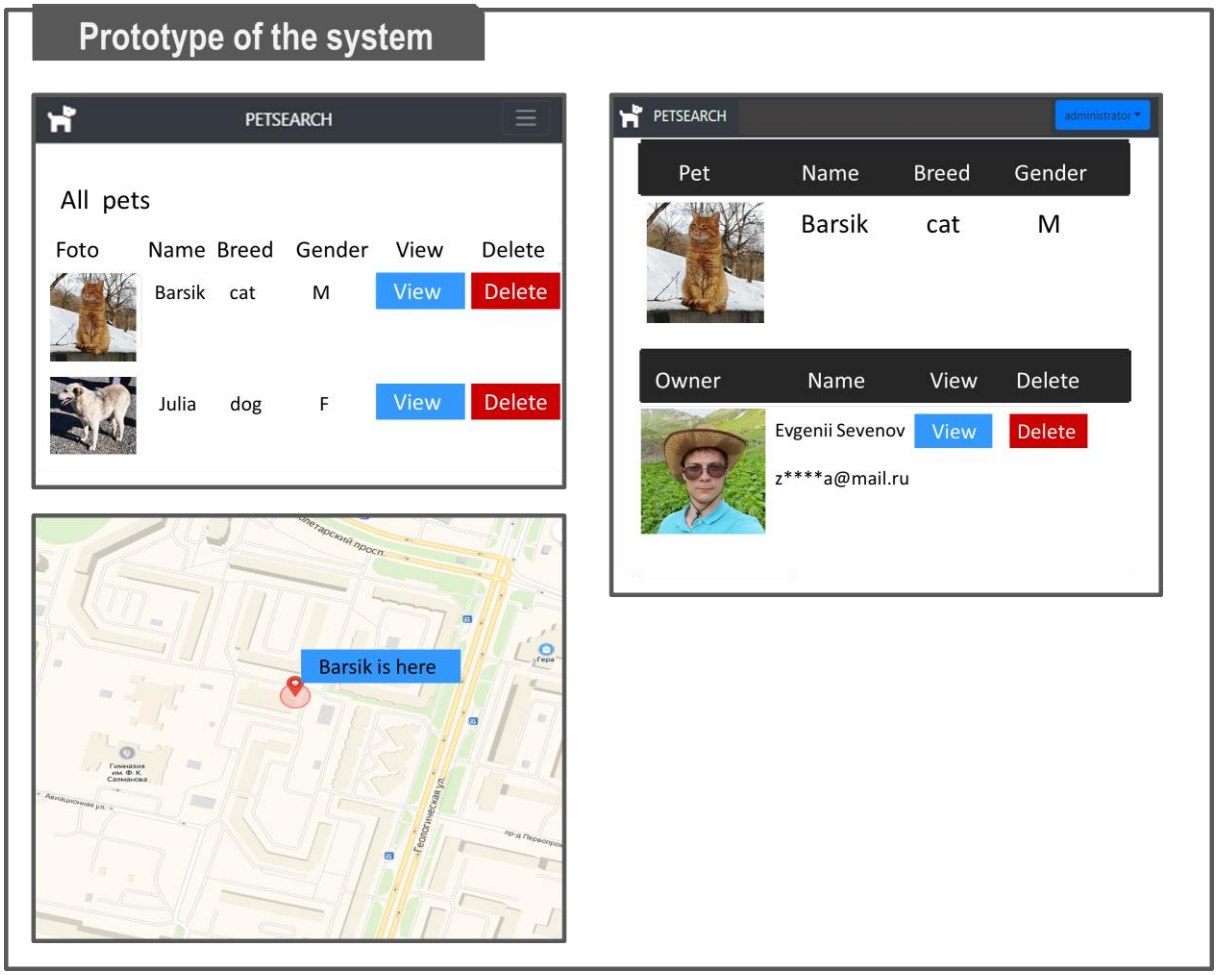

Figure 3. A prototype of the user interface of the pet search system.

It should be noted that the combination of the eduScrum methodology with the ideology of CDIO design activities gives a positive synergistic effect. Most of all, it manifests itself in the Operate stage. When detecting various kinds of malfunctions in the system operation, the source of the error is determined in a short time. A prerequisite for this is the distribution of role competencies that was performed at the Conceive stage. The effect is evaluated in comparison with similar projects completed earlier without the use of eduScrum methodological technology. The project has aroused interest among representatives of student entrepreneurship as a promising business project.

PERSPECTIVE PROJECTS

Successful experience in the implementation of the "PetSearch" project was developed in the following projects. In addition to the described project, there are a number of socially-oriented IT projects in work. Sprint Conceive of the "Psychological Consultant" and "Volunteer" projects have now begun.

Project "Psychological Consultant"

During the pre-project study, it was revealed that in Russia, the level of public awareness of the psychological assistance services' activities and psychologists in general, needs to be improved. Moreover, there are those who do not even know about their existence. It is believed that healthy people do not need help. That this is only a show of weakness - you need to pull yourself together and stop being nervous. Many people are afraid to seek help because of public opinion, some stereotypes, or because of general misunderstanding/ignorance. Attempts at introspection often lead to destructive dependencies. Recently, a big problem is the romanticization of mental disorders or the perception of them as some kind of additional resource (especially by adolescents).

In view of the above-mentioned reasons, came the idea of developing an information system that supports three activity areas:
1. Development of psychological services within the university.
2. Improving public awareness about the work of psychologists, psychological services (about what they work with) and psychological problems *
3. Informing the public about emergency help methods (for example, during panic attacks).
The project also intends to focus on the problems of autism spectrum disorders.

Currently, at the Conceive stage, a team consisting of third-year students is formed. Two students are enrolled in the "Clinical psychology" program and two students in the "Software engineering" program. A survey of students was conducted, and a bundle of the most relevant, for them, topics of psychological consultations were identified.

Project "Volunteer"

The project is dedicated to the development of a mobile service. There are many people who sometimes need help. For example, elderly and disabled, people with limited mobility, etc. They often encounter restrictions of the urban environment to special needs, especially in winter, and experience difficulties in resolving everyday issues. The service uses geolocation data to quickly find volunteers nearby who are ready to help. It is enough for a person who needs help to click the icon on the screen of his smartphone, and the volunteers who are nearby will receive a signal. If necessary, the call may be accompanied by an explanatory text, image, video, or voice message.

CONCLUSIONS

This paper presents the practical results of the socially-oriented IT project implementation. The need to solve social problems using modern IT technologies stimulates the necessity for a combination of interdisciplinary competencies. The objectives of such projects make it appropriate and effective to include students of various study areas in the project team. Involving students of humanitarian and IT fields in the project team allows the creation of software products demanded by our society. Students of the humanitarian field effectively conduct surveys of society demands. They have knowledge of psychology and rules of interpersonal interaction. They can form information presentation formats. IT field students get the opportunity to apply their competencies in the field of modern technologies to solve socially important problems. The implementation of a specific project necessitates the search for the best solution. In this case, students are not limited to the first solution received. They learn

how to optimize design decisions, taking into account the experience of the actual operation of the product.

The use of the eduScrum methodology allows students to efficiently build project implementation paths. The experience of limiting sprints to CDIO stages allowed us to improve the structuring of project processes. It lets students understand more fully the purpose and features of the stages. It has been confirmed that involving students in the implementation of socially-oriented projects in the field of IT technologies allows the implementation of all four stages (Conceive Design Implement Operate) of the CDIO initiative with a high degree of efficiency. In any average IT project, the first three stages are successfully implemented. The fourth is often poorly implemented. But solving socially-oriented problems significantly increase the motivation of students to operate and maintain the product. Compared to abstract educational projects, solving real socially-oriented problems significantly increases students' motivation to operate and maintain the product. The role distribution at the Conceive stage in accordance with the eduScrum methodology, made it possible to effectively separate competencies and problem areas. This approach has been beneficial in the Operate stage. When problems in operation are detected, role differentiation makes it possible to eliminate the root cause of the error in a short time. Thus, it becomes possible to fully implement the fourth stage.

Gained positive experience in implementing socially-oriented IT projects allows us to expand the scope of such projects. Teachers, together with students, compiled a pool of topics, the implementation of which is planned in the near future.

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PROJECT TRAINING IN THE IMPLEMENTATION OF PRACTICE-ORIENTED DISCIPLINES

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ABSTRACT

In accordance with the provisions of the CDIO standards, project-based learning (PBL) allows students to adapt to subsequent professional activities quickly. It is revealed that in the conventional implementation of academic disciplines, not enough attention is paid to project activities. The use of active teaching methods and the acquisition of professional knowledge and skills in the process of project activities can improve the effectiveness of teaching disciplines. An example of the transformation of a single academic discipline using project-based learning, including a system for evaluating students' achievements, is given. Testing of this solution has shown positive effects, such as increasing students' motivation to study, increasing the level of mastering the discipline's material, and increasing the level of students' readiness for project activities. It is noted that a large role in the positive effects obtained is played by the educational achievements evaluation system that is clear to the student. The success achieved allows you to apply the experience gained to other disciplines of the curriculum.

KEYWORDS

Project Activity, Project-Based Learning (PBL), Efficiency, Standards 1, 5, 7, 8, 11

INTRODUCTION

The international initiative for engineering education CDIO offers a number of principles for building effective educational programs, which is why it is widely used in many countries. Many Russian universities have implemented CDIO standards in their educational programs and continue to develop them (Chuchalin, A., Tayurskaya, M., & Malmqvist, J., 2015). Surgut State University joined the CDIO initiative in June 2017 at the 13th International Conference at the University of Calgary with three Bachelor's programs. Two of those education programs are "Control on technical systems" (CTS) and "Software engineering" (SE). At the initial stage, estimates of a number of CDIO standards implementation were quite low, including standards 7, 8, and 11 (Zapevalov, A., Pauk, E., Zapevalova, L., Kuzin, D., & Bezuevskaya, V., 2018).

This is due to the fact that the conventional approach to building an educational program and teaching individual disciplines often does not pay enough attention to project work. Usually, the curriculum contains several separate projects, called course projects, related to certain disciplines in terms of content. This does not provide systematic development of project activity

skills. Much more effective is the implementation of project activities within the framework of the implementation of interdisciplinary projects during the entire training period.

However, the current state of the industry and IT requires graduates to be ready for project activities both as part of a team and independently. To do this, it is necessary to develop the student's skills of a project approach to solving professional problems of any scale. This can be both large corporate projects and small production tasks, which are performed in the project format to ensure that the expected result is achieved within the specified time frame.

To do this, it is necessary to transform the teaching process of individual disciplines by implementing the principles of project-based learning when performing current training tasks. Intensive use of project learning is one of the main provisions of the CDIO initiative (Crawley E. F., Malmqvist J., Östlund S., Brodeur D. R., & Edström K., 2014). Surgut State University has introduced an intensive use of project-based learning in educational programs. This article presents the experience of implementing the principles of project training on the example of the transformation of a single discipline.

PROBLEMS OF THE CONVENTIONAL ORGANIZATION OF THE ACADEMIC DISCIPLINE

Conventional teaching includes lectures to familiarize oneself with the material, tests, practical or laboratory work to consolidate the material, and an exam to assess the formation of competencies. The condition for admission to the exam is to perform all control and practical work during the semester before the exam (Figure 1). It is believed that the student will assimilate the knowledge obtained at the lectures, and the implementation of practical tasks will allow one to get the skills to apply this knowledge in professional activities.

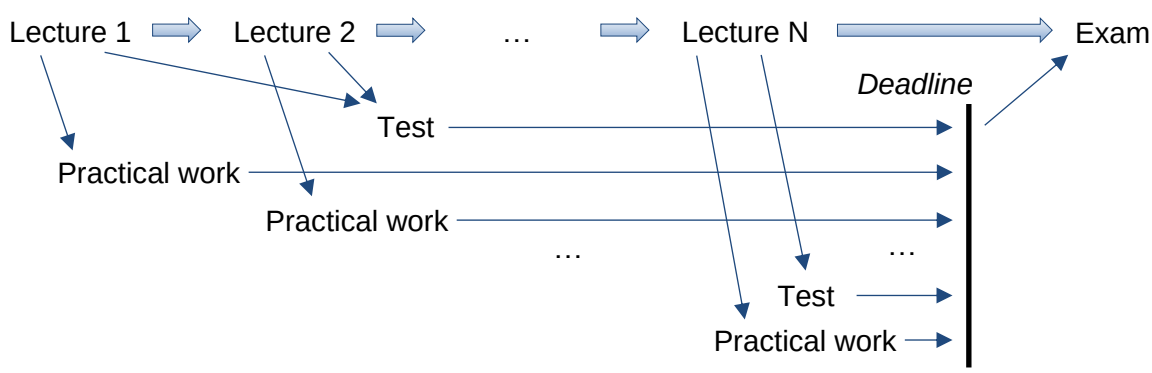

Figure 1. The Traditional Structure of the Discipline

This approach is ineffective for many students. During the semester, the student must complete a certain set of educational tasks, such as tests, practical and laboratory work. The teacher evaluates all tasks and counts them as completed in accordance with certain requirements. Admission to the exam is affected by the fact that the work is completed during the semester prior to the exam. The mark, which is obtained by the student in the exam as a result of the demonstration of knowledge and competencies in the subject area of the discipline, is the final grade for the discipline. Thus, the final grade does not take into account the nature and quality of the student's work during the semester. This leads to a number of negative effects:

- Students often perceive tasks not as an ordered system, but as a simple set of isolated tasks, without a contextual connection between them.
- A number of students have the illusion of having plenty of time. In the absence of sufficient self-organization skills, this leads to the postponement of work to a later date, closer to the end of the semester. At the end of the semester, many do not have enough time to do all the work well.
- The motivation of students is reduced. Many students try to perform only the minimum required amount of work with the minimum required quality in order to get the right to pass the exam in the discipline.
- The exam does not motivate systematic work during the semester, as it is an instant snapshot of knowledge and skills, focused primarily on learning. Memorization prevails over the formation of systemic knowledge, and reproductive activity prevails over practical skills.
- Examination assessment is largely subjective and highly dependent on the psycho-emotional state of the student at the time of the exam.

As a result, students' efforts are distributed unevenly over time and reach their peak at the end of the semester. At the same time, there is a low quality of work, a lack of understanding of the topic being studied, and a desire to provide the result of the work, rather than get it on your own. Students are focused on passing the exam, not on getting practical skills in the subject area. A decrease in students' motivation leads to a decrease in the volume of independent study of the subject, the depth and consistency of its understanding. As a result, the teacher tries to compensate for this by increasing the amount of information transmitted to lectures, which is an inefficient method.

Our experience shows that in each student group, only 2-5 people from 20-25 (8-25%) are able to independently organize their activities in studying the discipline during the semester, systematically and with high quality to complete all academic tasks and demonstrate on the exam Excellent material and practical skills. Up to half of the rest of the students also receive admission to the exam. Often they can answer the exam question well on some topic, but they have difficulty in demonstrating the relationship between the topics of the discipline and in applying knowledge to solve practical problems. Other students do not cope with work on time. They have the opportunity to take the exam later, but, unfortunately, some of them later stop studying due to unsatisfactory results of studying several disciplines.

The structure of the educational program involves the phased formation of learning outcomes that are necessary for the development of subsequent disciplines. The lack of timely planned results of mastering any discipline increases the risk of unsuccessful mastering of subsequent disciplines. If the discipline is the base for a module or a cycle of subsequent disciplines, this negative effect can be disastrous for all further training.

The described situation was observed when students mastered the discipline "Programming and the basics of algorithmization." This discipline is taught in the 1st year for two semesters. It is devoted to the formation of analysis and algorithmization skills, learning the C programming language, and its application to solve problems. This discipline is one of the fundamental for students of "Control on technical systems" and "Software engineering" education programs. The results of its mastering are necessary for the study of many of the following disciplines that are directly related to future professional activities.

PROJECT-BASED TRANSFORMATION OF DISCIPLINE

Positive changes can be achieved by changing the approach to the format of the discipline organization and using the principles of training based on project activities within the discipline. Project-based learning provides students with the foundation for a systematic approach to learning and future professional activities (Rebrin O, Sholina I., & Berestova S., 2014, Nguyen-Xuan, H., & Sato, K., 2018). On the one hand, involvement in project activities is an effective way to motivate students to study the subject area, which is confirmed by real experience (Siong, G., & Thow, V. S., 2017, Pereira de Carvalho, C., 2016). On the other hand, the subject area under study can be used as a material for developing project skills. This will allow us to focus on the study of key points and unify approaches to solving practical problems. A specific action template or "operational template" is generated.

Similar to the iterative development process, when studying a discipline, the necessary competencies can be formed in the course of practical activity in the form of small increments with an assessment of each increment.

In accordance with this, the discipline "Programming and the basics of algorithmization" was reengineered. Lectures were saved, and blended learning was used. The changed structure of the discipline is a set of topics. After studying the material of each topic, a test, an exercise, and laboratory work (task) follow. Thus, the study of each topic is a single iteration of the training cycle – the increment, as shown in Figure 2.

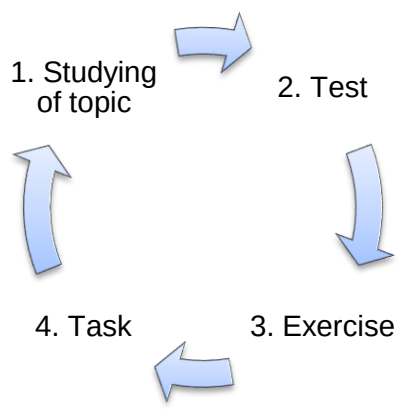

Figure 2. Cycle of Studying One Topic of the Discipline

Blended learning is implemented using the LMS Moodle, which is used at Surgut State University. This system also allows you to set the order of topics, implement the unified structure of the increment, and set the sequence of tasks within it.

When studying a topic, the teacher's lectures are supplemented by the student's independent work with electronic materials on the subject and other sources of information on the topic. Lectures and tests are of a reproductive nature and are aimed at learning, repeating, and assimilating basic knowledge.

The exercises are performed on each topic and are mainly reproductive in nature, without requiring significant knowledge in any subject area and performing search and research work. Each practical task is performed in accordance with an individual option and under controlled conditions – during a classroom session in a computer class within the provided time. The

complexity of all variants of the task is approximately the same, but a mandatory requirement is to perform the task independently. At the same time, students have full access to both e-course resources and any information resources in the University's local network and the Internet, except for social networks and cloud storage. The result must meet two conditions: the program must work and match the task. If it fails, the next attempt is provided, usually in the next lesson.

The task has a productive or creative character, requires not only knowledge of the programming language constructs, but also the ability to design the program code, use the means of the programming language to solve subject problems, and perform search and research works. The problem is solved by the student both during classes and independently.

The exercise and task differ in volume and complexity, but both require a project approach based on the product lifecycle. Thus, any task involves the following phases:

- analysis and formalization of the problem – corresponds to the Conceive stage;
- getting the design solution and its justification – corresponds to the Design stage;
- implementation of the solution in the form of program code – corresponds to the implementation stage;
- assessment of the adequacy of the solution and its presentation – corresponds to the Operate stage.

Thus, the activity carried out within the exercise is a short-term project (ST-project), and the task is a medium-term project (MT-project).

When performing ST-project as a simple, practical exercise, this procedure does not require much effort from the student but is a guarantee of success. Working on the MT-project, as a solution to a more complex task includes the preparation of a technical report that describes the results of each stage. This side of the project activity is associated with the formation of documentation and presentation skills. The teacher evaluates each stage of development, which allows timely and purposeful adjustment of the process of forming both project and subject competencies.

Thus, all practical activities during each semester of discipline development are a series of ST-project and MT-project lasting from tens of minutes to several weeks. Projects that do not require much time making it possible to quickly get a result, see errors and weaknesses of work. Multiple repetitions of this process with successive complexity of tasks give an understanding of the advantages of the project approach.

Students easily perceive the project approach, master the process of distributing tasks by stages of the project. Thus, an operational template for project activities is developed and fixed. In the future, they transfer this template from small tasks to more complex ones.

In addition, in the second semester, the process of studying the discipline "Programming and the basics of algorithmization" is supported by the implementation of the course project. In the course of its implementation, a software product must be created to solve a given range of tasks in a particular subject area. From the point of view of training, the purpose of the course project is a comprehensive application of programming tools and techniques, demonstration of the project approach application to solving problems in the professional field. This type of activity within the discipline is a long-term project (LT-project). Thus, the overall structure of the discipline is presented in Figure 3.

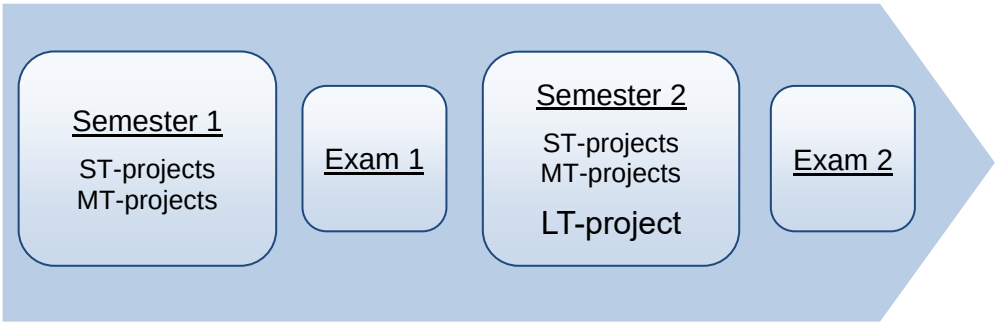

Figure 3. General Structure of the Discipline

As a result, the discipline implements three types of multi-scale projects that have a number of common conceptual parameters, such as the target, conditions, deadlines, and so on. The values of these parameters for different types of projects are shown in Table 1.

Table 1. Properties of Training Projects

Properties	**Project types**		
	Short-Term Project (Exercise)	**Medium-Term Project** (Task)	**Long-Term Project** (Course Project)
Target	Program	Program	Application
Requirements	Training (specific to the topic)	Functional (specific to the topic)	Functional and non-functional
Conditions	Means of the current and previous topics, classwork only	Means of the current and previous topics	Programming language and OS
Time limit	20-60 minutes	2-4 weeks	1 semester
Outcomes	Source code	Source code, technical report, brief speech	Source code, executable, design and user documentation, product presentation

Time parameters (terms and duration of projects) depend on the volume and complexity of the topic being studied, and the complexity of practical tasks. Each topic is based on the previous ones and includes a number of items, such as the syntax and semantics of the studied language constructions, peculiarities of their use, relationship to other topics, the relevant standard library functions, etc. Figure 4 shows the short names of the topics and shows the time distribution of their respective projects, as well as the place of LT-project in the overall structure of the discipline.

ACHIEVEMENT ASSESSMENT SYSTEM AND STUDENT MOTIVATION

The transformation of the structural organization of the discipline naturally leads to a change in the principles of assessing the quality of its development. The main idea, which shows the importance of a systematic, timely, and thorough performance of all training tasks, is that the final assessment of the discipline includes both the assessment received on the exam and the

assessment of the work during the semester. This motivates the student to complete all training tasks on time and with the best results.

Assessment of the student's work during the semester in the final grade is 70%. Of these, 40 points are for performing laboratory work (MT-projects), 20 points are for performing exercises (ST-projects), tests and working with information sources, and 10 points are for attending classes. The last part encourages direct communication with the teacher and the timely completion of training tasks.

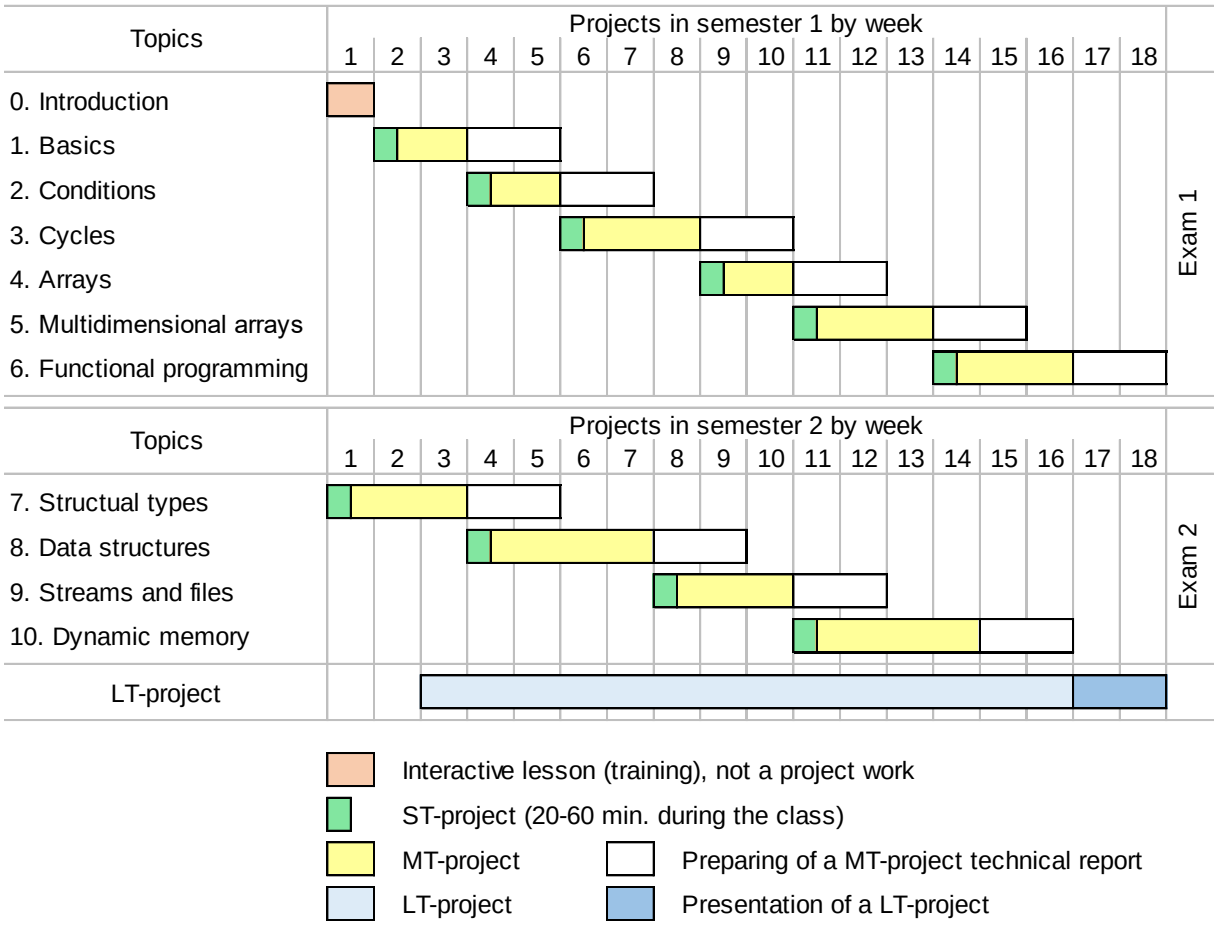

Figure 4. Detailed Structure of the Discipline

The remaining 30% of points a student can get on the exam, including 20 points for solving exam problems and 10 points based on the results of a conversation on the content of the discipline.

As a result, a student can get up to 70 points out of 100 for practical work, which is evaluated not only by its results in overall but also by the results of each stage of each project. This emphasizes the importance of applying practical skills of the project approach to solving professional problems and is a strong incentive for students. An additional incentive is bonus points that a student can get for excellent results, solving problems of increased complexity and more.

CONCLUSIONS

This paper presents the practical results of implementing project-based learning to improve the effectiveness of students studying the discipline "Programming and the basics of algorithmization," which has a practical orientation. The study material of the course is the basis for the mastering of the project approach, with the student personally performs every stage of the project and acts in each role.

The presented transformation of the discipline showed high efficiency both in terms of objective indicators and in the opinion of the students themselves. Having clear goals, evaluation criteria, sequence, and deadlines for completing tasks allows you to achieve the best results when using project-based learning. The number of students who completed all the tasks in time and passed the exam in the discipline "Programming and the basics of algorithmization" in 2016 was 17.5%. Since the start of the transformation, as the proposed approach has improved, this indicator had increased to 53.3% in 2019. Many students perceive the study of the discipline as a game or competition with well-known rules, which makes the learning process dynamic, arouses the interest of students, and contributes to the development of competencies. According to a student survey, 68.2% expect the same approach when studying other applied disciplines. The survey was conducted in 2019 among students who began to study the discipline "Object-oriented programming" after completing the discipline "Programming and the basics of algorithmization."

The positive experience gained in implementing the discipline "Programming and the basics of algorithmization" allows us to expand the application of this approach. The transformation of the next discipline, "Object-oriented programming" is planned. Further, the experience will be extended to a number of other practice-oriented disciplines.

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