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Sustainable international experience: A collaborative teaching project

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The 16th International CDIO Conference

Proceedings – Full Papers
Volume 2(2)

**Johan Malmqvist, Jens Bennedsen, Kristina Edström,
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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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REFORMED CURRICULA: TOOL FOR PROVIDING PROFESSIONAL GROWTH FOR STUDENTS

Mari-Selina Kantanen, Sanna Tyni

Lapland University of Applied Sciences, Finland

ABSTRACT

The engineers need a good knowledge of their special technical field but also, *e.g.,* social, analytical thinking, problem-solving, language skills, and especially how to combine their own knowledge with other specialists. Furthermore, there are always new areas of expertise that engineers should master, for example, bio and circular economy, which joins different sectors and experts together. The Lapland University of Applied Sciences (LaplandUAS) has reformed curricula of educations. The new curricula are based on competence and problem-based learning. The Mechanical Engineering curriculum consists of the academic years, and CDIO-type semester project courses are arranged in each semester. The curriculum permits flexibility to the contents, and it can be updated if there are new subjects from the engineering field to be taught for the students. For example, in the Mechanical Engineering studies, the circular economy is integrated into various courses. The students will have the know-how of the utilization of circular economy principles in their future careers. The academic year themes in the Mechanical Engineering are *Learning about Work of Mechanical Engineers*, *Engineer's Toolbox*, *Creative Engineers,* and *Pre-Engineers*. First year's semester projects are "On the way to Becoming an Engineer" and "Language of the Engineers." The second year's projects follow CDIO project steps more clearly so that C-D phases are taught in the autumn semester and I-O phases in the spring semester. The subject of the project is given by the teachers, and the students need a different kind of competence. The new curricula require collaborative teaching and development of the learning methods and environments. New themes and knowledge demand of the industry and society to future engineers direct teachers to update the content of the courses. All these new elements of the new curricula have increased the motivation of the students. Additionally, the level of dropouts has decreased, which indicates that the changes are heading in the right direction.

KEYWORDS

Development of curriculum, competence and problem-based learning, sustainability, bio and circular economy, motivation, Standards 1, 2, 3, 4, 5, 6, 8, 9, 10, 11

INTRODUCTION

Working in the technological field requires the ability to update knowledge and skills due to the continuous change of working life. Engineers should master new areas of expertise, and they should recognize the different ways to utilize their expertise in new situations. One example of this kind of change is the engagement of bio and circular economy in different areas of the industrial field. In the short term, bio and circular economy have become a megatrend that joins different sectors and experts together, providing several development possibilities in the vast technological field.

The transfer towards industrial bio and circular economy demands an educated workforce, who have the knowledge and understanding of how circular economy is implemented in their work. The Lapland University of Applied Sciences (LaplandUAS) has reformed curricula of the educations based on these identified demands. The new curricula started in the autumn of 2017 and are based on competence and problem-based learning. The professional growth of the mechanical engineers proceeds gradually from the first academic year to the last year. Every semester has a CDIO- type semester project course and various study modules reflecting the competences. In the Mechanical Engineering studies, the themes of the circular economy are taught in various courses, *e.g.,* material sciences, manufacturing, designing, energy technology, and maintenance. Additionally, the themes of the circular economy are also present in the semester projects.

During the update of curricula, LaplandUAS made an alignment of engaging the bio and circular economy to be part of the engineering education. The development work has been done through a European Social Fund (ESF)-funded "*Development of a study module for circular economy and industrial side flows and piloting it in cooperation with companies*"-project together with Kemi Digipolis Ltd. The aim of the project was to engage bio and circular economy in engineering education. The development work was planned together with regional industries, due to most of the graduated students are hired in local industries. In this way, the graduated students have the expertise which is most likely to benefit their future employers.

HEADING TO SUSTAINABLE DEVELOPMENT AND CIRCULAR ECONOMY

Global warming and environmental issues have become to the point where we must make changes globally. In Europe, the European Union has taken a guiding role and set up strategies and targets for the next decades to decrease environmental gas emissions. Additionally, the EU has been supporting the implementation of new, more sustainable technologies and solutions. Important progress has already done, but there is still constant pressure to move forwards, *e.g.,* in sustainable development in cities or industrial activities. Achievement of these demands requires significant investments and research to develop new technologies, energy efficiency, and potential ways to utilize new energy sources and raw materials. Above all, the EU needs educated engineers who can work with multidisciplinary fields of industry.

Alongside actions towards a more sustainable way to act, the EU has set targets for the implementation of a circular economy action plan. (EU Circular Economy Action Plan, 2020) EU has collected 54 actions, which will shape the economy towards a climate-neutral and more circular economy. Actions will minimize the impacts on natural and freshwater resources as well as ecosystems. Implementations are focused especially on the lifecycles of the different kinds of products. According to the estimations, the circular economy can offer benefits by decreasing the EU's carbon emissions by 450 million tons by 2030. Additionally, it will save 600 Mrd € for EU businesses and create 580,000 new jobs.

According to the EU, the circular economy consists of general measures such as product design, production process, consumption, from waste to resources (secondary raw materials), and innovation, investment, and other cross-cutting issues. (EU Circular Economy, 2019) Additionally, the EU has determined actions for specific materials and sectors, which are plastics, food value chain, critical raw materials, construction and demolition, biomass, and bio-based products, as well as a review of fertilizer legislation. These materials and sectors are most likely facing challenges as they are heading towards a circular economy, therefore needing an educated workforce to implement changes.

Alongside with EU, there are foundations such as the Ellen MacArthur Foundation (Ellen MacArthur Foundation) and the Finnish Innovation Fund Sitra (Sitra, Circular Economy), which are making a remarkable work at the European level as well as globally, to boost transformation towards bio and circular economy. Both have been funding development work of circular economy in the R&D sector as well as in the educational sector. They are continuously publishing new reports about circular economy activities. In 2016, Sitra published the world's first national road map for a circular economy. The focus of attention was on the role administrations can play in enabling things, on the encounters of different operators in society, and on cooperation between companies. The road map was updated in 2019. "Critical Move" describes the vision, strategic goals, and concrete actions accelerating the transfer towards a circular economy in Finland by 2025. (Sitra Critical Move, 2020)

The main idea of a circular economy is to avoid linear "Make-Take-Waste" economy and design systems so that material, components, products, and value bound to them circulates inside the system as long as it is possible. Production and consumption should be designed to avoid loss and waste. In the long term, material and energy efficiency creates environmental, as well as financial benefits. Alongside products, a circular economy is adding value by creating services and digital solutions based on intelligence. Transformation towards a circular economy requires systemic change, and therefore the changes must be made in policy actions as well as in municipalities or strategies of industries. The transition will also require knowledge and know-how, and above all, open-minded cooperation between operators. (Sitra Leading the Cycle, 2016)

The systematic transition towards a circular economy in the industrial sector will require a new kind of expertise and ability to utilize know-how in new ways with experts from various sectors. Therefore, there is a need for educational development to increase the understanding of the sustainability of the students.

CURRICULUM DEVELOPMENT AS A TOOL FOR ALLOWING FLEXIBILITY INTO TEACHING CONTENTS

The curriculum of Mechanical Engineering consists of projects and various study modules reflecting the competences. The learning and/or problem-based project is in the center of every semester's theme, and the contents of the different study modules are integrated into the content of the semester project. The names of these projects and study modules are inspiring and modern and try to illustrate better the theme of the academic year to the students. (Kantanen & Ruottu, 2017) The professional growth of the mechanical engineers proceeds gradually from the first academic year to the last year in every academic year and semester themes. Figure 1 presents an example of a semester project and how the study modules support this. (Kangastie & Mastosaari, 2016)

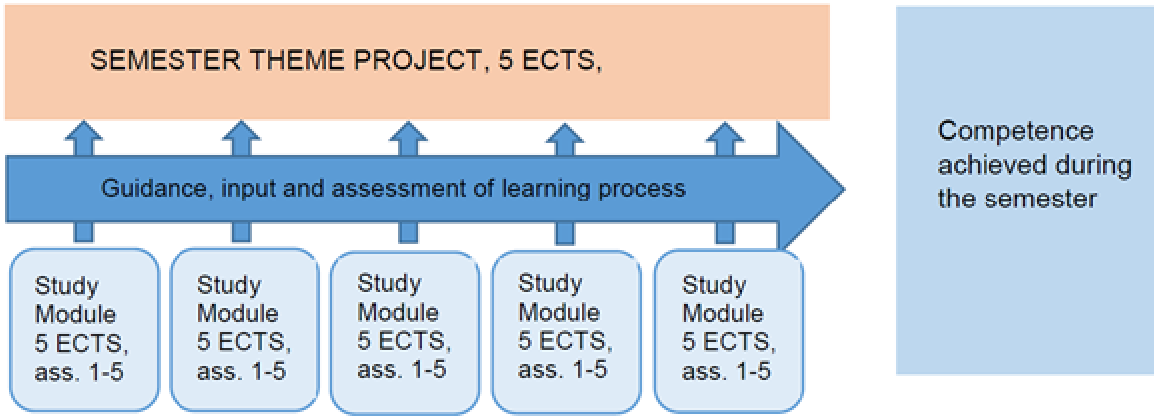

Figure 1. An example of the semester theme. (Kantanen & Ruottu, 2017)

In the first academic year, the students practice basic subjects of Mechanical Engineering combined with natural science, language, and social skill studies. The field of Mechanical Engineering becomes familiar to the students. First year's autumn semester project is *On the way to Becoming an Engineer* in which the students are familiarized with different kinds of industries of the Lapland region. In this project, the students learn some basics of the circular economy (*phase C - Conceive*), and they study how this theme is shown in the mining, steel, paper, forest, energy and machine workshop industries (*phase D - Design*). The semester project culminates with a fair where the students introduce their semester project results (*phase I – Implement)*, and the companies introduce activities and practical training possibilities for the students *(phase O - Operate*). The fair also contains competition for the teams. The participants of the fair can vote for the best poster and the best performance among the projects (Figure 2).

Figure. 2. The company booths at the fair (left) and the winners of the student projects (right).

First year's spring semester project is called as *Language of the Engineers*. In this project, the students build spaghetti bridges in smaller teams. The building of the spaghetti bridges requires competencies such as designing and technical mechanics. This project follows the CDIO-phases, where the students *Conceive* the structures of the bridges in project groups, and then they *Design* the selected structures with CAD programs. The *implementation* is made by building the structures, and finally, the *Operation* of the learning process is made by demonstration of the structures and strength tests of the bridges. The results are presented in the Project seminar day, arranged for the co-operative companies and other partners of the LaplandUAS. During the seminar day, student teams are also competing for the best implementation of spaghetti bridges. The participants of the fair vote for the greatest bridge, which is awarded at the end of the day. (Kantanen & Ruottu, 2019)

In the second academic year, the basic tools of Mechanical Engineering become more familiar, and the students learn how to apply all the knowledge they have achieved. The students can also work on the projects, and they can apply different kinds of problem-based methods. The CDIO model is divided into the academic year so that phases *C (Conceive)* and *D (Design)* are implemented in the autumn semester and the phases *I (Implementation)* and *O (Operate)* in the spring semester.

The autumn semester project, *Engineer's Toolbox*, is a product development project. The theme of the project is to design a table fan in a smaller group, and the theme is given by the teachers. Supporting courses, such as *Engineer's Mathematics*, *CAD as a Tool*, *Technical/Engineering Mechanics*, and *Automation Solutions,* are provided for the students to build up the required knowledge for the product development. The students participate in the designing process, CAD labs, material selection, and planning the designing and functions of the product. They also draw up technical drawings and charts, as well as evaluate the expenses and cost-effectiveness of the product. The exchange students are also participating in the project; therefore, teaching is also given in English, also providing internationalization for the Finnish students at home. (Kantanen & Ruottu, 2019)

During the spring semester's project, *Pouch the toolbox,* the students complete the designing of the products (*I – Implementation* phase) and prepare a prototype (*O – Operate* phase). Therefore, they need competencies, *e.g.,* in material science, 3D design, effective production methods (Lean, 5S), as well as energy technologies. The students can utilize 3D printing or machining steel into the manufacturing of the parts of the table fans. The manufacturing of the parts can be done at school, home, or at work. It is also required to pay attention to the life cycle of the product and make improvements in the product design. Additionally, Operation and maintenance are considered, and students learn how to productize products and services. The designed and manufactured table fans are demonstrated in the semester Project seminar day together with the first-year student's spaghetti bridges (Figure 3). (Kantanen & Ruottu, 2019)

During these two first years of studies, the bio and circular Economy themes are taught to the Mechanical Engineering students in different courses. The teachers are selected what themes suites best to the content of the course. In Mechanical Engineering Education, all of the students accomplish extensive knowledge of the bio and circular economy, Figure 4.

Figure 3. The first year's students, presenting spaghetti bridges (left) and a winning table ventilator solution by the adult student team (right).

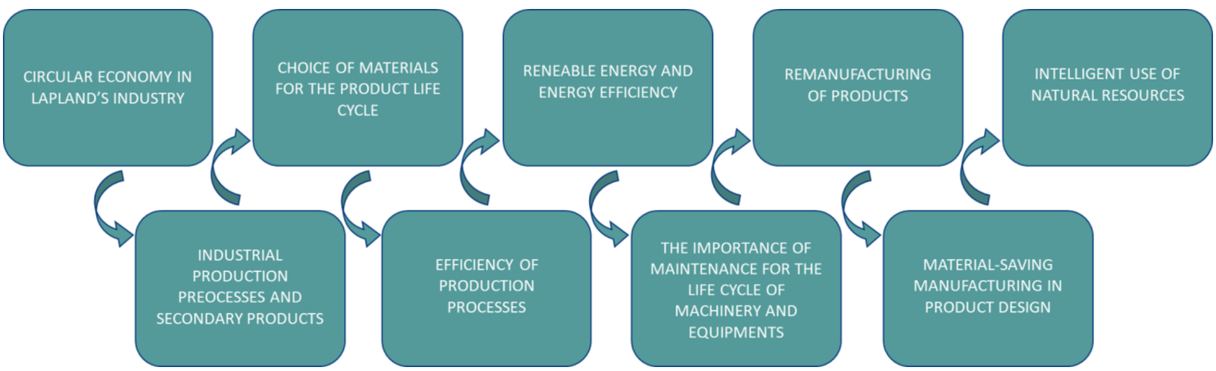

Figure 4. The content of the bio and circular education in Mechanical Engineering.

The theme of the third academic year is *Creative Engineers,* and the semester projects are based on the real working life problems provided by regional companies. There are three different kinds of alternative professional study options in the Mechanical Engineering education curriculum. The students are allowed to choose one of them to be completed during the third academic year. These alternative professional studies are *Industrial Professional*, *Product Development Professional*, and *Mining Professional*. In the region of Lapland, the industrial sector is mainly consisting of steel, paper, energy, mining, design, and engineering workshop companies; therefore, the subjects of the projects can vary a lot. The student is allowed to pick up the project subject suiting best for his/her career plans. One theme is also related to the circular economy or contains aspects of it. (Kantanen & Ruottu, 2019) First company-based projects, implemented with a new curriculum, started in autumn 2019 with C and D phases. The I and O phases are going to be progressed during the spring semester 2020. In their last academic year, the students deepen the Mechanical Engineering competence before they graduate at the end of the year.

DEVELOPING ENGINEERING EDUCATION WITH ESF-FUNDED PROJECT

Since 2017, Lapland UAS has been developed engineering education to contain bio and circular economy alongside engineering education. Development work has been done in the European Social Fund (ESF)-funded "*Development of a study module for circular economy* *and industrial side flows and piloting it in cooperation with companies*"-project together with Kemi Digipolis Ltd. The project is also called *CircularSchool,* and it will be finished by the end of the year 2020. The total budget of the project is 230,352 €, which contains 184,280€ ESF-funding provided by the North Ostrobothnia Centre for Economic Development, Transport and the Environment (ELY Centre).

The project was planned to develop bio and circular economy contents inside the engineering studies and study projects. The theme is broad, and therefore every study field has its own perspective, how the circular economy is conducted inside specific themes. Mining, steel, and forest industry are the main industrial fields in the Finnish Lapland. Production is concentrated on material production; therefore, the production of final products is rare. Bio and circular economy underline the circularity of the systems and reusability, recycling and remanufacturing are the ways to improve the systems to be more sustainable. In the future, the aim is to improve the utilization of industrial side flows as a raw material for other industrial processes.

The transfer towards industrial bio and circular economy demands an educated workforce, who have the knowledge and understanding of how circular economy is implemented in their work. In Finland, especially in scarcely populated areas such as Finnish Lapland, there are difficulties in getting enough workforce in the companies. Usually, people who have born and studied in the area are most likely going to stay there, and therefore it is highly important to provide high-quality education for the residents in the area.

The development of the circular economy education was done together with regional companies. Lapland UAS implemented meetings and interviews with regional companies to discover the needs of companies especially related to bio and circular economy. On this basis, the new bio and circular economy contents were planned to be fitted inside the engineering education. The cooperation with regional companies especially appears in the semester projects. Companies can offer themes or subjects for the students to be solved during the projects. The challenge to be solved by the students might be related, *e.g.,* to an industrial side flow, which the company would like to utilize as a raw material for the production of another product. As mentioned above, the supporting subjects are provided alongside the project so that the students have the required knowledge to solve the challenge.

CONCLUSION

The new curricula in LaplandUAS are based on competence and problem-based learning. The curricula require collaborative teaching as well as the development of the learning methods and environments. The students learn working life skills alongside their engineering studies. Additionally, they have to take more responsibility for their studies. The Mechanical Engineering curriculum consists of academic years. CDIO-type semester project courses are arranged in each semester, and different courses are integrated into the projects to give an overall insight into the contents of the semester theme. The challenges in lifelong learning and development of the competencies require educators to develop the contents of the degree programs. The new curriculum permits flexibility to the contents by providing the possibility to be updated if new subjects are popping up from the engineering field. In the case of the circular economy, the students will have the know-how of the utilization of circular economy principles in their future careers.

The ESF Funded *CircularSchool* project has enabled the bio, and circular economy contents are included inside the engineering studies and study projects. The development of the circular economy education was done together with regional companies, which assure that the teaching contents are relevant and the companies can get a skilled workforce now and in the future. The theme is broad, and therefore every study field has its own perspective, how the circular economy is conducted inside specific themes.

The attractiveness of the engineering studies can be improved with the development of the curriculum and teaching contents. This is especially important in scarcely populated areas such as Finnish Lapland, where different industries and companies need a skilled workforce. With all these efforts, made in engineering education in the Lapland University of Applied Science, the diversified professionals are educated for the industries and companies. It has also been seen that dropouts of the studies have decreased by the two-year experience of this new competence and problem-based curriculum. Additionally, the motivation of students to their studies has improved, and the students are interested in the new themes, such as bio and circular economy, in their studies. The development of teaching is continuing.

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REVERSE ENGINEERING AND INTRODUCTION TO ENGINEERING DESIGN

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ABSTRACT

This paper describes practical elements during two terms of a first-year module within which CDIO standards are implemented. The aim of this practical module is for students to practice their fundamental knowledge and develop the required skills to complete projects that are structured according to industry standards. Several skills are involved in working within a professional engineering environment, beyond the strictly technical knowledge. The intention is to make the students also aware of these skills. During the first term of year one, the module includes a team-based reverse engineering project. Students are assigned to teams and given an appliance. They are expected to conceptually and physically deconstruct the device and analyze the relevant aspects of both of its parts and as a whole. Aspects would include scientific principles related to function, design considerations, the context of use, etc. The teams will then propose improvements on individual parts and the device as a whole, in terms of either function, price, manufacturing, or sustainability. The work is presented to the class and compiled into a group report. During the second term, the students are trained in design software (Autodesk Fusion 360 CAD, CAE, CAM), including basic finite element simulation, and are given two design tasks. The first is to use laser cutting to design a small wooden bridge based on certain specifications (e.g., dimensions, load-bearing), including some aesthetic elements, using limited resources (i.e., material allowance). The second is to design and optimize (in terms of mass) a support structure of certain dimensions and load-bearing capacity. The structures are then manufactured and assembled, i.e., laser-cut, and 3D printed correspondingly, weighted and tested for their load-bearing capacity. Assessment is based on a relevant portfolio. Throughout the two terms, lectures are delivered on project management and product development, as well as case studies by guest lecturers of various engineering fields. The module has been very well received with high student ratings in relevant surveys.

KEYWORDS

Introduction to engineering, design process, CAD/CAE/CAM, active learning, Standard 1, 3, 4, 5, 8, 11

INTRODUCTION

Since 2017, Nottingham Trent University (NTU) has established a new engineering department. The following paper describes practical elements during two terms of the first-year module in engineering, called Innovation and Engineering Solutions. The module covers about a third of the first-year curriculum, and the described elements account for 50% of the module grade. The module is taught across all engineering courses offered by the department, i.e., Electronic, Biomedical, Sports, and Mechanical engineering. All engineering courses are structured so that to include engineering fundamentals, e.g., mathematics, specialized modules for each course (e.g., electronics). And practical skills modules such as the module described below. The aim is to have the students practicing their knowledge and develop the skills required to complete projects that are structured according to industry standards. There is a number of skills involved in working within a professional engineering environment (e.g., team building, communication, etc.) beyond the strictly theoretical knowledge of the topic. The intention is to make the students aware of these skills, in addition to the purely engineering practical skills.

Students taking the module are either domestic or international with a wide range of educational backgrounds. Entry qualifications may vary, i.e., A level, BTEC, foundation, as well as different backgrounds in terms of the educational systems they attended. In addition, students may vary in terms of their talents and dispositions (Thomas & May, 2010). Provided the students achieved the entry requirements, the department and University have additional provisions in order to assist students in acquiring necessary prerequisite knowledge in related topics, e.g., math or chemistry, regardless of the differences in educational background. Provisions are also made in terms of learning disabilities, e.g., dyslexia, according to University guidance. The projects described below are multifaceted in a way that can allow students to build upon their strengths but also push beyond their comfort zone such that they can identify and develop new skills. Tasks were designed to require several skills, including critical thinking, effective communication, technical knowledge, science and engineering fundamentals, independent study, creativity, team building, etc. Students were guided through a structured process that aimed to facilitate active learning.

Other institutions have reported modules with similar elements in terms of technical content and structure and in accordance with CDIO standards. A reverse engineering module was used as part of innovation training (ZU et al., 2012). CAD, CAE, CAM environments, and CNC machines were used to introduce students to the engineering design tools and process as part of a 4-week independent activities course (Deweck et al., 2005). 3D desktop printers were used at NTNU for a group design project (Haavi et al., 2018) in which students were able to choose their own teams out of participants from two courses. An engineering design and optimization module, based on CDIO standards and including industry involvement, was developed as part of a postgraduate course (Quist et al., 2017). The NTU module, described in this paper, aims at integrating and introducing these tools, processes, and practices, early in the student's engineering education (i.e., first year).

FIRST TERM: REVERSE ENGINEERING

During the first term of the first year, the students are required to complete a reverse engineering project during weekly 2-hour lab sessions. The intended learning outcomes roughly include an introduction to the basics of engineering design, engineering considerations within the design (e.g., materials), processes, and methods of working (e.g., team collaboration). The students are assigned into mixed teams, in terms of engineering courses, in order to avoid potential clustering of similar dispositions and, therefore, to introduce some diversity in the teams. Each team draws a number from a ballot that corresponds to an appliance or device that the team would have to work on. The project was structured in a way common for industry, i.e., with the use of three "gateways" or checkpoints as feedback opportunities at which the students would have to pause and provide certain deliverables as a form of formative assessment. Upon passing the gateway, the students are 'allowed' to progress to the next stage of the project. Roughly, the project "Gateway 1" would include tasks of an initial analysis of the product in terms of external description, concept analysis, function, need it serves at a specific and general context, price, market and history and then if possible some potential improvements at first instance, that could be analyzed further during the next stages. Passing through to "Gateway 2" the students would physically disassemble the device to its constituent parts for which a bill of materials would be filled. The function, materials, price, etc. of each part would be recorded, and pictures of each part would be numbered and archived. The students would be able to use any available reliable source to obtain the relevant information and understand the potential reason behind the design considerations and function of each part. The part would then be numbered and placed on boards in an orderly manner (Figure 1).

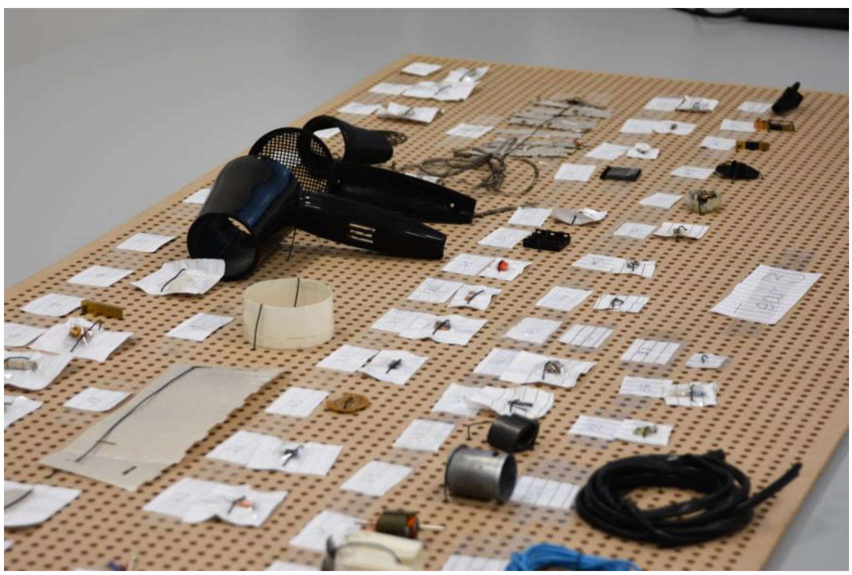

Figure 1. Example of a board with parts from a reverse engineering project

Progressing to the 3rd gateway, the students would have to deliver two paragraphs for each part. The first paragraph would have to be a description and a critical evaluation of the role of the part in the device. The second paragraph would need to propose, when possible, potential improvements in terms of either price, function, manufacturing, or sustainability. Each team would then finally need to present their findings to the class (formative assessment) and get feedback from peers and tutors. They would then compile a report that would be the actual item on which they would be graded (summative assessment).

Each lab session would start with a brief (approximately 10 minutes) introduction to content relevant to the lab tasks for the day. In parallel to the lab sessions, there would be lectures, delivered at a different time, that would cover design and product development aspects (Eppinger & Ulrich, 2015). Additionally, invited guest lecturers would deliver talks on case studies from their professional experience. This would assist in eliciting important aspects and approaches to product design and engineering projects through experienced practitioners. All content, including recorded lectures, would then be available for students to access online.

The reverse engineering project structure and content were chosen so as to try and enable active learning as much as possible. The method is also included in the NTU teaching development framework standards. The students were given direction and instructions so as to perform actions collectively. During the process, i.e., dismantling an appliance, the students would have to engage in critical thinking and reflect, so that to be able to describe each part's function within the appliance and its relation to the whole. This is in alignment with (Bonwell & Eison, 1991) (p.iii) who argue on the value of student actively performing actions and thinking on the actions they are performing. Additionally, the students would be encouraged to research each part, e.g., materials, using any medium they choose (e.g., internet, library) and at their own pace. In this way, they could build their own knowledge, connect the new ideas and form an enhanced understanding (Brame & Director, 2016) in a wider context, e.g., considering the need that the appliance is serving, the appliance itself, and the relation to individual parts. This was in alignment with the work of (Tynjälä, 1999) (p.365) who recommended the choice of tasks that enhance the process of active knowledge construction.

The team element was designed in a way so as to promote inclusivity. The students were mixed regardless of educational background and furthermore between different courses. This was done to promote diversity of backgrounds, and potentially mixed talents and dispositions. The variety of tasks would also enable students of various educational backgrounds to engage in the process. Some tasks were more technical, e.g., dismantling a device and identifying functions, which could potentially be easier for the student from a more technical background, and some tasks more theoretical such as written descriptions. The students could choose tasks that either felt more comfortable doing or try venturing outside their comfort zone and develop in new areas. This would give the opportunity for everyone to engage, participate, and contribute. Commonly, engineers are assigned to teams. The skill to be able to effectively collaborate within a team can be important in a professional environment.

The literature on collaborative learning, i.e., students working in teams towards a common goal (Prince, 2004), suggests that a social element may enhance the process of constructing meaning (Tynjälä, 1999) and that peer to peer interactions may promote the development of 'extended and accurate mental models' (Brame & Director, 2016). The idea of constructive alignment as an effective method in teaching is also proposed in the literature (Biggs, 2011). The premise is that the learning outcomes, teaching and learning activities, and assessment tasks should be aligned. In this example, the students would perform tasks observed and guided by the module leader, which would result in the deliverables that would compose their assessed work. Through this process, the learning outcomes would be achieved. This method was preferable rather than lecturer performing tasks and observed by the students. Engineering is an example of a discipline that involves practice as well as the accumulation of various information.

Arguably, this project at the beginning of the first year gives students the opportunity to rethink the way they view everyday objects. This would align with the idea of threshold concepts in which acquired concepts, that might be challenging for learners, can lead to conceptual transformation and reveal hidden interrelatedness (Schwartzman, 2010).

The teaching in this example was aimed to give structure and case study experiences leading to the desired outcomes. The students engaged in discussions within the team during the various parts of the project, e.g., the practical dismantling of the appliances, led to reflection and analysis. Their work was presented verbally to the class, which allowed them to practice an important required skill and get feedback from both their peers and tutors. Feedback during the gateways and from their peers after the presentation would be incorporated in the required report for their actual assessment. The project was designed as a multi-layered learning experience. Rather than going through a description of case studies in a lecture format given by a tutor, a more practical approach was implemented to approach the desired outcomes.

During the laboratory sessions, there was high attendance, and students seemed quite eager to proceed with the projects. There were certain elements that seemed to produce excitement, e.g., the ballot draw for the appliance assignment, or especially towards the dismantling stage. On several occasions, the students would try and stay longer beyond the session so that to continue working. This, however, was not possible due to room bookings. Teams seemed engaged in relevant discussions that seemed constructive, pleasant, and cheerful. Tutors would periodically pass by the groups and join the conversation answering any potential question and suggesting guidance as to how they could find out relevant information. Arguably, the pleasant social element and the excitement during tasks (e.g., dismantling devices) could be elements of positive reinforcement within the learning experience. Positive reinforcement could be an effective motivational factor, preferable to a negative one, e.g., the threat of a bad grade.

The resulting reports that were submitted by the students were of a good standard with a high overall average mark. Student surveys scored high in overall student satisfaction. In combination with the various opportunities at which students got feedback either by their peers or tutors, the increased interest and enjoyment could arguably be the reasons for the student performance. A peer review element was also included. Confidential peer review forms were submitted in which students had to rate their team members from a scale between 0-5, with 0 being no contribution or absent, and 5 being significant contribution above average. Action in terms of grade differentiation within a team was only taken when multiple members of a team rated a teammate with 0 or 1. Additionally, within the report, a section was included that would roughly summarize the parts with which each member contributed. The team grade was a reflection of the collective result. The grades were also moderated in accordance with NTU regulations. However, individual efforts within team projects are practically difficult to assess precisely. It remains a challenge for tutors to establish a system that would accurately and perfectly capture individual effort. Nevertheless, the long-term individual benefit, in terms of knowledge and experience, is often proportional to engagement and effort, regardless of the grade. Overall the goals of the module were achieved, and important skills were elicited and practiced in agreement with the relevant literature. The students were exposed to several challenges and were benefited in various ways.

SECOND TERM: WOODEN BRIDGE AND SUPPORT STRUCTURE OPTIMISATION

Having reflected on design concepts and considerations during the reverse engineering project, the students would then progress to design projects for the second term. They would be asked to complete two small projects (wooden bridge, optimizing a support structure) that would include basic characteristics of typical engineering projects, i.e., resource restrictions, functional and dimensional specifications, some space for creativity, etc.

During the second term of the same module, the students are introduced to laser cutting, which is a manufacturing technique that involves cutting sheets of material using a laser beam. The assessment would be based on a portfolio style presentation of their work. Prior to the start of the project, guest instructors were invited from a CAD software company (Autodesk) in order to train students on Fusion 360, which would be used for the projects. We organized three days of training with company instructors on campus. Within this time, the students would follow the instructor's steps for small tutorial projects that would include all the necessary steps, which would then be useful for their module. During these tutorials, the students would be assisted at each step by the instructors. The students were also provided with online tutorials and teaching resources related to the topics that were covered during class.

After the software training, the students would be encouraged to research bridge designs and then use Fusion 360 software to design their own. The type of bridge was left open for the students to decide; however, there were some resource restrictions (in terms of use of the material), basic dimensions, and load-bearing specifications (support 1kg). Apart from the purely functional side, the students were urged to include an aesthetical aspect of their designs. The design should be made in a way that would be compatible with the manufacturing method (i.e., laser cutting). The use of adhesives for structural purposes was prohibited. That would provide them with an opportunity to further think and understand the manufacturing method and how manufacturing affects design.

The wooden bridge project had 3 "Gateways," which would serve as formative assessments of the student's progress. The students would have to submit predefined deliverables on which they would get feedback. Those were all necessary stages that would be included in their final portfolio as parts of their summative assessment.

For the first gateway, the students would have to use the software to design a bridge (to be manufactured with the laser cutting method) and assemble it virtually as a three-dimensional model. The second gateway would include using the software for the simulation of the bridge with the predefined load. Potential improvements would be made to the design, if necessary, to reinforce the structure. For the third gateway, the students would use CAM (computer-aided manufacturing element) to ensure compatibility with the manufacturing method, export the drawings in a format compatible with the laser cutter and queue for cutting and assembly (Figure 2). On the final day of the term, the session was organized as an event in which the students test their design for structural integrity. Prizes were given by guests from an independent, engineering-related, professional body on the best bridge design.

Similarly, for the support structure design, an initial template of a support structure was given with certain dimensions defined. The structure would have to be optimized using the simulation tools and stress distribution in order to reduce the use of the material as much as possible for supporting a 5kg load. The structures would then be 3D printed, weighted, and tested on the final day of the term (Figure 3). A small prize was given to the student with the lightest structure that would support the 5kg.

The tasks leading to the portfolio were chosen in order for the students to acquire some necessary skills for prototyping with consideration to available manufacturing methods. The projects served as an introduction to designing, modeling, manufacturing, and then presenting their work. The CAD software was taught by experienced instructors, i.e., professional experts, and then online resources were provided to revisit the material and potentially expand their knowledge. During the projects, the students would have to engage in active learning, i.e., individually performing tasks and building their own knowledge and understanding of the available tools (NTU academic policy and practice). All guidance material would be available online at the NTU online learning system, i.e., NOW, and students could monitor their own progress in addition to the feedback they would be receiving.

The assessment would "encourage the students to position themselves as active learners" Aswin et al. (2015, p257) towards critical thinking and constructive judgment of their work. In this example, both formative and summative assessments require the students to perform the necessary tasks and then present them visually, which puts them in a position to view them as a third party and reflect. The portfolio representation would have to present their work and convey the skills that the student has used to complete the project. The tasks were directly linked to the learning outcomes as they were necessary for the effective use of the manufacturing method at hand. This is in alignment with the authors mentioned above and the concept of constructive alignment. The students having to exhibit their process within a portfolio allows them to view the process themselves and gives them a greater picture of the steps required for prototyping and communicating an idea and its implementation. Revealing the relevance of a taught topic can increase motivation. This was implemented in teaching mathematics (Deshler & Burroughs, 2013). However, it could also apply to other disciplines. Potentially, when students see the value of certain skills, they might be more motivated to acquire them. On this occasion, the students were able to experience a creative process from concept to prototype.

Figure 2. Example of a wooden bridge project (example of student work curtesy of Mr. Edward-Joseph Cefai)

The projects were designed to have several feedback opportunities for the students, e.g., the "Gateways," which are formative assessments. According to Hattie and Timperley (2007, p.86), the aim of feedback is "to reduce discrepancies between current understandings and performance and a goal." In addition, often in engineering, there are more than one ways to reach a goal or solve a problem. Feedback is also given in order to help students with practical difficulties or to point out a potentially more efficient way that a certain outcome could be achieved. Deconstructing the goals, examining the process, and identifying the activities towards progress, allows students to step back and reflect on their approach. More specifically, in this example, the software has a number of tools for designing structures, and a manufacturing process might have certain strengths and limitations. Helping the students use the tools in the best way, and designing with efficient manufacturing in mind adds another important dimension to their work. The intermittent formative assessments allow for picking up on weaknesses and working with the student towards developing new skills, early in the project, and before the summative assessment. This approach also provides the student with a general process of regularly evaluating their work and identifying weaknesses and areas for improvement. "Gateways" or checkpoints, i.e., scheduled points within a project were they can stop, reflect, and seek advice, is a process often used in professional engineering environments. This is in agreement with the NTU quality handbook were the inclusion of reflection and future development is promoted. Ashwin et al. (2015, p. 253) also point out the importance of "assessment for longer-term learning." Regular formative assessments in the form of discussion also assist students in developing a way of thinking that is related to their subject area. As was done in this example, and during the gateway discussions, the students were able to better understand the value of the process and enter into a dialogue with the tutors to clarify any ambiguity. This enhances the experiential learning aspect, which is important in practical skills. Practical elements can be more complicated to express in a written manner than it is to demonstrate and discuss. By understanding the important and relevant values and principles through experience, the students can develop or enhance their internal value system that feeds to their creativity. Developing an internal professional value system is important. Similarly, Hattie and Timperley (2007, p. 91) advocate "self-regulation." During the projects, tutors would try and provide suggestions for alternative ways to proceed for various tasks and explain the benefits and potential costs of each. Students were given choices rather than instructed on a single course of action. The purpose was to promote the development of an internal values system and empower the students with choice and ownership over their projects.

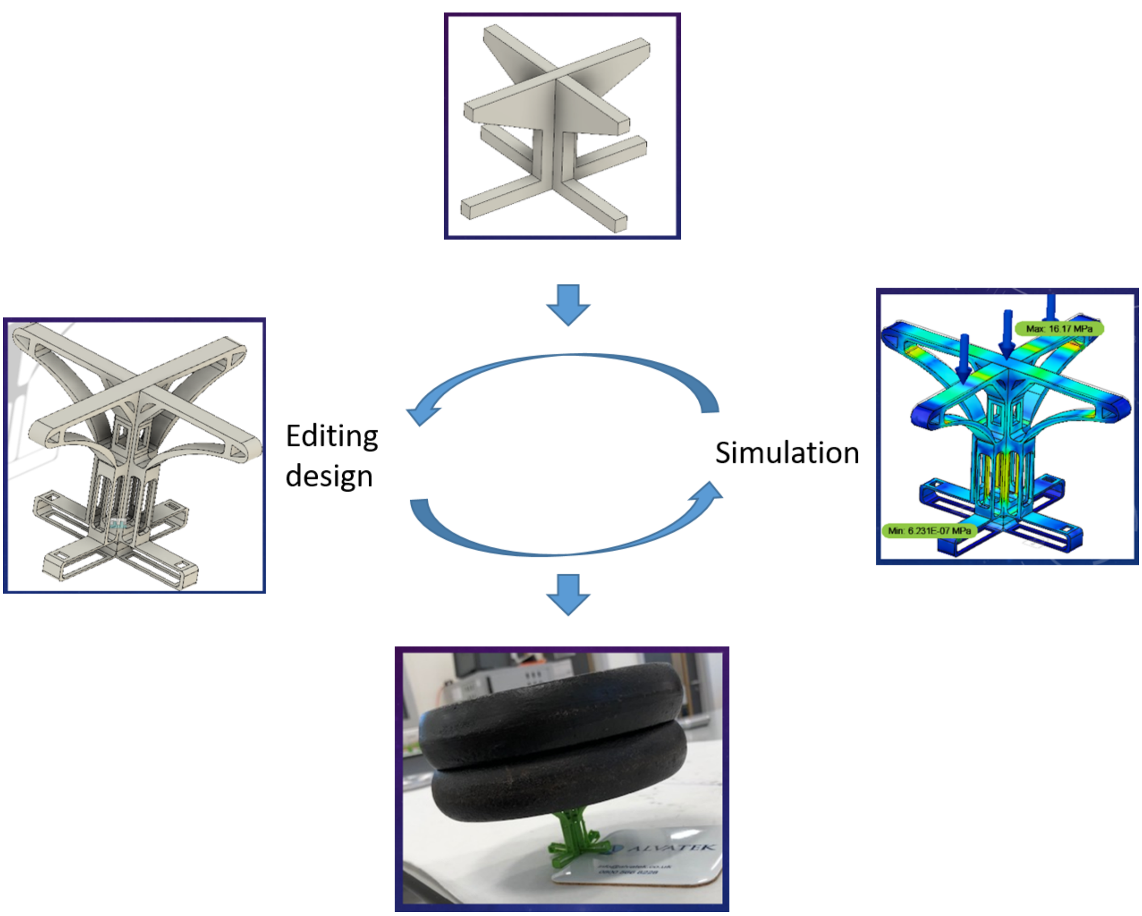

Figure 3. Example of the optimization process for the pier support structure (example of student work curtesy of Mr. Christie Teehan)

Students were encouraged to discuss and assist each other with practical difficulties in using the tools. The final day at the end of the term was also aimed at students seeing the work of their colleagues. Explaining a concept or discussing it amongst peers is a way to increase one's understanding of it and reveal weaknesses (Falchikov, 2013). Richard Feynman was a known advocate of using teaching for increasing one's own understanding. As he mentions, the questions of learners can reveal general ambiguities (Feynman & Leighton, 1992). Explaining something in a simple manner often requires depth in understanding it. Similarly, the students would have the opportunity to explain their design to their peers or tutors and assist others with their approach.

Student attendance was quite high for these sessions, and students seemed absorbed in their tasks. Even though some might have initially struggled with the software, they progressively improved. Students recognized that it was challenging; however, they also recognized the value of the process. On one occasion, a student said that it was "the most creative thing" she had ever done. Students would engage and ask questions, and often they would proceed to resolve the problems with the assistance of their peers. Whenever a prototype was manufactured, there was obvious interest from peers.

In terms of sustainability, biodegradable material, i.e., wood, was used for the bridge designs, and recently funds were secured in order to obtain the necessary equipment to recycle used 3D printed filament from older projects.

The level of competency in the software varied significantly in the beginning. However, the discrepancy seemed to reduce as the projects evolved. Tracking the progress between the formative assessments and the final product, there was a noticeable improvement (also noted by an academic observer). The progress was reflected in the evolution of designs and the choices made by the students, e.g., to focus on either aesthetics, efficiency, structural integrity. The submitted portfolios were of very good level, and the cohort's overall grade was relatively high. The process of having an idea and using modern software and manufacturing methods to bring into reality was appealing and helped generate interest that arguably increased the attendance. The portfolio and the manufactured structures gave the students, in addition to the completion of the module, a record of their process and a tangible object (e.g., the bridge) that would represent their experience and gained knowledge.

CONCLUSION

The practical elements of two terms of a first-year module were described above. The module was designed as an extended introduction to engineering. Various elements of CDIO principles and educational literature were implemented in the context of teaching and supporting learning, and assessments and feedback, for engineering topics. The elements included a reverse engineering project which provided the students with some context and allowed them to explore various relevant aspects of product cases. They were able to apply knowledge from other modules of the curriculum (e.g., fundamentals) in explaining the principles behind the function of the products and consider aspects such as product lifecycle and alternative, improved designs. The reverse engineering project was followed by two design exercises that included elements of CAD, CAE, CAM, and manufacturing as well as optimization concepts that were then physically tested. Active learning was central throughout the module.

The projects were structured in a multifaceted way, in terms of useful skills and technical knowledge. These elements were included within the assessments. The projects had several elements of typical engineering projects, including limited resources and also space for creative thinking—aspects of working within teams or individually were also elicited. Equitable individual assessment in team projects can be a challenge. However, some mitigating elements were added (e.g., peer reviews, task allocation summary) that could sometimes correspond to equivalents in professional environments. Overall the module was very well received and scored highly in student feedback surveys.

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EXPLORING STUDENT MOTIVATION IN A BLENDED AND SELF-DIRECTED GROUP-LEARNING ENVIRONMENT

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ABSTRACT

This paper presents a study that was conducted to explore the effectiveness of conducting self-directed learning (SDL) in a blended and self-directed group learning environment to motivate learners to learn by themselves. Many of our learners tend to be extrinsically motivated by the attainment of course credits, and that often results in poor participation and completion rate for topics delivered through SDL. With the implementation of SDL in a blended and self-directed group learning environment, we hope to tap on a different set of motivation that is proposed in the self-determination theory to encourage learners to participate and complete the SDL topics presented to them. The study gathered perceptions and opinions of learners on their SDL experiences in the blended and self-directed group learning environment. We analyzed to see if their needs for competence, autonomy, and relatedness could be met and whether the initial exposure of SDL in the blended and self-directed group learning environment could help them become more independent to self-direct their learning in more advanced topics. Initial results found that participation and completion rate for this SDL implementation was encouraging. Most learners reported that they faced less stress and found it easier to clarify doubts they had had the option to interact with other learners face-to-face.

KEYWORDS

Blended Learning, Group Learning, Self-Directed Learning, Student Motivation, Self-Determination Theory, Standards 5, 7

MOTIVATION

Getting learners to do self-directed learning (SDL) has become ever more important, especially under the background of the Singapore government, embarking a movement to develop skills in Singaporeans (Seow, 2015). This is also enabled by the advancement in technology evident in the explosion of availability and accessibility of Massive Open Online Courses (MOOCs). The importance of SDL can also be seen in our institutional approach to pursue eLearning and blended learning to deliver effective and engaging lessons to our learners.

On the ground, lecturers can possibly agree on the importance of getting learners to self-direct their learning too. Yet, there is also the fear that learners are not motivated enough to complete a piece of SDL task, sometimes, even if marks are allocated to the task.

This paper presents a study that was conducted to explore the effectiveness of conducting SDL using a different approach to motivate learners to learn by themselves. The results obtained from the study could provide some insights into student motivation using alternative approaches of SDL.

LITERATURE REVIEW

Studies had shown that factors such as motivation, attitude towards eLearning, confidence in SDL skills, and life-long learning behaviors were some of the key success factors in SDL (Bonk & Lee, 2017; FitzPatrick, 2012; Kim, 2004; Li, Tancredi, Co, & West, 2010).

In terms of motivation, Bonk & Lee (2017) found that majority of the respondents who embarked on SDL in MOOCs were motivated by their wants to acquire a new skill. Many of them hoped to help others or society with the skills that they would be acquiring. In other words, they were largely intrinsically motivated, and that drove them to embark on SDL. On the other hand, studies such as Kim (2004) confirmed that the main reason for learners dropping out of SDL was due to a lack of motivation. Putting these studies together, the implication is that intrinsic motivation like the ones suggested by Bonk & Lee (2017) contributed to the success of SDL in learners.

However, the profiles of our learners are largely extrinsically motivated as opposed to the intrinsic motivation suggested by Bonk & Lee (2017). That is, our learners are motivated by attaining the course credits required by the diploma, which they are studying for.

Perhaps, another way to motivate these groups of learners would be to apply the self-determination theory (Deci & Ryan, 2000) into the way SDL is conducted, which is to meet learners' innate needs for competence, autonomy, and relatedness to motivate them. In particular, the need for relatedness appeared to be the most difficult to meet in SDL. Many studies on SDL suggested that learners were learning alone in SDL. In fact, Kim (2004) also found that the lack of human interaction found in the online learning environment to be a major cause of a decreased motivation to persist learning. As such, it is important for us to address the need for relatedness in SDL.

Studies showed that alternative implementation of SDL, such as a blended learning approach or a self-directed group learning approach, could meet the learners' needs for relatedness. In a study conducted by Cleveland-Innes et al. (2017), they reported that opportunities to discuss with other learners online and in a blended learning environment was rewarding for the learners. In another study conducted by Fukuda et al. (2014), which attempted to get learners to meet for SDL study sessions together, they found that getting learners to agree on a common time to do self-directed group learning can be a challenge.

RESEARCH DESIGN AND METHODS

Our study seeks to explore the effectiveness of conducting self-directed learning in a blended and self-directed group learning environment to motivate learners to learn by themselves. The target implementation presented will attempt to address some of the shortcomings of the approaches introduced by Cleveland-Innes, et al. (2017) and Fukuda, et al. (2014).

Willing learners were asked to participate in interviews or surveys that were conducted at least seven weeks after the deadline of the SDL phase. This also allowed them to apply what they had learned in their SDL in their projects, giving them a better perception of how the SDL had or had not helped them in their learning.

Blended and Self-Directed Group Learning Approach (The "MakerLab" Implementation)

The blended and self-directed group learning approach of SDL was implemented in a prescribed elective titled 'Internet of Things Application Development,' which was offered to Year 3 students of the Diploma in Multimedia and Infocomm Technology offered by the School of Engineering, Nanyang Polytechnic. Known as the "MakerLab" implementation, it was designed by applying the self-determination theory (Deci & Ryan, 2000) such that learners' need for competence (the sense of being able to complete and achieve something out of the MakerLab), need for autonomy (the sense of having control over their learning) and need for relatedness (the experience of someone being in the learning journey with them) were met.

The "MakerLab" comprised two components, the environment, and the content. The environment where "MakerLabs" were conducted aimed to meet the learners' needs for autonomy and relatedness. They took place in classrooms during scheduled face-to-face classes. No actual teaching took place to allow learners to go at their own pace. To enhance interaction between learners, leaners were seated in groups and encouraged to learn from each other. They could also clarify and bounce ideas with the instructor of the day who would be monitoring their progress. The "MakerLab" content was compiled in an interactive digital format. Learners were led through a series of tasks such as programming, watching videos, and reading curated documentation and articles. Knowledge check quizzes for formative self-assessment purposes interleaved the tasks regularly to provide learners with customized feedback based on their responses. At the end of each series of tasks was a programming assignment where they will be "making" (or developing) a mini prototype using the knowledge they learned.

To meet the learners' needs of competence, the content was ordered in increasing difficulty. The content was made with more detailed instructions and explanation, more bite-sized, and with more interactivity to help learners maintain focused.

The "MakerLab" implementation was also not a problem-based learning (PBL) and project-based learning (PjBL). In PBL and PjBL, learners are usually given an open but focused problem or project where they will need to learn skills along the way that help them solve their problem or complete their project. The "MakerLab" implementation is closer to a traditional lab session where learners are guided with an option for learners to go beyond the compiled learning content whenever they want.

Selection of Participants and Data Collection

Thirty-five willing learners of varying academic abilities and sociability participated in an interview (16 learners) or a survey (19 learners).

Academic abilities were chosen as a dimension to study as it could affect the self-efficacy of learners in SDL. It was determined through the Grade Point Average (GPA) and the grades obtained from the lab test.

Sociability was chosen as a dimension to study as it can affect how well learners can meet their needs for relatedness during SDL. Participants were classified as "introvert" or "extrovert" based on the instructors' day to day classroom observations on their level of interaction with their peers and the learners' personal assessment of their personality. The terms "introvert" and "extrovert" used in this paper were defined as the sociability of the learner in the context of the module they were learning. It was chosen to be defined as such because we also observed that learners could be more socially active or withdrawn depending on the subject matter they were interacting with.

The first batch of 16 participants out of a total of 34 learners who were offered the module shared their experiences of the "MakerLab" through interviews. Interviews were used as it allowed an in-depth exploration of factors that could affect the learner's motivation in the self-directed learning process. Most interviews were conducted in a focus group to explore the extent of group dynamics within a clique of friends learning together. A few learners were interviewed alone to give them a safe environment to share the more sensitive experiences they had.

The second batch of 19 willing participants out of a total of 33 learners who were offered the module was asked to complete a survey. A survey was chosen instead of this time around with the aim of getting more participation from learners for a better picture in addressing the gaps found from the first round of analysis gathered from the interviews. One gap was to explore if learners were motivated enough and can continue their self-directed learning at home, after having gone through some sessions in a blended and self-directed group learning environment. To explore this factor, the second batch of learners were dismissed on their fourth face-to-face class to complete their SDL on their own.

As the principal investigator was also one of the instructors delivering the module and this relationship may influence the willingness of the participants to give honest opinions, (1) all participants were assured that the aim of the research was to find out about how to help the participants learn better in a self-directed approach and has nothing to do with the grading process, (2) the interviews and surveys were conducted only after grades for the self-directed learning portions of the work were finalized and made known to the learners, and (3) 50% of the participants were drawn from another group of learners guided by a different instructor.

In terms of the comparability of the two batches of participants, participants were only drawn from the learners who were in their Year 3 Semester 2 of their studies even though it was also offered to those in their Year 3 Semester 1 of their studies. The number of participants broken down by their academic abilities and sociability profile is summarised in Table 1.

Table 1. Profile of the Research Participants

	Batch 1 (Year 2018)		**Batch 2 (Year 2019)**	
	Introvert	**Extrovert**	**Introvert**	**Extrovert**
High Academic Ability	**4**	**4**	**7**	**4**
Low Academic Ability	**5**	**3**	**5**	**4**

Data Analysis

Interviews conducted with the first batch of participants were recorded and transcribed for further analysis. The extracts of the transcripts of the interview were labeled and regrouped into categories: responses related to the needs for autonomy, competence, and relatedness as proposed in the self-determination theory (Deci & Ryan, 2000), and sentiments relating to distinct features of the implementation.

Similarly, open-ended responses from the survey conducted with the second batch of participants were also labeled and regrouped into categories.

Patterns, major themes, and exceptional cases found through the analysis were compiled under the findings section of this paper.

Limitations of the Research

As the selection of participants relied on their willingness to participate in the interviews and surveys, it was possible that learners who had no interest in the module at all may refuse to participate in the research. This potentially missed out on the input from learners from those profiles, rendering it impossible to learn more about their motivations in the SDL implementation that was being studied.

Classification of the learners by their sociability relied mainly on day-to-day classroom observations. While instructors had the opportunity to work with the participants for between 40 to 60 hours, it could still be influenced by the personal opinions of the observers, which may result in discrepancies.

This study was also largely restricted to qualitative data, learners' perception, and their motivation. No quantitative measurements were made on how much the participants improved in self-directed-related skillsets or outcomes they perceived to have gained.

FINDINGS

Meeting the Need for Autonomy

Participants cited different ways which they could learn: researching on their own (favored by introverted participants), asking a friend (favored by extroverted participants), or asking the instructor. They switched between approaches seamlessly, depending on what they felt suited the moment. As one participant said, "*For some cases, I searched the Internet on my own, some cases, it was under the guidance of the lab instructions. If there were Internet links provided in lab instructions, I would see the link [sic] to see exactly the specific parts. But some part [sic] I want to understand more, I will go on my own." (Student 1H, extroverted with high academic ability)*

Participants found it easier to ask someone for help in the "MakerLab" implementation. As an extroverted participant with low academic ability puts it, *"When you do e-learning at home, communication by texts is [sic] really hard to understand, face to face is more conventional" (Student 2H).*

Participants can also choose the amount of time to spend understanding the material. They reported that they experienced less stress. One participant reported, *"The self-paced is fine for me because honestly, I won't feel pressured? Because other teachers they want like [sic] get it done and do away with, but as for the self-paced ones, it will be like easier for us, for the slower ones." (Student 1F, introverted with high academic ability)*

Meeting the Need for Relatedness

Most participants found it more enjoyable, more engaging, and safer to study with friends. However, at least two participants also felt that it might be distracting at times. One of them noted that *"I cannot work with my friends. *laughters* Because I will chat with them all the time. Especially N *laughters* Without N talk [sic] to me, I will work all the time. I rather work alone." (Student 1U, extroverted with high academic ability)*

Participants said that they did not start off knowing each other. Some felt that through working on the "MakerLab," they had built teamwork and friendship. Sitting in groups also helped them to communicate with each other.

One probable issue with group learning we explored with some of the low academic ability participants as if they would feel inferior when they found that they were slower than their classmates. They reported that such stress was more on the positive for them. Learners often supported and motivated each other. One participant even said, *"B is faster. So sometimes, she will ask me and D where we have completed till, and that helps to speed us up. She will ask us where we have progress till. After that, sometimes, we tell ourselves that we must catch up with her." (Student 1X, an introvert with low academic ability)*

Meeting the Need for Competence

Participants generally felt a greater sense of achievement, leading to some believing that they could do more. They also felt they understood the material better because they understood the content in their personal way and can understand in other manners having discussed with their friends on the problem. As one participant said, *"We are in a group, we learn [sic] ourselves, then we can consult like our friends, which they give [sic] different advice. But instead, if the lecturer just [sic] teaching in front, they just go through the textbook kind of style, then after that, we just learn the textbook kind of way, then just follow according to what [sic] the textbook says." (Student 1P, introverted with high academic ability).* On a flipped side, a few participants also reported that they were unsure if they understood the content with enough depth.

When asked which part of the learning experience they felt that they were able to achieve something, the majority of the participants reported that:

- **Seeing** the LCD lights hardware responding to the codes they have implemented (generally mentioned by learners with lower academic abilities), and
- **Understanding** how the turnstile works and implementing the prototype for themselves (generally mentioned by learners with higher academic abilities)

was an achievement for them. A few participants also reported that these achievements were the most memorable part of the learning experience.

One thing to note was that such competency was built through a period of time. Several participants pointed out that they were initially doubtful about whether they could remain focus or even cope with learning in the "MakerLab." Factors that gave them confidence include completing intermediate assignments, availability of detailed instructions and knowledge check quizzes, and time to get accustomed to the self-directed process. As one participant put it, *"At first when I heard it (that I need to do SDL), I was like 'Oh no'. But after I see the notes, it's actually quite detailed; then I was quite assured that it will come [sic], it will happen." (Student 1R, introverted with low academic ability).* They also reported that they have improved in self-directed-related skillsets such as independence, time management, and responsibility by the end of the "MakerLab" phase. Participants were able to see how the skillset was important in the work context.

Instances where Needs were not Met

An introverted participant with low academic ability opined that the "MakerLab" did not work for him. In his words, *"It's not the best way of learning for me because when I lack the fundamentals, it's hard to just self-learn. Have to have someone to guide. So self-learning is quite difficult." (Student J)*. He was uncomfortable to ask his classmates for help as he was unfamiliar with them, and he felt that the guidance provided by the instructor was insufficient.

Transiting to Self-Directedness Outside of Face-to-face Time

Whether conducting the SDL in a blended and self-directed group learning environment initially can help learners to feel more motivated to complete their own SDL, to explore this in more depth, the second batch of learners were dismissed from their fourth face-to-face class and asked to complete the "MakerLab" on their own.

Participation Rate, Completion Rate and Motivation

16 of the 19 participants surveyed attempted the "MakerLab" for one to two sessions outside of their pre-arranged face-to-face class. Out of the 16, 15 reported that meeting the deadlines for the completion of the "MakerLab" tasks was their primary motivation for doing SDL while one learner cited that exploring the material was his primary motivation. 8 of the 16 participants chose to meet their friends to work on their SDL. 12 of the 16 participants spent between one to three hours per session working on the SDL. Two participants with lower academic ability reported spending up to 6 hours per session on the SDL.

For the three participants who did not attempt the "MakerLab" outside of class time, they reported that even though they knew they were behind time in meeting the deadlines for completion of the "MakerLab," they were either busy with other commitments outside of class or not motivated to self-direct their learning. Nevertheless, 85% of the learners were able to complete all "MakerLab" tasks satisfactorily.

Learners felt limited in the pure SDL approach

Despite high participation and completion rate, some participants cited difficulties in displaying the same level of competence when they had to complete their "MakerLab" outside of the blended and self-directed group learning environment. Participants who chose to work on the "MakerLab" alone reported lower competence level in completing the tasks. For instance, Student 2E, an extroverted participant with high academic abilities, mentioned that "*Sometimes I do not know if I'm doing the right thing*."

Participants also find it difficult to ask questions and receive timely feedback. For instance, some participants found it troublesome to include screengrabs of their work in order to ask a question through email. They also had to wait for the reply, and that broke their learning flow.

DISCUSSION AND FUTURE RESEARCH

The "MakerLab" implementation addressed two issues of the SDL: increasing opportunities and improving accessibility for learners to discuss with other learners (Cleveland-Innes, Stenbom, & Gauvreau, 2017; Fukuda, Suzuki, Hashimoto, & Okazaki, 2014).

The findings indicated that the reception for the "MakerLab" implementation was generally positive. Participants felt that they understood the content better and improved in skillsets such as independence, time management, and teamwork.

Participants had the autonomy to choose how they want to learn and can change from one way to another seamlessly, leading them to learn in a manner that fits the moment and their learning styles.

When participants chose to ask someone, the "MakerLab" was more accessible than home-based SDL: learners found it easier to ask questions to whom they trust (which can be their friends or the instructor). They were also able to express their questions more accurately and receive timely feedback from other people. Timely feedback was important to keep learners' momentum so that they can clarify essential questions in order to continue their learning.

In terms of the need for competence, findings showed that successfully implementing a prototype contributed to most participants' most memorable learning experiences. It was then important to plan for learners to attain such achievements consistently to help reinforce that they are improving to improve their motivation (Madtha, 2015).

Progressing to Full Self-Directed Learning

The participation rate of the pure SDL learning session planned for them and the completion rate of the "MakerLab" was encouraging. Several participants had cited a lack of confidence when they were first introduced to the "MakerLab" learning approach but also felt that they improved in their SDL skillsets by the end of the SDL phase. Based on this understanding, learners should be given the opportunity to do SDL in a blended and self-directed group learning environment in the initial phase so that the learners can get used to the method, thus giving them more confidence to transit to participate in SDL by themselves. This is not surprising as confidence is one of the top characteristics associated with success in self-directed learning (Li, Tancredi, Co, & West, 2010). However, a more detailed collection and analysis of quantifiable data of their participation habits will be needed to affirm this initial sensing.

The "MakerLab" approach to SDL did not change the learners' motivation to an intrinsic one. A clear majority of the participants reported that they were still extrinsically motivated by deadlines, and it was this which encouraged them to complete their SDL outside of the preplanned face-to-face sessions. They still showed some limitations in meeting their needs for competence as they cited difficulties in their learning experiences without timely feedback. Maybe this was why 50% of the participants completed their SDL tasks with their friends.

Perhaps, an intermediate step to get the learners to be even more confident would be to designate full self-directed learning sessions during face-to-face class but without the instructor's presence. This could give learners the protected time for better accessibility to their friends to bounce ideas, instead of leaving it to themselves to schedule their own learning sessions which may or may not take place.

Easing Learners with Lower Academic Ability into Self-Directed Learning

Not all learners can cover the content by themselves and had friends that they trust enough to seek help from. An unconfident and shy learner will continue to face problems in the "MakerLab," such as in Student J's case, limiting his options for different learning approaches. Possible approaches to improve learner's motivation could then include:

1. Identifying such learners early and having the instructor to offer directed guidance to lead them into the SDL process, easing the learning curve to help the learner to achieve something: This is to meet the learner's need for competence.

2. Creating a conducive classroom environment that encourages collaborative self-directed group learning that celebrates effort in learning: This is to provide a safe learning environment for the learner; in the long term, to meet the learner's need for relatedness and hence, opening the option of approaching friends for help.

The latter is important as it develops learners' independence to learn by themselves, freeing the instructors' time to focus on learners and learning topics that require their attention, for learners to learn more effectively.

Other Potential Research Areas

Beyond the self-determination theory, there were also other factors that influenced student motivation. These include the subject matter, the quality and form of instructional content and the role of the instructor in a blended and self-directed group learning environment. Further exploration could shed light on how each of these factors could affect or work together to make SDL more effective.

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BIOGRAPHICAL INFORMATION

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EVALUATING A SERVICE-LEARNING EXPERIENCE IN GEOLOGICAL ENGINEERING, UCSC, CHILE

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ABSTRACT

This work presents the results of assessing the impact on students of the implementation of the Service-Learning methodology in the Geological Risks course of the Geological Engineering program at the Universidad Católica de la Santísima Concepción. This experiential methodology (Standard 7, 8) integrates learning objectives and community needs with a strong participatory and reflective approach. To assess this implementation, an anonymous and voluntary Likert-type survey was applied to the students, which considered four dimensions: disciplinary knowledge and reasoning (CDIO 1.3), personal and professional skills and attributes (CDIO 2), interpersonal skills (CDIO 3.1 and 3.2) and CDIO in the enterprise, societal and environmental context (CDIO 4.1, 4.2 and 4.3). Results show that 100% of the students positively value the service-learning experience, related to the fact that it helped them put into practice knowledge, methods and/or disciplinary tools, while 95% stated that it allowed them to identify the strengths and weaknesses of their technical knowledge. Also, they remarked that it fostered decision making (90%), perseverance in achieving the objectives (86%), and the assessment of ethical behavior in their profession (95%). At the same time, they highlight the importance of teamwork (86%), the development of communication skills (81%), and awareness of the discipline's impact in today's society (90%). Our results show that the service-learning experience fostered the development of skills, attitudes, and values necessary for the students' conduct in today's society, reinforcing this methodology as an aid for comprehensive and meaningful learning. Finally, all stakeholders must carry out a permanent reflection relating to the implementation and results of these experiences in order to make adjustments and improvements for the benefit of the learning process.

KEYWORDS

Active learning, Service-Learning, Engineering education, Standards 7, 8

INTRODUCTION

The Universidad Católica de la Santísima Concepción (UCSC) 's current educational model is based on competencies and learning outcomes that foster student-centered learning. In this context, an important milestone is acquiring the Commitment and Social Innovation competence, which is developed across the curriculum through the philosophical-theological coursework and through the implementation of the Service-Learning methodology (S-L) in a required course. This competence seeks to educate students capable of contributing solutions to the community's real needs in the context of solidarity activities for the benefit of the common good.

At the same time, since 2011, the School of Engineering adheres to the CDIO (Conceive-Design-Implement-Operate) Initiative, which proposes an educational framework for engineering education. This framework defines 12 standards aimed at producing professionals up to the challenges and needs of today's society (Crawley, Malmqvist, Ostlund, and Brodeur, 2007). At the same time, the School of Engineering fosters the use of the Service-Learning methodology as part of its institutional seal (Cea et al., 2014).

This work presents an impact assessment, from the student's perspective, of the implementation of the Service-Learning methodology in the course of the UCSC geological engineering program. This evaluation considers items related to knowledge and disciplinary reasoning (CDIO 1.3), personal skills (CDIO 2) and interpersonal (CDIO 3.1 and 3.2), and CDIO in the business and social context (CDIO 4.1, 4.2 and 4.3).

In the next section, we present the theoretical aspects of this methodology, followed by background information about the implementation and the evaluation processes. Finally, we present conclusions and remarks about the educational process.

FRAMEWORK

Service-Learning is a teaching and learning methodology that links educational institutions and social entities, generating a virtuous circle that allows students to achieve effective learning through community service (Brodeur, 2012; Batlle, 2015). Thus, Service-Learning serves as a powerful educational tool that fosters meaningful learning through experience (CDIO Standard 7, 8), contributes to social awareness and community problem solving, and fosters students' values development (Jouannet, Salas & Contreras, 2013). Likewise, for Aramburuzabala, Cerrillo & Tello (2015), Service-Learning not only facilitates the acquisition of knowledge, but it is also a model of sustainable development for students since, in practice, they develop services for social and environmental sustainability. Similarly, Sotelino, Mella & Rodríguez (2019) point out that this methodology contributes to the students' civic-social development, increasing their commitment, and civic participation.

This methodology's implementation requires that the educational process incorporate reflection as an articulating axis, so that students understand the scope of their intervention in the community, thus giving new meaning to the service performed (Jouannet, Salas & Contreras, 2013).

In general, higher education institutions have initiated substantial changes in their educational models, incorporating teaching and learning methods focused on experience and action, in order to ensure quality educational processes (Silva & Maturana, 2017). From that perspective, the Service-Learning methodology is considered an innovative practice, since it fosters situated learning, that is, the application of knowledge in a real environment generating benefits in society (Zavala-Guirado, González-Castro & Vásquez-García, 2020).

SERVICE-LEARNING IMPLEMENTATION

In the context of the educational model of this institution and the CDIO framework, the UCSC geological engineering program has implemented the Service-Learning methodology in the Geological Risks course since 2016. This course belongs to the 9th semester of the 11-semester program.

In this work, we present results corresponding to the 2019 version of this course, which had an enrolment of 29 students. The goal of the service defined for this course is to generate technical documentation to support decision making in the field. In this case, the technical documentation consisted of evaluating the geological risks associated with mass wasting processes present in the town of Caleta Chica de Cocholgüe, Tomé municipality, Biobío Region, Chile, with the purpose of advising the community about its tourism prospects, an explicit need expressed by the social partner. The model proposed by Batlle (2015), used for the School of Engineering Service-Learning projects, was followed for the project planning. This model is shown in Figure 1.

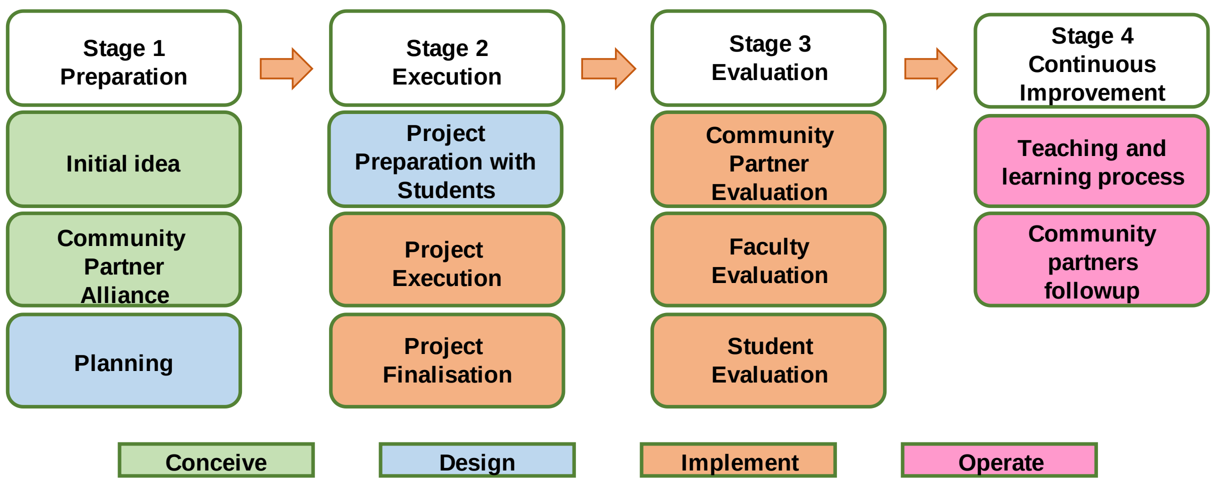

Figure 1. Service-Learning Project Development Stages and their Relationship to CDIO Stages (based on Batlle, 2015)

In the preparation stage, the Geological Risks faculty, along with the School of Engineering Service-Learning projects coordinator, worked on an initial idea for the project, defining where to carry it out, detecting possible community needs, and identifying the potential service to be performed. Additionally, they specified the knowledge, attitudes, and values to be reinforced through this experience. To confirm the project's viability, a meeting with the Cocholgüe community's social representatives was held, to know their real needs, define the service to be done by the students, and to agree on cooperation and coordination strategies (Conceive). A written document was obtained as an output of this Community Partner Alliance, in which both parties state their commitments to the Service-Learning project development. Finally, we plan the service, specify the project's pedagogical aspects, and specify other matters related to its organization and management.

The execution stage considers an initial project preparation with the students, in which a reflection session was held to sensitize the group regarding the project's social needs emphasizing the importance of each student's commitment and actions. As a result, students understood the service to be performed, its usefulness to the community partner, and the learning outcomes they would achieve through the project development. Also, working groups were set up, and each student's responsibilities within them were specified. Additionally, the work schedule was defined together with the students (Design). The project execution (Implement), as such, allowed promoting real-life learning, reinforced aspects such as attendance, punctuality and work rigor and provided an opportunity for communication with the project's beneficiaries. Figure 2 shows the methodology implemented by the students to develop the Service-Learning project and its technical Report, which is the service's final product. It details the work done before the two days of fieldwork, the fieldwork itself, and the work performed after. Project finalization involved delivering the technical Report to the community partners (Figure 3) and a reflection activity on the service performed and the learning outcomes achieved through its development. Also, there was an activity designed to show the service's results throughout the community. At the same time, the project itself was promoted to the rest of the educational community through the institutional website (UCSC, 2019).

The evaluation stage integrates several approaches so as to obtain a comprehensive vision of the Service-Learning experience. The next section describes the evaluation process in greater detail. Evaluation results are used as input to improve the Geological Risks course and the Service-Learning project to be performed the next academic term. At the time of this paper, the community partners followup and feedback after delivery of the final Report was still pending (Operate).

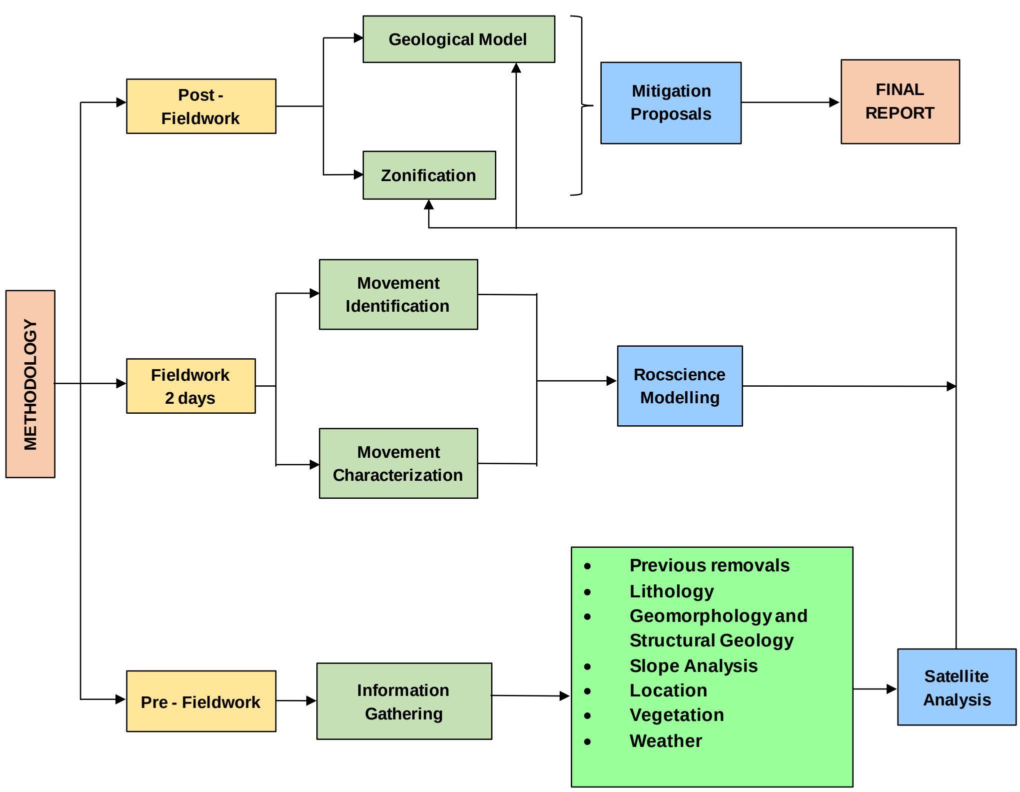

Figure 2. Service-Learning Project Methodology (Cea & Fernández, 2019)

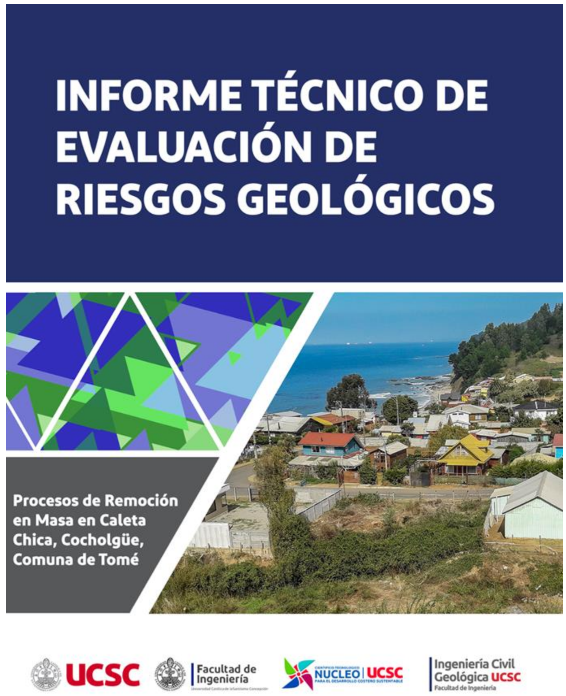

Figure 3. Final Report handed to the community partner. (Cea & Fernández, 2019)

SERVICE-LEARNING PROJECT EVALUATION

The Service-Learning project evaluation as a whole had reflection as its central axis and integrates input from all participating stakeholders: community partner, faculty, and students.

For this article, we present preliminary results of the students' impact evaluation done once the service is finished. The evaluation is a Likert-type questionnaire, of an anonymous and voluntary nature, consisting of 21 items, in which the following aspects were evaluated: Disciplinary knowledge and reasoning (CDIO 1.3), personal skills (CDIO 2.1, 2.2, 2.4 and 2.5), interpersonal skills (CDIO 3.1 and 3.2) and CDIO in the business and social context (CDIO 4.1, 4.2 and 4.3). Answers ranged from strongly disagree to strongly agree.

Table 1 shows the statements of the 21 items that make up the questionnaire applied to the students and their relationship with the CDIO syllabus competences. This questionnaire was answered by 100% of enrolled students. Figure 4 shows the results obtained from the student impact evaluation questionnaire for all 21 items. Only the sum of the "agree" and "strongly agree" answers are plotted in relation to each statement.

Results show that, in general, students evaluate the Service-Learning experience in the Geological Risks course positively. Specifically, 100% of students indicated that they strongly agree or agree that the activity allowed them to put into practice the knowledge, methods and/or disciplinary tools. Regarding the CDIO personal skills, 95% of them stated that it allowed them to identify the strengths and weaknesses of their technical knowledge. Likewise, they also positively evaluated the project related to the fact that it promoted decision-making (90%), perseverance in achieving the objectives (86%), and allowed them to assess self-learning (95%) and ethical behavior in the exercise of their profession (95%).

Regarding CDIO interpersonal skills, 86% of students agree or strongly agree that the Service-Learning project helped them assess the importance of teamwork, while 81% of them indicated that it was an opportunity communication skills development and that the use of technological resources aided achieving the service's goals.

Similarly, they agree that the activity helped them recognize the importance of proper planning, control, and evaluation in achieving the objectives (100%) and allowed them to understand the needs of the community partner (90%) and become aware of the impact of discipline in today's society (90%).

Overall, our results show a very positive evaluation of the experience's impact. However, more work is needed on aspects such as time management, linking with professionals from other areas, closer contact with different organizational cultures, and the development of innovation and entrepreneurship skills. Specifically, in these items, students' positive evaluation is between 67% and 76%. Even though these percentages are reasonably good, they are the lowest results for the questionnaire.

Table 1. Questionnaire Statements and related CDIO syllabus competences.

ITEM	CDIO	STATEMENTS
1	1,3	Working in this activity allowed me to put into practice theoretical concepts seen in classes in this or other subjects
2		I could appreciate the importance of using disciplinary methods and/or tools in the activity development
3	2,1-2,2-2,4-2,5	I had to search and analyze information from different sources to understand the problem and propose a solution
4		I was able to make decisions and defend them before my team
5		For the service learning activity to succeed, I had to work constantly and persevere to achieve the goals
6		This activity helped me be flexible and improved my ability to adapt to changes
7		Working in this activity helped me identify my technical knowledge's strengths and weaknesses
8		This activity helped me realize the importance of self-learning for professional development
9		I had to properly manage time and resources in order to reach the activity's goals
10		Working with the community allowed me to value the importance of ethical behavior in my profession
11		Working on this activity fostered my commitment to respect other participants
12		Working with the community partner helped me connect to other professionals and/or people from other places and realities
13	3,1-3,2	Through this activity I realized the importance of being able to work in a team
14		Through this activity I was able to improve my oral and written communication skills
15		Information and communication technologies helped achieve the activity's goals
16	4,1-4,2-4,3	Defining the roles and responsibilities of the work team members was essential for the activity's development
17		The development of this activity helped me realize the impact of my discipline on society and on the environment
18		Through this activity I was able to meet different organizational cultures
19		I was able to understand the community partner's needs and use them to define goals
20		Planning, control and evaluation of the activity's development helped achieve the objectives
21		This activity helped me develop my entrepreneurship and innovation skills

Figure 4. Student impact evaluation (%).

CONCLUSIONS AND FINAL REMARKS

Our results show that the Service-Learning experience led geological engineering students to develop those skills, attitudes, and values necessary to meet the demands of today's society, validating, in this way, this methodology for the benefit of comprehensive and meaningful learning. Considering this last aspect, it is important to emphasize that this experiential methodology allows students not only to acquire knowledge and problem-solving strategies related to their area of expertise, but also fosters behaviors, values, and attitudes that allow them to become an ethical professional conscious of their social responsibilities and an engaged and committed citizen.

The students' impact evaluation results show a very positive opinion of the Service-Learning experience. At the same time, students improve their confidence and self-perception. The results obtained in the impact evaluation applied to the students, of the Geological Risks course, show a very positive assessment of the vivid experience and an improvement in the perception of themselves. Even though this paper bases it results on only one application of the questionnaire, we have systematized the assessment process so as to gather data from future Service-Learning experiencies to guide our continuous improvement process both regarding our teaching and learning processes and our community partnerships.

Finally, it is important to hold reflection activities with all stakeholders throughout the entire process to benefit not only the expected and achieved learning outcomes but also to benefit the continuous improvement process that ensures a high-quality learning process.

Regarding future work, we are aiming to incorporate and contrast the impact evaluation of students' Service-Learning experiences among several courses in order to assess the methodology's impact and compare it to other approaches. Also, we intend to follow up with our community partnerships to assess the projects' impact on the community through time.

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BIOGRAPHICAL INFORMATION

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FACULTY ADOPTION AND PERCEPTION OF TEACHING METHODS: TRADITIONS, TECHNOLOGY & TRICKS

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ABSTRACT

Different methods and technologies supporting the learning process are discussed, and many times also applied, in most higher education institutions. Using versatile, activating methods, instructors can help students make connections among key concepts and facilitate the application of the acquired knowledge to new settings (CDIO Standard 8). Some early adopters are willingly experimenting with new approaches, whereas others prefer utilizing more traditional settings. However, the effect of these methods, and utilization of emerging educational technologies, are often critically discussed by at least a part of the faculty. There has been a series of educational developments piloted and implemented at the Department of Information Technologies at Åbo Akademi University, too. In addition to the general goals to improve learning as well as to meet the challenges connected to student attrition typical in ICT-engineering education, the dual-campus environment has required novel approaches as students are not always physically present. In this paper, the current structure of the M.Sc. in Computer Engineering curriculum, and the different methods and educational tools recently applied at the department are presented. The faculty members' experiences, reflections on the different approaches, and their possible impact on learning results and teachers' workload are analyzed based on semi-structured interviews. Also, future insights are discussed based on the results.

KEYWORDS

Active Learning, Computer Science, Curriculum Development, Learning Analytics, Learning Methods, Project-Based Learning, Standards 3, 5, 8, 10

INTRODUCTION

Globalization, new technologies, migration, international competition, changing markets, transnational environmental and political challenges are all addressed as drivers for the need of new learning methods in a working paper from Unesco by Scott (2015). Still, much of teaching is performed using the traditional lecturing model, where the teacher/lecturer talks the students through the material. This model originates from the model of copying written material by one reading, the rest writing it down. This was the copying machine before technology brought in alternatives. The technology of printing books changed things a lot, not necessarily needing to copy the book itself, but emphasizing the part of books that the teacher found important. Activating students was performed by making them write down and take notes.

Today, most information ever produced is available on any handheld device in a few seconds. The information might even be produced almost at the same time as it is consumed. This enables completely new ways of learning and sharing of information. TED Talks (www.ted.com) founder Chris Andersson (2016) gives a good example of this by the dancing group Legion of Extraordinary Dancers that performed a stunning show by learning from YouTube. A new generation is growing up with access to all information produced, sharing how-tos, and guidelines using social media. This generation is hard to activate using the traditional learning-by-writing-down pattern. Therefore, the educational industry, higher education institutions as a part of it, is looking for new learning and teaching methods that motivate and activate students.

Different methods and technologies supporting the learning process are discussed and applied in most higher education institutions. The CDIO Initiative emphasizes that active learning methods engage students directly in thinking and problem-solving activities. Using versatile, activating methods, instructors can help students make connections among key concepts and facilitate the application of the acquired knowledge to new settings (CDIO Standard 8; www.cdio.org). The increasing volatility, uncertainty, complexity, and ambiguity of the world challenge educators to help students develop a reliable compass and navigation skills to find their way during their career. For example, embedding decision skills into engineering curricula has been considered essential for future engineers to prepare them for unforeseen situations (Rouvrais, LeBris & Stewart, 2018).

The field of Computer Science and Information Technology is closely-coupled to the rapid technological development, and also the engineering education institutions in this domain have been very active in developing their curricula and applying new teaching and learning methods to respond to these challenges. For example, the development of first-year student experience and activities have been reported by several authors (e.g., Teo, Tan & Wah, 2013; Martinez & Muños, 2014; Marasco et al., 2016). This field is also ideal for different project-based learning applications since many of the professional industrial R&D activities are implemented as complex projects. CDIO-oriented project-based learning case studies and developments have been documented, for instance, by Kulmala, Luimula & Roslöf (2014), Nyborg, Probst & Stassen (2015), Mejtoft & Vesterberg (2017), and Säisä, Tiura, & Matikainen (2019).

Typically, some early adopters are willingly experimenting with new approaches, whereas others prefer utilizing more traditional settings. However, the effect of these methods, and utilization of emerging educational technologies, are often critically discussed by at least a part of the faculty. At the same time, as proactive seeking for new, improved ways to enhance the learning process is needed, one can argue that many experiments are done without structured planning and analysis of the outcomes. It can also be argued that sometimes developments are implemented due to external requirements (the old method is no longer possible to use), or alternatively just because of a desire to try out new technology and gadgets. Creating a clear shared vision to guide educational development and providing support to the faculty members is important to facilitate the process (Andersson et al., 2012). In addition to different training programs, also mentoring approaches and other peer-focused activities have been found useful to help the teachers to realize that "just" preparing good lectures is not enough but, instead, they should focus on planning the students' learning process and come up with active learning experiences to induce this process. (Loyer & Maureira, 2014).

There have been several educational developments implemented at the Department of Information Technologies at Åbo Akademi University (ÅAU) as well. In addition to the general goals to improve learning and to face the challenges connected to student attrition typical in ICT-engineering education, the dual-campus environment has required novel approaches as students are not always physically present. The aim of being able to scale courses to suit the needs of small vs. very large groups has also been affecting the work. Several different methods and tools have been utilized during this process. For example, learning journals, flipped classroom applications, self-correcting assignments, virtual lectures, mini-projects, and capstone-type project courses have been introduced. Although ÅAU is not a member of the CDIO Initiative at the moment, the development of the M.Sc. in Computer Engineering program has been inspired by the CDIO Standards for some time already. For example, the Master-level project course in Software Engineering and the competitive elements connected to it (Roslöf, Björkqivst & Virtanen, 2012; 2017) have connections to the CDIO framework.

In this paper, the current structure of the M.Sc. in Computer Engineering curriculum, and the different methods and educational tools recently applied at the department are discussed. The faculty members' experiences, reflections on the different approaches, and their possible impact on learning results and teachers' workload are analyzed based on semi-structured interviews. In addition, future insights and potential research topics are studied.

DEGREE PROGRAMME STRUCTURE

The Degree Program in Information Technology at ÅAU is a combined B.Sc. and M.Sc. program in the ICT domain. The focus is set to develop the students' competences to apply the principles of Mathematics, Engineering, and Computer Science to develop new computer-based solutions to fulfill the needs of our modern society. The Computer Engineering specialization leading to a Master's degree in technology [in Swedish: Diplomingenjör; ÅAU is the only Swedish-speaking university in Finland] has a special emphasis on the engineering of software-intensive systems, with a focus on cloud computing, the industrial internet, as well as safety-critical and autonomous systems. The total extent of the program is (180+120) 300 ECTS (European Credit Transfer System) credits, and it is planned to be completed in (3+2) 5 academic years (Åbo Akademi University, 2020). The curriculum structure is illustrated in Figures 1 and 2. The student who is accepted to the Bachelor's program can continue directly to the Master's studies after completing the B.Sc. degree.

Vipunen (https://vipunen.fi/en-gb/), the Finnish education administration's reporting portal maintained by the Ministry of Education and Culture and the Finnish National Agency for Education, provides statistics on the student flows of the higher education institutions in Finland. The data is categorized by the fields of education. That is, the degree programs in the field of Information and Communication Technology at ÅAU are displayed jointly, and the details of the B.Sc. and M.Sc. (Tech.) programs in the Computer Engineering specialization are not directly available. Yet, the overall figures provide an overview of the volume and efficiency of these programs. During the past ten years (2009-2019) 417 students have started the Bachelor-level education (having the right to continue to the Masters without a new admission process) and 246 the Master-level education in the field of ICT at ÅAU. Respectively, a total of 289 B.Sc. and 315 M.Sc. students have graduated from these programs during the past ten years available in Vipunen (2008-2019). The intake volumes to the different programs have varied and, thus, it is not possible to make any specific interpretations based on this data. Yet, the success rate of the programs during this period is 69% on the Bachelor-level and 48% on the Master-level. Although these challenges are present in all fields of education, engineering is one of the main areas of concern dealing with student attrition. In general, approximately only one-half of the students entering engineering education ever graduate (Shuman et al., 1999), and the field of ICT is considered to be one of the most challenging domains due to the high demand of these professionals. In other words, the drop-out rates of the ICT programs at ÅAU are rather typical, or even satisfactory, in the global context. However, there is room for improvement.

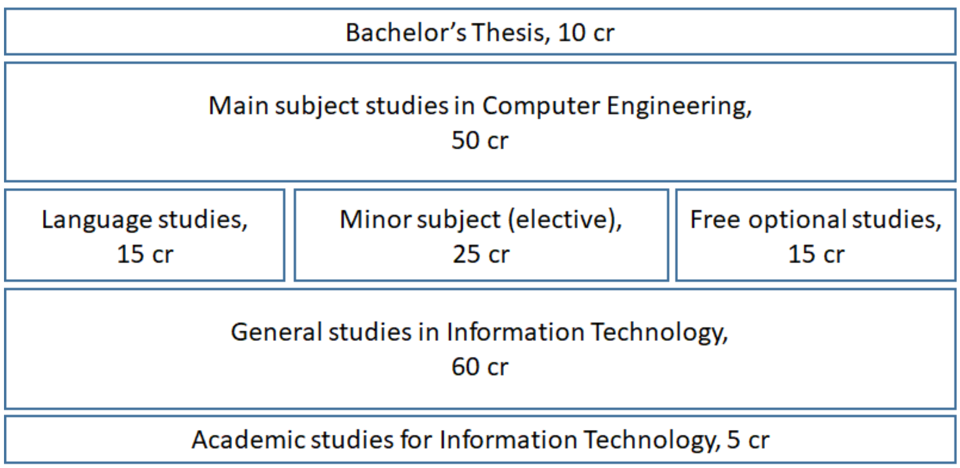

Figure 1. The curriculum structure of the B.Sc. Degree Program (180 ECTS credits) in Information Technology (Computer Engineering specialization) of ÅAU.

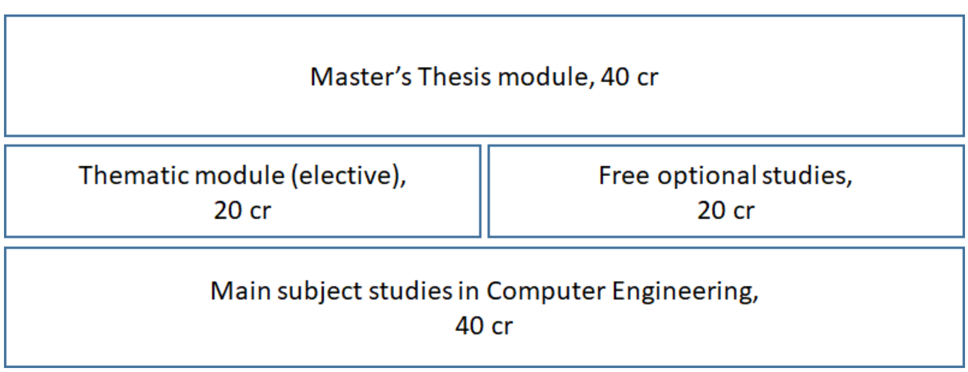

Figure 2. The curriculum structure of the M.Sc. Degree Program (180 ECTS credits) in Information Technology (Computer Engineering specialization) of ÅAU.

The engineering education at ÅAU also has the challenge of being given on two campuses, one in Turku and one in Vaasa. The campuses are more than 300 km apart, so giving a course that is available for students on both campuses requires planning the course to support this. The main methods here have so far been lecturing over video links, using local exercises, and lecturers visiting the other site for a couple of days. On the other hand, this also supports students that already during their studies have started their working career and can take advantage of course virtualizations.

In the ÅAU ICT programs, there have been ongoing activities for improving study program performance. Study program performance is here means how the program works overall – including student performance, drop-out-rates, student throughput, and teacher workload. These activities have included planning in subgroups with their own topics. These topics have included learning and teaching methods, program overview, and curricula, as well as marketing and student recruitment. So there has been a long history of discussing how to improve. These discussions have motivated many to implement changes to the courses. Among methods tested are learning journals, flipped classroom, automated exercises, project- and problem-based learning. During the last academic year (2019-2020), many courses were produced in parallel as virtual courses, where all lecture-room-time was recorded and provided online for students that could not physically attend the lectures.

RESEARCH QUESTIONS AND METHODS

The research question of this study was to find out how the faculty members of the Department of Information Technologies apply and perceive the different learning and teaching methods. Besides, the goal was to gather their experiences on possible utilization of different tools, applications, and platforms to support their work and the students' learning.

The faculty members' experiences, reflections on the different approaches, and their possible impact on learning results and teachers' workload are analyzed based on semi-structured interviews. The interview consisted of 9 quantitative and 9 qualitative questions. The department has 14 full-time faculty members currently (excluding the first author of this paper). The study was presented in a faculty meeting, and an open invitation to participate in the interviews was submitted to all.

In total, ten interviews were conducted that provided rather nice coverage of the department's teaching staff. The interviews were performed during December 2019 and January 2020. All the interviews were conducted face-to-face, and the responses were documented jointly by the author(s) and the respondent during the discussions. Most of the interviewees had several years of teaching experience. Both the average and median of the teaching experience was 18 years, ranging from 1 to 33 years. Eight respondents defined their primary teaching role as course-responsible teachers, one as a lecturer and one as an exercise instructor. The number of courses that the interviewees have been giving during the past five years was 44.

The interviews were performed by the authors, one of which is part of the regular faculty staff of the department. This might have affected the interviews and biased the answers. Also, the department curriculum, i.e., computer science and engineering, might bias the interviewees' answers, as they may perceive that an ICT-education should use more ICT-tools than other curricula. This possible bias cannot easily be removed, so it is acknowledged, but not handled in the results. All the discussions were experienced as relaxed and open. That is, the authors believe that the received results were not heavily affected by the setting.

RESULTS FROM INTERVIEWS

The objective of the interviews was to study the faculty members' opinions and experiences of new teaching and learning methods. It should be noted that even if these methods are here called *new methods*, many of them have been around for quite a while. Hence, the interpretation should be *new* in the sense that they are new for the course, for the study program, or the faculty member him/herself.

The interview started with finding out the interviewees' interest and willingness to test new learning methods in general. In Figure 3, the respondents' own willingness is compared with the experience on the willingness of the rest of the department. In general, there seems to be quite a good atmosphere for exploring new ways of learning and teaching. Especially the feeling of freedom to test new methods is almost at the top.

The learning environment and technology should also support new learning and teaching methods. For example, other room setups than a traditional classroom can be required, the facilities might need support for group activities, the infrastructure should support video recording and editing, and tools for enabling online material distribution should be available. The results illustrated in Figure 4 indicate that the available learning environment is usually not considered an obstacle. However, the responses differ between the interviewees.

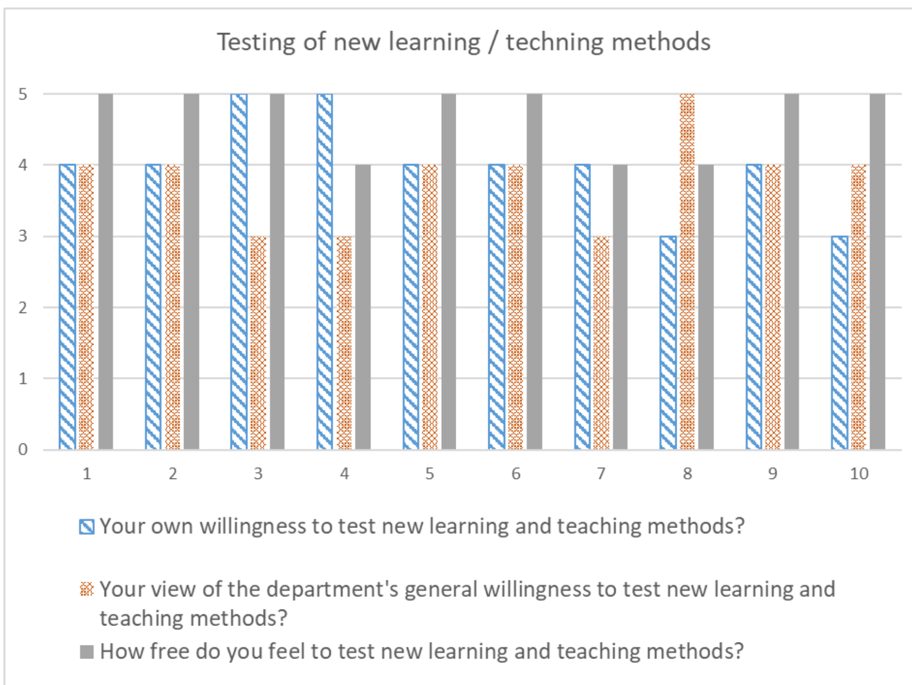

Figure 3. Willingness to test new learning and teaching methods and experience on the freedom to implement new pilots.

Another quantitative question was to find out the interviewees' expectations on their workload due to the introduction of new methods in the end. The average was 2,4 (in scale: 0 decreased a lot – 5 increased a lot), showing a belief that the workload should be slightly reduced. However, most of the lectures stated that changes are not implemented primarily to decrease their workload but to increase quality. If practical work related to a course is reduced, more time is available for course development and quality improvement. This was a common comment; nobody believed that their workload would actually decrease, but the time will be used to improve the quality of the courses.

The workload did not change too much; for example, online students tend to contact me via private channels that take a lot of time. I tried to steer them to common discussion channels; it often takes more time to answer questions online than face-to-face. [Respondent 6]

For courses in which the fundamental theory is "constant", it is worth it [the workload decreases]. But if the content needs to be updated all the time, the saving of time is not as clear. [Respondent 9]

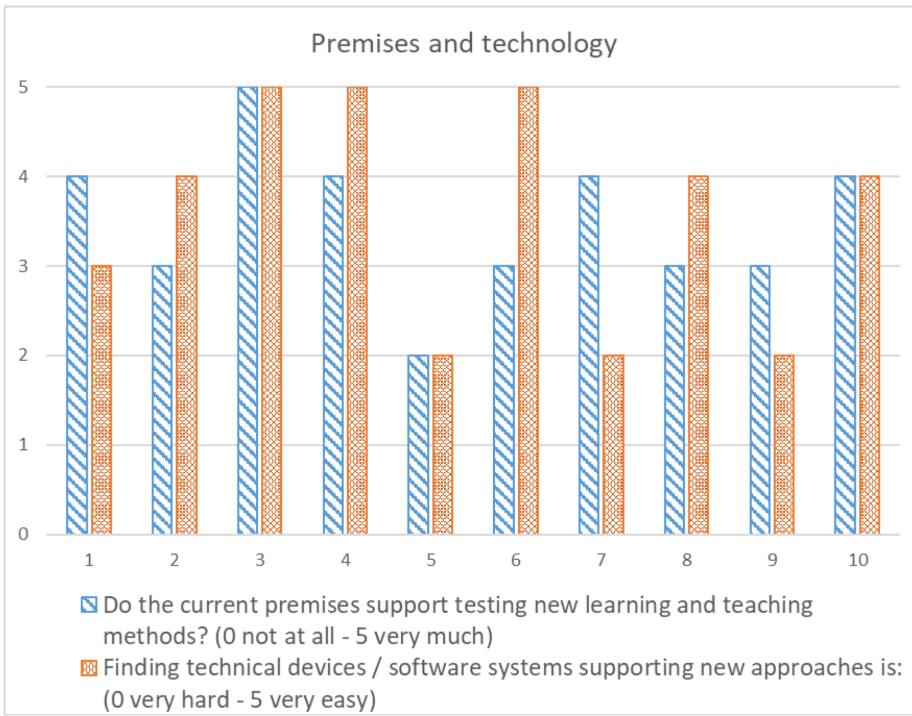

Figure 4. Does the learning environment (premises and technology) support the use of new learning and teaching methods?

The number of teachers using specific teaching methods is shown in Figure 5. The most common method is still the traditional lecturing model with exercises. However, problem-based and project-based methods are regularly used to increase motivation among the students. Furthermore, some lecturers use gamified learning applications and learning journals to increase student motivation and to activate them during the course. One teacher provided fully online courses.

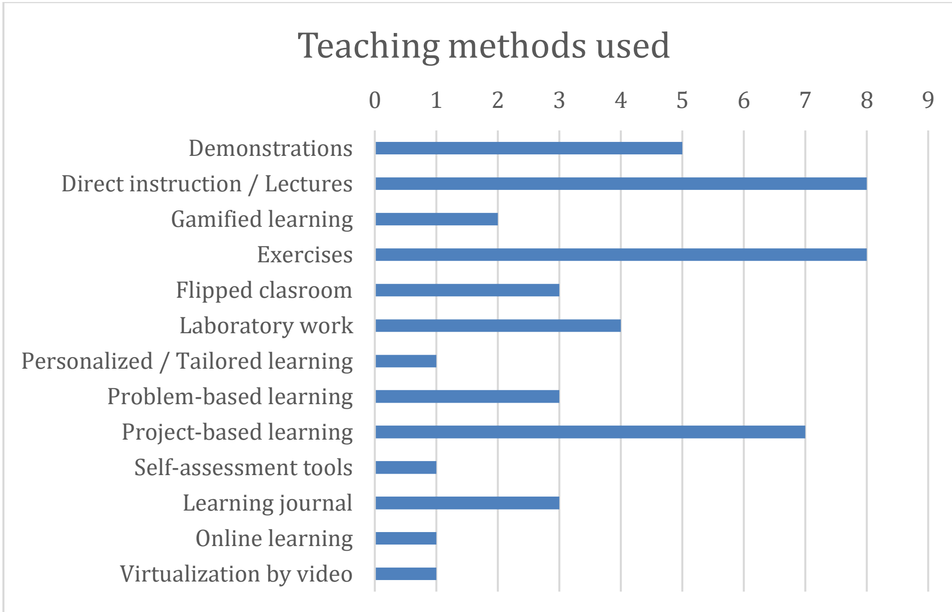

Figure 5. The number of lecturers using a specific learning and teaching method.

One of the questions was why the teachers had selected to test these methods. The most common answer was that they wanted to motivate and activate the students. The objective was to transfer the learning time from passive listening to more active "learning by doing" to get the students involved in practical activities and group work. The reason for self-assessment tools, like self-correcting exercises, was to take away work from "boring" exercise correction and to use it to provide feedback to students either on a personal or a group level instead.

> Activating methods, pair work, and teamwork; "doing" during the lectures. The students shall WORK. [Respondent 3]

> To make the course content more motivating. The traditional methods are not attractive; teamwork works well if just the team functions. [Respondent 7]

We also asked the respondents' opinion on the benefits of the change, and if the learning results were affected. Common answers were that the benefits are visible when the students work more actively, and they work as groups. But also concerns were mentioned – interactive methods only work when the students are motivated and active. Naturally, this interactivity depends on the teacher's ability to facilitate the process. Yet, the teachers cannot force students to learn; that requires work by the students themselves, too. Improvement of the learning results (grades and throughput) were mentioned, but very significant conclusions on learning outcomes improvements were hard to derive.

> Course results have improved, especially the feedback (to the teacher) on what they have learned during the course has become much clearer (what has been considered difficult/easy etc.). [Respondent 7]

> No relevant change was noticed with the small group of mine. Fundamental motivation plays a greater role. [Respondent 8]

It was also asked whether the utilization of new learning methods also require the course content to be updated or not. Almost all respondents answered that this is the case. That is, introducing new learning methods also leads to transforming the course into an updated and more interesting format. In general, introducing a change, the system can also be improved. And for sure, without any changes, no improvement can happen.

There were also several requests on learning analytics that could be useful for the faculty members. Most of these included a need to get detailed and direct feedback on the course content. Information on which parts of the course were good vs. not so good from the students' learning perspective and, for example, how much time the students used for the different parts. Which course elements get the students' attraction, and for how long? If there is video material available, which parts of them are actually watched, and how long or how many times?

As a general comment, there was concern that the increasing side-streams (e.g., open university students and other life-long learning participants) of students are not fully supported by the current course implementations. These students are not automatically following the same model as full-time students, but they might be a larger share of all students in the future. Furthermore, the motivation and (pro)activity of the students was again emphasized as the key to good learning results. Open discussion and different ways to share good ideas and practices among the faculty were considered very important. Guest experts on active learning and teaching methods should be invited to give advice. Finally, a comment from the youngest among the interviewees: "There is great value also in "old-fashion" lectures and exercises, given that they are well-planned and inspiring."

CONCLUSIONS

The main outcome of this paper was to present the results of interviews performed among the faculty members responsible for the learning and teaching activities of the ICT degree programs at the Åbo Akademi University, Finland. Also, background information on the program and its context were discussed. The objective was to study and share the faculty members' views on the question of the title, "Do new tricks & tech really support the learning process?"

As a general conclusion, the answer to the question of whether new learning and teaching methods, application of educational technologies, and "tricks" is worth it or not, is YES. Different changes, new methods, and alternative ways to learn and teach do usually improve the learning process according to the interviewees. Yet, all the development steps do not necessarily lead to rapid improvements in the learning results, and, sometimes, several iterations are required. These efforts may also require more resources than the results save on short notice.

It is important that the teachers have an interest in developing their courses, and that the environment supports that in different ways. The Department of Information Technologies at ÅAU clearly has a culture that supports the faculty to develop their work and actively try different alternative ways forward. If no changes and pilots take place, it is certain that no positive development steps are taken either. However, as another conclusion, one could say that the most successful improvements do not necessarily come from the methods themselves, but more from the teachers' objectives and desire to activate the students during the courses. New methods and tools may help to achieve this increased level of learning activity. To reach good learning outcomes, we need processes that motivate and activate students of today.

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CURRICULUM AND IMPLEMENTATION OF KOSEN ENGINEERING EDUCATION AT KOSEN-KMITL, THAILAND

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ABSTRACT

Japanese College of Technology (known as "KOSEN") for engineering education, starting at the age of 15, is Japan's original five years tertiary education school has played important roles in fostering innovative engineers in Japan in the last fifty years. In May 2019, the first KOSEN in the Kingdom of Thailand, KOSEN-KMITL, was opened at King Mongkut's Institute of Technology Ladkrabang (KMITL) under the mutual collaboration between Thailand and Japanese stakeholders to foster innovative future engineers as Thailand's industrial human resource development project. The KOSEN-KMITL is established to provide engineering education as same as Japanese NIT's KOSEN and is operated by KOSEN-KMITL's Thai faculties and Japanese KOSEN experts. In order to ensure educational equivalency between KOSEN-KMITL and Japanese NIT KOSEN, its curriculum is designed based on NIT's "Model Core Curriculum (MCC)" that covers learning contents with specific attainment target levels, students' professional and generic competencies, curriculum design policy, educational approaches, quality assurance measures, etc. as the minimum standard for NIT's KOSEN. In this paper, KOSEN engineering education starting at KOSEN-KMITL, including extracurricular activities and international collaboration, is reported. It is shown that the KOSEN-KMITL curriculum well matches with the CDIO standard and syllabus. Since KOSEN-KMITL is a newly opened school in collaboration with 51 NIT's KOSEN colleges, many educational challenges are being implemented. The details of the comparison result with a subject mapping based on educational outcomes and the progress of KOSEN education in Thailand are presented.

KEYWORDS

KOSEN education, Continuous Improvement of Education, Curriculum Design, Standards 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

INTRODUCTION OF KOSEN EDUCATION

KOSEN Education

KOSEN starting from the 1960s, is a 5-year Japanese style College of Technology for engineering education. "KOSEN" is an abbreviation of the Japanese word "Koto-senmon-gakko" meaning College of Technology, where "Koto" stands for high-level and" Senmon" stands for major (engineering). Figure 1 shows the Japanese education system and KOSEN. At present, there are 57 KOSEN nationwide in Japan: 51 national KOSEN run by the National Institute of Technology (NIT), three prefectural/municipal KOSENs, and three private KOSENs. Most of the KOSENs provide engineering education programs for associate degrees.

KOSEN was first founded to meet the strong demand from industry for practical engineers in 1962 during rapid economic growth in Japan. Presently, about 1 percent of the lower secondary school graduates at the age of 15 years enter the KOSEN. Since secondary education in Japan covers junior high school (lower-secondary) and the high school (upper secondary) followed by tertiary education, this 1 % of students in the middle of secondary education jump into tertiary education and start high-level engineering education.

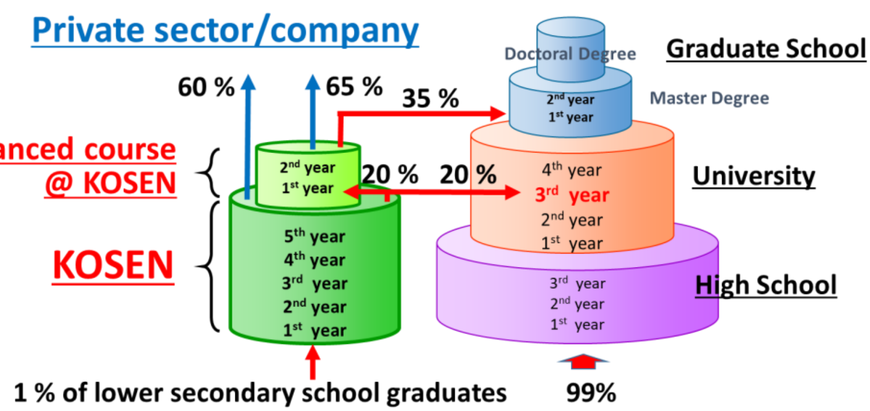

Fig. 1 Japanese education system and KOSEN

As lower secondary school graduates enter KOSEN, the KOSEN curriculum basically covers an upper secondary education. However, five-year consistent engineering education, including project-based learning/academic research works, enables the students to be practical and innovative engineers effectively. The KOSEN curricula are designed to provide scientific knowledge, experiments, workshop training to foster practical manufacturing skills of students. KOSEN education has been highly regarded by the public, by industries, and by international institutions. As mentioned, the outstanding characteristic of KOSEN education is its five years (regular course as college part) of consistent early engineering education starting from the age of 15 years; the KOSEN is an early engineering education and a fast track to foster high-quality young engineers.

Table 1 shows a summary of NIT KOSEN. At present, there are 51 NIT KOSEN (55 campuses), and approximately 50,000 students from the age of 15 to 22 years are enrolled. It should be noted that the number of students who graduate from both regular and advanced courses of KOSEN is about 10 % of the total number of new graduates of engineering departments, including junior colleges, universities, and graduate schools in Japan.

Table 1 Summary of NIT KOSEN

	Description	remarks
Number of NIT KOSEN	51 Colleges (55 Campuses)	
Admission requirement	Completion of lower secondary education	
Degree to be obtained	5-year regular course: Associate degree	
	2-year advanced course: Bachelor degree	
Number of Students	48,509 (5-year regular course: 185 departments), 2,995 (Advanced course: 105 courses)	As of May 2018

Model Core Curriculum and CDIO Syllabus & Standards

With the development of society, education and learning have changed significantly over the last decades. To improve the preparation of KOSEN students to meet these high demands in a rapidly changing world and technology, "Model Core Curriculum (MCC)" for 5-years regular course has been developed as an educational framework for all NIT KOSEN (National Institute of Technology, 2019). The MCC is designed in reference to international standards (e.g., the criteria of ABET: Accreditation Board for Engineering and JABEE: Japanese Accreditation Board for Engineering Education) as well as the CDIO Standards and Syllabus (The CDIO Initiative, 2019a, b). Table 2 shows the contents of the MCC and the specified knowledge, expertise, and competencies. The MCC consists of three parts. Chapter 1 covers *the rationale* and educational modalities based on the MCC. Chapters 2 to 4 describe the required knowledge, expertise, and competency for engineers. Quality assurance functions, including curriculum design, educational approaches, faculty developments, etc., are covered in chapter 5. The MCC provides the NIT's concept of curriculum design, pedagogical approaches, quality assurance measures, etc. as well as required learning contents. To archive these targets, 5-year long educational plans are well designed, and several courses integrated into educational themes as subject module blocks are given in parallel and consecutively depending on the students' development. It should also be noted that each NIT KOSEN develops its original educational programs reflecting regional characteristics as well as educational assets to provide the students with contextualized learning opportunities, in addition to the MCC. Therefore, KOSEN-KMITL also provides its original programs.

Many educational studies have been focusing on the comparison between CDIO Standards & Syllabus (CDIO Initiative, 2019a, b) and other educational frameworks and programs (Malmqvist 2009), (Alcion & Levy, 2009), (Cloutier, Hugo & Sellens, 2010), (Rynearson, 2011), (Aburatani 2019). Table 3 shows a comparison between NIT MCC and CDIO Standards and Syllabus. As listed in Table 2, the required knowledge, expertise, and competency are provided in the MCC chapters 2, 3, and 4; the CDIO Syllabus is covered by these chapters. Especially for implementation of Conceive, Design, Implement, and Operate, "IX. Integrated Learning Experience & Creative Thinking" in chapter 4 includes these mostly. NIT KOSEN provides the students with subjects/programs such as research work, project-based learning, etc. based on the concepts of "Engineering Design" and "Monozukuri education." Notably, the research work in the 5th-year grade that requires the engineering design approach and C-D-I-O process is the uniqueness of KOSEN education and plays a very important role. The concept of CDIO standards providing the fundamentals for a program is covered through the MCC. Therefore, NIT MCC correlates highly with both CDIO Standards and Syllabus. However, the MCC has a weak correlation with CDIO syllabus 4.2 (entrepreneurship part), because this part is set to belong to the education at the advanced course after the five-year regular course at each KOSEN colleges.

Table 2. The Contents of the Model Core Curriculum

Chap.	Contents	Categories
1	Educational Modalities and the Model Core Curriculum	1.1 Competencies Relating to Engineer Education 1.2 Achievement Targets 1.3 Approaches for Engineering and Interdisciplinary Programs
2	Basic Competency for General education and Basic Engineering	I. Mathematics, II. Natural Science, III. Humanities & Social Sciences, IV. Basic Engineering
3	Knowledge, Expertise, and Competency for Major engineering education	V. Knowledge and expertise for each Engineering field, VI. Engineering Experiments & Practice Competencies
4	Interdisciplinary Competency for Engineers	VII. General Skills, VIII. Mindset and Direction (Personality), IX. Integrated Learning Experience & Creative Thinking
5	Quality Assurance Functions of the Model Core Curriculum	5.1 Curriculum Design and Syllabus Based on MCC, 5.2 Efficient and Effective Evaluation Method for Students' Attainment Levels, 5.3 Collaboration on educational contents and teaching methods 5.4 Systematic Implementation of FD/SD 5.5 Mechanisms for Students' Self-Directed Learning 5.6 Evaluation and continuous improvement of the Model Core Curriculum

Table 3. The Contents of Model Core Curriculum (MCC) and CDIO Syllabus and Standards

MCC Chapter and contents		CDIO Syllabus	CDIO Standards
1	Educational Modalities and the Model Core Curriculum		1,
2	Basic Competency for General education and Basic Engineering	1.1, 1.2 3.3 4.1, 4.2	2, 4 1, 7, 11
3	Knowledge, Expertise, and Competency for Major engineering education	1.3 2.2, 2.3 4.3, 4.4, 4.5, 4.6	2, 3, 5, 6, 1, 7, 11
4	Interdisciplinary Competency for Engineers	2.1, 2.2, 2.3, 2.4, 2.5 3.1, 3.2 4.1, 4.3, 4.4, 4.5, 4.6 4.2	2, 3, 5, 7, 8, 1, 11
5	Quality Assurance Functions of the Model Core Curriculum		1, 3, 8, 9, 10, 11, 12

Note: Underlined numbers indicate a weak correlation.

KOSEN EDUCATION AT KOSEN-KMITL

In May 2019, KOSEN-KMITL was opened at King Mongkut's Institute of Technology Ladkrabang (KMITL) under the mutual collaboration between Thailand and Japanese stakeholders to foster innovative future engineers in Thailand. At newly opened KOSEN-KMITL, twenty-four students selected nationwide are studying in the "Mechatronics" department. Table 4 shows a comparison between NIT KOSEN and KOSEN-KMITL. The KOSEN-KMITL is established to execute engineering education as same as Japanese NIT KOSEN, and KOSEN-KMITL provides the students with the latest NIT's MCC based curriculum.

Table 4. A comparison between NIT KOSEN and KOSEN-KMITL

* As of AY 2019.

	MCC Curriculum	Total Credits	Language	Number of depts. at each KOSEN	Class size (per class)
NIT KOSEN	◯	>167	Japanese	3 to 5	40
KOSEN-KMITL	◯	>186	Thai, English, + Japanese	1 (Mechatronics*)	24*

Three departments (Mechatronics Engineering, Computer Engineering, Electrical, and Electronic Engineering) will be operated with a full student capacity of 48 for each department from 2024.

KOSEN-KMITL Curriculum Design and Introductory subject modules

KOSEN curriculum is designed to provide the students with a well-balanced General Education subjects (Liberal arts, Science and Mathematics) and Major Engineering subjects in accordance with students' development. Figures 2(a) and (b) show the basic concept of the KOSEN curriculum structure of the 5-year regular course and actual one for KOSEN-KMITL. In a wedge-shaped structure (Fig. 2 (A)), which has been used to explain KOSEN curricula, the number of major engineering subjects gradually increase. The concept of the KOSEN-KMITL curriculum is also based on this wedge-shaped structure. However, a sufficient number of general engineering subjects as introductory subjects are placed in the first year intensively.

There are two reasons for this modification. First, although these wedge-shaped curricula provide sufficient learning opportunities for the students to study theoretical knowledge and to conduct scientific/engineering experiments, workshop training, and research work to develop practical skills, KOSEN education also faces various changes in education and learning. Engineering education is a long process and needs to be much more proactive to changes in technology, teaching, and learning. These introductory subjects provide the students with a foundation not only for engineering majors education but also for learning and for developing the mindset as engineers.

Second, as KOSEN-KMITL is a newly opened school with only one class, it is necessary and essential to show and to teach the students what is "Engineering," what are "Engineers," and what is "KOSEN" in class. In KOSEN, the senior and junior students collaborate together through school events, extracurricular activities, etc. This relationship is an essential part of KOSEN's hidden curriculum and formation of KOSEN students' mindset. Without the presence of senior students and any graduates who represent school identities, these introductory general engineering subjects play an important role in establishing students' mindsets as KOSEN students in addition to other school activities.

Figure 3 shows these introductory general engineering subjects and modules for the first and second years semester 1: Introduction to Engineering Approach I and II, Introduction to Engineering Design, Reverse Engineering I and II, and Lab work I, II, and III. The engineering design module provides students with the concept of Engineering design and Monozukuri (manufacturing) in KOSEN to solve problems and develop products. "Reverse Engineering I and II" as well as Lab work subjects provide students with hands-on opportunities to learn and to examine technologies in products to deepen their understanding of engineering. "Intro. to Engineering Approach I and II" and "Intro. to Engineering Design" cover the basic knowledge and logical approaches for problem-solving, including 21st Century skills, 4Cs, and PBL for tackling engineering problems. In these subjects, the KOSEN education, Engineering, and roles of Engineers are shared and discussed repeatedly to form their identity as newly establish KOSEN-KMITL students. Figures 4 (a) to (f) show pictures of these subjects.

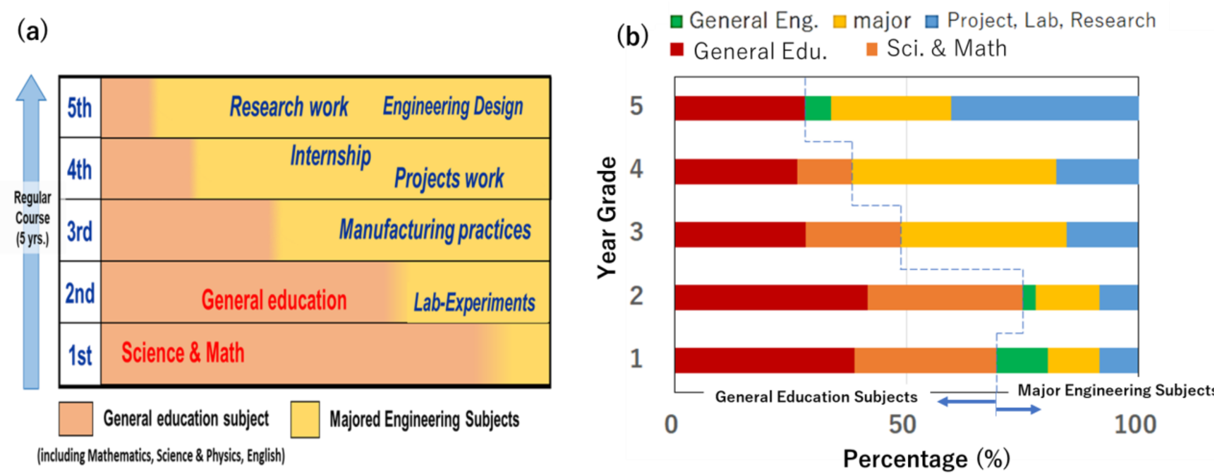

Fig. 2 Basic concept of (a) KOSEN curriculum structure and (b) KOSEN-KMITL curriculum

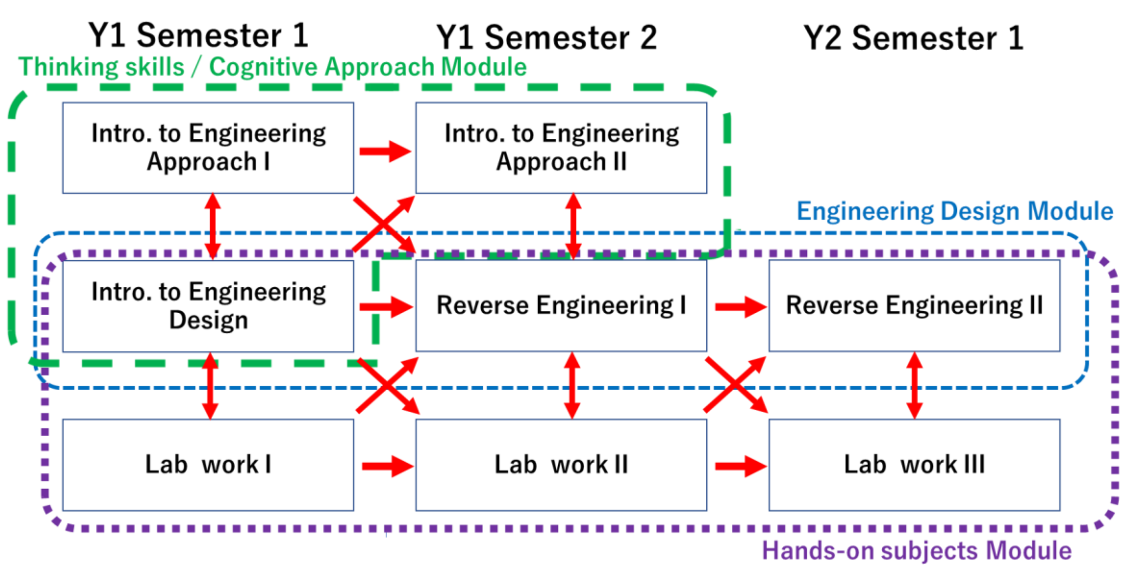

Fig. 3 Introductory general engineering subject modules for the first and second years

KOSEN education and 4Cs

Figures 5 show examples of PowerPoint slides used in the "Introduction to Engineering Approach" class. The left slide shows the relationship between 4Cs (Creativity, Critical Thinking, Collaboration, and Communication) and KOSEN education. In addition to 4Cs, "Continuity," which is a crucial factor in KOSEN education, is added. Continuity in engineering learning experiences is key to develop students' skills and understanding, and to guide them to new ideas, challenges, and innovations. As 5-year of KOSEN education starting from 15 years (middle adolescence) provides the students with many opportunities, these approaches encourage students' challenges at KOSEN-KMITL in Thailand.

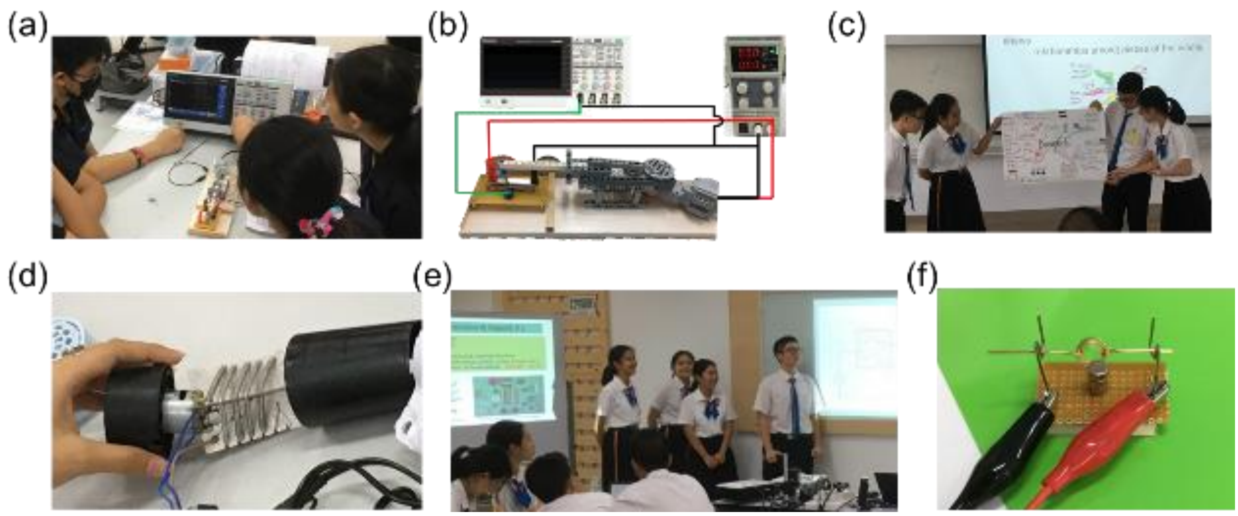

Fig. 4 Pictures of (a), (b): Lab work class (Crank and displacement measurement), (c) Engineering approach (Mind map), (d), (e): Reverse Engineering (Hairdryer disassembling and analysis), and (f): Engineering design (Coil motor development)

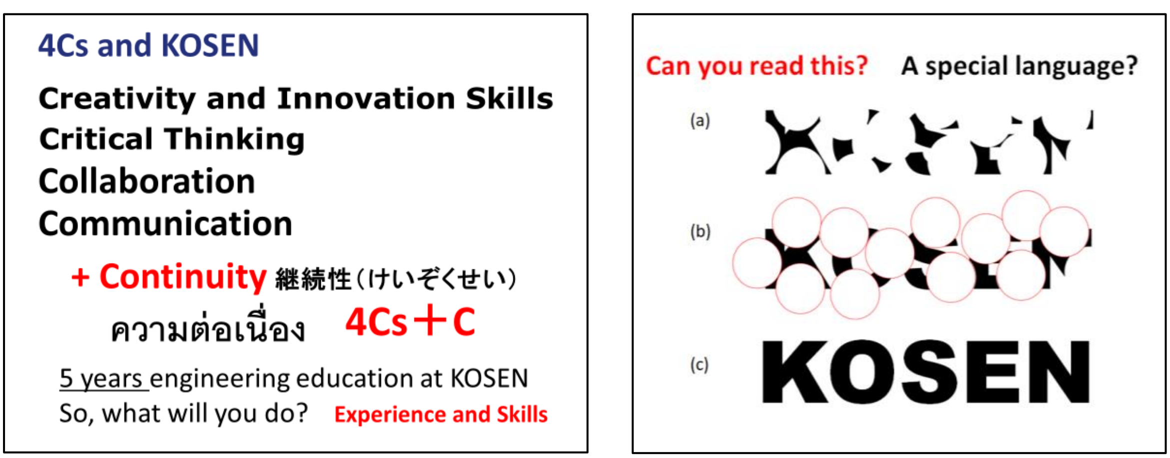

Fig. 5 Examples of PowerPoint slide for KOSEN education and Engineering study

The right slide explains "What is KOSEN" and "How we study Engineering" using a cognitive approach (Aburatani 2014). When the letters are concealed with white circles without border, (a) the remaining parts seem to be a random pattern that has no meaning. However, with borders of circles are shown, it can be read as (b) "KOSEN." This effect is an example of our ability to understanding the continuity of existence of objects (i.e., objects permanence) even when they cannot be seen. Unreadable letters "KOSEN" represent their present understanding of Japanese KOSEN and its education. The blotted letters become meaningful when the borders are provided. This process analogically indicates the procedure to understand not only KOSEN education but also Engineering study itself to the students

(Aburatani, 2014). These are examples of our multiple approaches to initiate and to develop KOSEN engineering education in Thailand; It should be noted that cognitive approaches are effective in delivering the message to the students.

Comparison between KOSEN-KMITL and Japanese KOSEN Curriculum

Although MCC is a common educational platform for NIT KOSEN, each NIT KOSEN provides its own distinctive engineering program, which reflects regional characteristics as well as educational assets. Figure 6 shows a comparison between KOSEN-KMITL and a Japanese KOSEN concerning the ratio of major subjects (Kisarazu College, 2019). Mechatronics consists of the integration of Mechanical engineering, Electrical and Electronic (EE) engineering, and Computer engineering (Programming/IT). A "Control Engineering" department similar to the mechatronics is chosen for this comparison since there is no NIT KOSEN department name with "Mechatronics" at present. The selected Kisarazu KOSEN is accredited by JABEE (Rynearson, 2011) and also a member of the CDIO. For the subject comparison, the major subjects are classified into four groups: EE engineering, Mechanical engineering, Programming/IT, and Mechatronics as the integration of the preceding engineering fields.

It is shown that the ratio of these subjects is reasonably similar to each other, expect the EE engineering and the mechatronics. This difference is due to the nature of mechatronics in which the electrical and electronic engineering plays an important part. A major difference is found for Lab work, project work, and the general engineering mentioned above. KOSEN-KMITL curriculum emphasizes to provide the students with contextualized opportunities to practice independently and build their knowledge through project work and the research work.

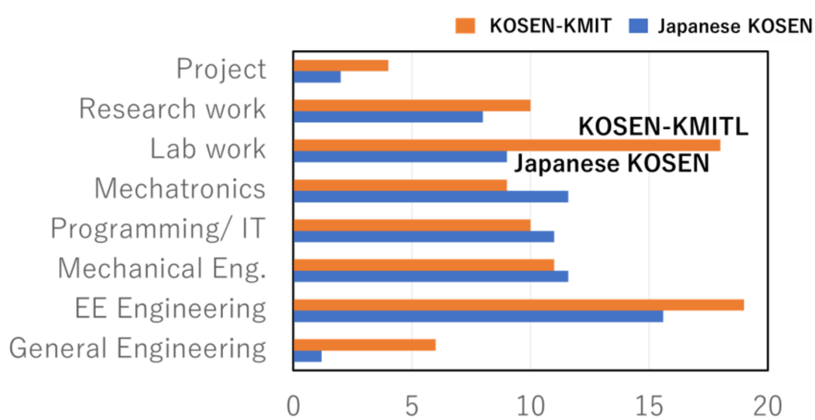

Fig. 6 A subject comparison between KOSEN-KMITL and a Japanese KOSEN

Figure 7 shows a part of the curriculum map related to the lab/project and research work. There are four project-based learning (PBL) subjects through the 3rd to 4th-year grades in conjunction with social study subjects executed in parallel. Topics for the project will be chosen to solve social problems. Especially, UN's Sustainable Development Goals (SDGs) have been included in the curriculum, and the students have started SDGs study from the 1st year. The sequential cycle of learning through the social study and project work towards the final year research/project will provide contextualized learning and encourage student empowerment as well as implement C-D-I-O cycle.

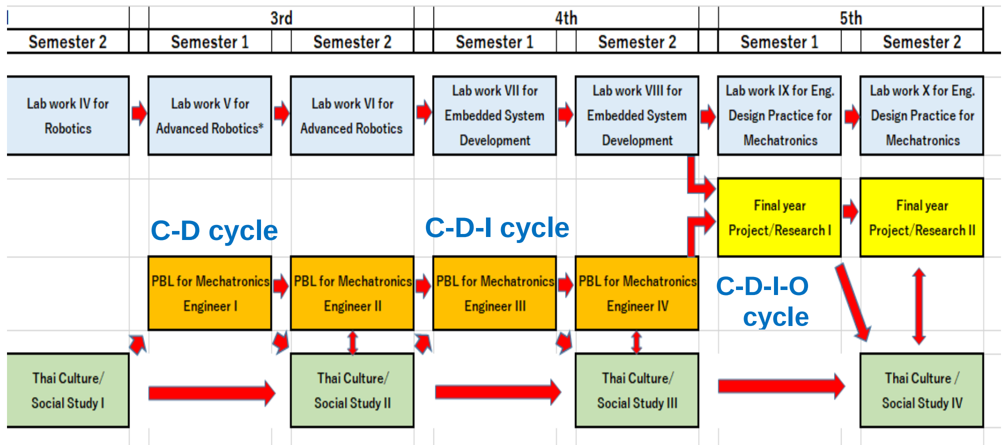

Fig. 7 A part of the curriculum map related to project work and social study

KOSEN Extracurricular Activities and International collaboration

Since KOSEN-KMITL is a newly opened school in collaboration with 51 NIT's KOSEN colleges, many educational challenges are being planned to promote KOSEN education in Thailand. Extracurricular activities within and outside school play very important roles in KOSEN education. Especially, an annually held robot contest known as "KOSEN RoboCon" with approximately 30 years of history and a programming contest (PROCON) among KOSEN colleges are very popular in Japan and attract many prospective students. KOSEN-KMITL is preparing to join these Japanese KOSEN events in the future. Instead of these events, selected four students have already joined KOSEN events in Japan: a Robot festival and a presentation contest. Also, seven student groups attended a robot contest held in Bangkok last year and one group won a prize. KOSEN-KMITL continuously supports and encourages the students to challenge many things to foster their creativity and skills as an important part of KOSEN engineering education.

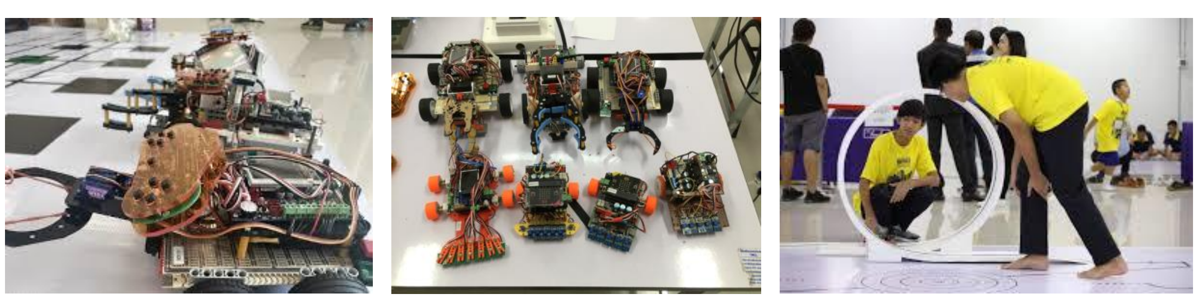

Fig. 8 Pictures of robots for a robot contest held in Bangkok 2019: World Roboto Games

CONCLUSION

In this paper, the engineering education at the Mechatronics department of KOSEN-KMITL, including extracurricular activities and international collaboration between KOSEN-KMITL and NIT KOSEN, is reported. Since KOSEN-KMITL is newly opened KOSEN outside Japan based on NIT's MCC and engineering education concept, many educational challenges are being implemented. It is shown that, as a newly established school without senior students, introductory subjects play a significant role in fostering the school's identity and young students' mindset as KOSEN students as well as for the engineering.

The curriculum reflecting its uniqueness is compared to NIT KOSEN's one and the CDIO Standard and Syllabus. It is shown that the KOSEN-KMITL curriculum and education well match with the items and the scope of CDIO. The curriculum is designed to promote practical "Monozukuri" education and C-D-I-O process through project-based learning and the research work. From these results, it is shown that KOSEN-KMITL provides the students with Japanese NIT KOSEN quality engineering education as well as the program satisfying the CDIO concepts. It is expected that educational challenges at KOSEN-KMITL will promote further development of engineering education in Thailand to foster the innovative engineers for the future.

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DESIGN OF CDIO CURRICULUM FOR UNDERGRADUATE ENGINEERING PROGRAMME: INDIAN CONTEXT

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ABSTRACT

Autonomous institutions in India have the freedom to design and develop innovative curriculum, content delivery, and assessment methodologies. In 2013, the Outcome-Based Education (OBE) framework was made mandatory for accrediting undergraduate engineering programs in India by the National Board of Accreditation (NBA). However, in reality, cognitive aspects are addressed to a greater extent than the affective and psychomotor aspects of learning. After attending the 11th International CDIO conference, we realized that the CDIO framework would be highly suitable for improving the undergraduate engineering curriculum in addressing all 12 graduate attributes of the International Engineering Alliance (IEA). As a pilot study, *Engineering Design* and *Capstone* courses were introduced in the OBE curriculum at our institute to emphasize hands-on practices, personal and interpersonal skills. These courses helped us to strengthen the mapping between course outcomes and 12 graduate attributes/program outcomes. This motivated us to adapt the CDIO curriculum for all undergraduate engineering programs at our institution in 2018. The major challenge was in the introduction of new courses in the curriculum such that all four sections of the CDIO syllabus are addressed within the framework given by the regulatory authorities in India. This paper presents the methodology followed in adapting the CDIO syllabus at our institution, satisfying the requirements of regulatory authorities in India. In the proposed CDIO curriculum, a specialized new course was introduced at each semester of the program to improve the personal, interpersonal, and system building skills of the students, in addition to disciplinary knowledge and reasoning. The courses are, namely, *Engineering Exploration*, *Lateral Thinking*, *Design Thinking*, *Project Management*, *System Thinking*, *Engineering Design Project*, *Capstone Design Project,* and *Major Project*. The course outcomes of all the courses in the curriculum are articulated by combining the knowledge, skill, and attitude domains of learning. A model CDIO curriculum designed for Electronics and Communication Engineering program is presented in this paper.

KEYWORDS

Curriculum Design, Graduate Attributes, Course Outcomes, Programme Outcomes, Standards 1, 2, 3, 4, 5

INTRODUCTION

Engineering education programs throughout much of the 20th century offered students plentiful hands-on practices. Accomplished and experienced engineers taught courses that focused on solving tangible problems. In due course of time, due to rapid advancement in science and technology, engineering education drifted towards the teaching of engineering science. Teaching engineering practice was increasingly de-emphasized. As a result, industries in recent years have found that graduating students, while technically adept, lack many abilities required in real-world engineering situations. To address the increasing gap between scientific and practical engineering demand and to meet the global requirements of professional Engineers, the CDIO curriculum was introduced.

All India Council for Technical Education (AICTE), Government of India, has taken many initiatives in recent years to recalibrate the technical education in India. The initiatives include the development of model curriculum for undergraduate engineering programs, self-learning content through MOOCs, a new policy for the training of technical teachers, three-week student induction program, enunciating guidelines for the mandatory internship and examination reform policy to examine the effectiveness of earlier initiatives of AICTE and also those on the anvil (All India Council for Technical Education, 2018).

Our institution, Thiagarajar College of Engineering (TCE), Madurai, was granted autonomous status in the year 1987 by the University Grants Commission (UGC), New Delhi. This has given us the freedom to design and develop an innovative curriculum in alignment with the guidelines of AICTE and Affiliating University, content delivery, and assessment methods. As a major initiative in the teaching and learning process, a competency-based curriculum Bloom's taxonomy based course learning outcomes & assessment methodologies were introduced in 2008. As Outcome-Based Education (OBE) has been made mandatory for accrediting Engineering Programmes in India, the curriculum was suitably modified in the year 2014 (TCE-OBE Syllabus, 2014). Though the undergraduate program curriculum is designed based on the OBE framework, the hands-on practices, system/design thinking leading to product development, and interpersonal skills have not been much emphasized in the curriculum. Cognitive aspects are addressed to a greater extent than affective and psychomotor.

After attending the 11th International CDIO conference at Chengdu, China, we realized that a CDIO based curriculum is organized around the disciplines, but with CDIO activities are interwoven. The CDIO activities include projects, internships in industry, and active learning in theory and practical courses in which modern state-of-art laboratories are considered as workspaces (Johan Bankel et al., 2005). CDIO framework has been implemented in many universities all over the world as it maps with the Washington Accord graduate attributes. It motivated us to introduce 'Engineering Design' and 'Capstone' courses in our OBE curriculum as an experimental basis to emphasize hands-on practices, system/design thinking, and interpersonal skills. These courses helped us to improve the coverage of attainment of graduate attributes/program outcomes and student engagement.

However, we felt that the transition from the existing model to the CDIO framework would be more challenging. In the interaction with faculty members from various Universities at CDIO international conferences and Asian Regional meetings, we understood the challenges in implementing the CDIO framework first time in a country. In this connection, the authors explained the steps to be followed in designing the CDIO curriculum first time in a country. They described the design and implementation of the CDIO framework based design directed Engineering Curriculum in Shantou University, China (Gu et al., 2006). This has given us the confidence to implement the CDIO curriculum first time in India, as we had strong support from the administration and commitment from the faculty members. With this motivation, we adapted the CDIO syllabus (Edward, Johan, William, & Doris, 2011) for all seven undergraduate engineering programs at our institution from the academic year 2018-19.

The rest of the paper is organized as follows. The development of the TCE-CDIO curriculum is described in the following section. After that, an example CDIO course is discussed in the context of template, Program outcome (PO) mapping, and reflection.

TCE - CDIO CURRICULUM DESIGN ACTIVITIES

CDIO core committee was formed at TCE comprising of two faculty members from each department under the leadership of Dean (Academic Process) and Dean (Research and Development). These faculty members were chosen based on their proficiency in curriculum design. A series of workshops were conducted for the core committee members to enrich the exposure in the CDIO syllabus (Edward F. Crawley, 2001). After a series of discussions among the CDIO core committee members, templates for the CDIO curriculum at TCE addressing the four sections of CDIO syllabus and course design were designed, and a new proficiency scale named as TCE Proficiency Scale (TPS) was formed, as shown in Table 1. The core committee members conducted workshops to their respective department faculty members on CDIO syllabus, CDIO standards, three domains of Bloom's taxonomy (Cognitive, Affective & Psychomotor), and TCE Proficiency Scale.

Table 1. TCE Proficiency Scale (CDIO Curriculum Framework)

TPS	Proficiency	Cognitive	Affective	Psychomotor
TPS1	To have been exposed to	Remember	Receive	Perception, Set
TPS2	To be able to interpret and Imitate	Understand	Respond	Guided Response
TPS3	To be skilled in the Practice or Implement	Apply	Value	Mechanism
TPS4	To be able to participate in and contribute	Analyze	Organize	Complex Overt Responses
TPS5	To be able to judge and adapt	Evaluate	Organize	Adaptation
TPS6	To be able to lead and innovate	Create	Characterize	Origination

Table 2. CDIO Courses at TCE

Semester	Course	Course type	Credits	CDIO
I	Engineering Exploration	Practice Dominated Theory	3	C
II	Lateral Thinking	Practice Dominated Theory	1	C
III	Design Thinking	Practice Dominated Theory	2	C(D)
IV	Project Management	Practice Dominated Theory	3	C(D)(I)
V	System Thinking	Practice Dominated Theory	3	CD(I)
VI	Engineering Design Project	Project	3	CDI(O)
VII	Capstone Design Project	Project	2	CDIO
VIII	Major Project	Project	9	CDIO
Total Credits for CDIO courses			**26**	

A set of new courses were identified and diligently scheduled without violating AICTE model curriculum requirements on technical knowledge and reasoning. About 20% of total credits have been allocated to CDIO courses. The semester-wise CDIO courses, common to all undergraduate engineering programs, are listed in Table 2.

The detailed syllabi for these courses were prepared by CDIO core committee members and reviewed by a section of final year students, Senior Faculty members, employers, and recently passed out alumni.

TCE-CDIO CURRICULUM

The TCE-CDIO curriculum was designed in the context suitable for India. The four sections of the CDIO syllabus, namely *'Technical Knowledge and Reasoning, Personal and professional skills, Interpersonal skills, and CDIO'* are addressed in the curriculum by introducing new courses and redesigning previous courses. A systematic process was followed to design the CDIO curriculum such that the new curriculum is more coherent and better focussed than the previous version and offers more flexibility to students in choosing their preferred area of specialization.

Based on the inputs namely CDIO Syllabus 2.0, Guidelines of Regulatory Authorities, Guidelines by professional societies such as American Society for Mechanical Engineering (ASME), Institute of Electrical and Electronics Engineering (IEEE) etc., on Curriculum Design, Washington Accord Graduate Attributes/Programme Outcome, Credit distributions at reputed higher learning institutions in India and abroad and the feedback report on existing Curriculum by Students, Faculty members, Employers, Alumni, the Dean (Academic Process) design Institution's Regulation of Undergraduate Programme. The regulations cover the Minimum Number of Credits to be earned, Credit Distribution, Policies on Assessment, Internship, Community Projects, and Industry Supported courses. The CDIO core committee is authorized to design Specialized Courses on CDIO.

AICTE, India has proposed the model curriculum for four-year undergraduate engineering programs in January 2018 to improve the quality of technical education in India. The AICTE model curriculum stipulates total number credits, course categories, and their credit distribution to design curriculum. However, AICTE, India permits autonomous institutions to make minor variations in the credit distributions. Based on this, we have made the credit distribution, including the Specialized CDIO courses at TCE. The credit distribution at TCE is given in Table 4.

In order to synergize academic and sponsored research activities with the teaching and learning process, Special Interest Groups (SIG) were created. Each engineering department has a theme area based on faculty expertise and infrastructure. The faculty members attached to SIGs have been empowered to design courses and foster industrial linkage in the respective domains and theme areas of the department. This innovative approach has enabled sustained academic excellence at our institution. Further, it also motivated to redraft the curriculum and syllabi of courses pertaining to SIG. Based on Programme Outcomes (POs) and the reports of feedback by internal and external stakeholders of a particular engineering program.

Table 3. TCE Curriculum Design Process

Inputs:

- *CDIO Syllabus 2.0*
- *Guidelines of Regulatory Authorities*
- *Professional Societies Guidelines on Curriculum Design*
- *Washington Accord Graduate Attributes/Programme Outcome*
- *Credit distributions at higher learning institutions*
- *Feedback Report on existing Curriculum by Students, Faculty members, Employers, Alumni*

Process

- *Development of Institution's Regulation of Undergraduate Programme by Dean (Academic Process) covering the following*
  - *Minimum Number of Credits to be earned, Credit Distribution, Policies on Assessment, Internship, Community Projects, Industry Supported courses*
- *Design of Specialized Courses on CDIO by CDIO Core Committee Members*
- *Preparation of 'Scheduling of Courses' at a program level, covering the all the four sections of the CDIO Syllabus*
- *Identification of the courses under each category of credit distribution and its type of implementation. The type includes theory, practical, Practice dominated Practical, Theory Dominated Practice course, Project.*
- *Review of 'Scheduling of Courses' by CDIO Core committee and incorporation of suggestions by the core committee*
- *Course Design as per the Course as per the Course Design Template by Core Committee*
  - *The courses are designed by faculty members in a relevant Special Interest Group(SIG)*
- *Review of Scheduling of Courses and detailed syllabus for each course at Board of Studies Meeting and incorporation of suggestions by the members.*
- *Review of Curriculum and Syllabus of the engineering programs at Academic Council Meetings and Approval is given for implementation after the incorporation of suggestions by the members*

Output

- *Regulations for Undergraduate Engineering programs at the institute*
- *TCE- CDIO curriculum*

The program, the course outcomes are identified in each SIG. Subsequently, courses for each curricular component in each Special Interest Group (SIG) are identified. Based on this and the Institution's Regulations, courses are classified as Core or Professional Elective Course. There are five types of courses in the TCE-CDIO Curriculum. They are theory courses, Practical Courses, Theory dominated Practical courses, Practice dominated Theory courses, and projects. The department level coordinator prepares a course map for the program in discussion with coordinators of SIGs in the department and 'Scheduling of Courses' in alignment with the CDIO curricular components and Regulations of TCE-CDIO Curriculum. This is followed by assigning credits and type for each course. The scheduling of courses is presented at the CDIO Core Committee to review the ''Scheduling of Courses' and suggestions given by members are incorporated. The 'Scheduling of Courses' for Undergraduate Electronics and Communication Engineering (ECE) programme is presented in Table 5. Syllabus for each course is designed using 'Concept Map' for each course by SIG faculty members in the respective department, and eventually, a consolidated syllabus is formed. The Department of ECE has the following SIGs.

1. Microwave Engineering
2. Signal Processing
3. Image Processing
4. Communication Networking
5. VLSI Systems
6. Embedded Systems

Table 4. Credit Distribution for Undergraduate Engineering Programmes

S.No	Category	Suggested Credits* by AICTE	Credits at TCE
1	Humanities and Social Sciences including Management Courses	12	9-11
2	Basic Science courses	25	21
3	Engineering Science courses	24	23-26
4	Professional core courses	48	55
5	Professional Elective courses relevant to chosen specialization/branch	18	18 -24
6	Open subjects – Electives from other technical and /or emerging subjects	18	12 -18
7	Project work, seminar, and internship in industry	15	15
8	Mandatory Courses [Environmental Sciences, Induction Program, Indian Constitution, Essence of Indian Traditional Knowledge]	Non Credit	Non Credit
	Total (TCE: Minimum Credits to be earned for the award of the degree)	**160**	**160**

**Minor Variation is allowed as per the need of the respective disciplines*

The first step of SIG based course design is to identify course designers from each SIG. The course designers prepare/ redefine course outcomes with corresponding Bloom's level and target level of attainment. Then, designers ensure that the course outcomes are correlated with Programme Outcomes. After this, designers form Bloom's taxonomy based assessment pattern followed by preparation of concept map, course content, lecture schedule, and course level assessment questions. Then, the course design (syllabus) is presented in the SIG meeting for review and to incorporate suggestions given by SIG members. After the syllabus is designed for all the courses following the process discussed above, and the final syllabus is formed. The professional core courses designed by each SIG for ECE undergraduate Programme are listed in Table 6.

The syllabus is reviewed in the Board of Studies (BoS) meeting. The composition of the Board of Studies is two academic experts in the program, industry experts, faculty members nominated by affiliating University, Alumni, faculty members in the respective department, and student nominees. After incorporating suggestions from the BoS members, the syllabus is forwarded to the Academic Council for approval. The academic council is the highest authority for reviewing and approving the academic regulations of the institute and syllabus of all the programs in the institution. After incorporating suggestions from the Academic Council members, the syllabus is distributed to the faculty members and students.

One of the CDIO courses, namely 'Design Thinking,' is given as an example. The Course outcomes (COs) are given in Table 7. The Course outcomes mapping with CDIO Curricular components and TCE proficiency scale are illustrated in Table 8.

Table 5. Scheduling of Courses (B.E. ECE Programme)

Sem-ester	Theory/ Theory cum Practical						Practical		*CDIO Courses*	Credits
I	18MA110 Engineering Calculus (4)	18PHB20 Physics (3)	18CHB30 Chemistry (4)	18EG180 English (2)	-	18ME160 Engg Graphics (4)	18EG170 English Lab. (1)	18PH180 Physics Lab. (1)	*18ES150 Engg Exploration (3)*	22
II	18MA210 Matrices and Differential Equations (3)	18EC220 Network Theory (3)	18EC230 Electronic Devices (3)	18EC240 Semiconductor Physics (3)	-	18EC260 Digital System Design (3)	18EC270 Circuits and Devices Lab (1)	18EC280 Workshop (1)	*18ES290 Lateral Thinking (1)*	18
III	18EC310 Complex Analysis and Linear Algebra (3)	18EC320 RF Passive Devices and Circuits (3)	18EC330 Electronic Circuits (3)	18EC340 Signals and Systems (3)	18EC350 Microprocessors and Microcontrollers (3)	18EC360 Programming for Problem Solving (3)	18EC370 Microprocessor and Microcontroller Lab (1)	18EC380 Electronic Circuits Lab (1)	*18ES390 Design Thinking (2)*	22
IV	18EC410 Optimization and Numerical Methods (3)	18EC420 RF Active Circuits (3)	18EC430 CMOS VLSI Systems (3)	18EC440 Signal Processing (3)	18YYFX0 Foundation Elective I (3)	18EG460 Professional Communication (2)	18EC470 RF Circuits Lab (1)	18EC480 Signal Processing Lab (1)	*18EC490 Project Management (3)*	22
V	18EC510 Data Communication Networks (3)	18EC520 Antenna and Wave Propagation (3)	18EC530 Analog and Digital Communications (3)	18ECPX0 Prog. Elective I (3)	18YYGX0 General Elective (3)	18EC560 Digital Image Processing (3)	18EC570 Data Communication Networking Lab (1)	18EC580 ADC Lab (1)	*18ES590 Capstone Design Project (3)*	23
VI	18EC610 Accounting and Finance (3)	18EC620 Control Systems (3)	18EC630 Data Structures (2)	18ECPX0 Prog. Elective II (3)	Program/ Foundation Elective (3)	Engineering Sciences Elective (3)	18EC670 Commn System Design Lab (2)	18EC680 Data Structures Lab (1)	*18ES690 Engg Design Project (3)*	23
VII	18ECPX0 Prog. Elec.III (3)	18ECPX0 Prog. Elec IV (3)	18ECPX0 Prog. Elec. V (3)	18ECPX0 Prog. Elec. VI (3)	-	-	18EC770 Elective Lab (1)	-	*18ES790 System Thinking (2)*	15
VIII	18XXPX0 Prog. Elec. VII (3)	18XXPX0 Prog. Elec. VIII (3)	-	-	-	-	-	-	*18EC810 Project (9)*	15

Table 6. Professional Core Courses in ECE Programme

Microwave Engineering: • RF Passive Devices and Circuits • Electronic Circuits • Electronic Circuits Lab • RF Active Circuits • RF Circuits Lab • Antenna and Wave Propagation **VLSI Systems:** • Network Theory • Electronic Devices • Semiconductor Physics • Digital System Design • Circuits and Devices Lab • Electronic Circuits • Electronic Circuits Lab • CMOS VLSI Systems **Image Processing:** Digital Image Processing	**Signal Processing:** • Signal Processing • Signal Processing Lab • Analog and Digital Communication Systems • Analog and Digital Communication Lab • Control Systems • Communication System Design Lab • Wireless Communications **Networking:** • Problem Solving Using Computers • Data Structures • Data Structures Lab • Data Communication Networks • Data Communication Networking Lab **Embedded Systems:** • Microprocessors and Microcontroller • Programming • Microprocessor and Microcontroller Lab • Electronics Workshop

Table 7. Course Outcomes of Design Thinking Course

CO Number	Course Outcome Statement	Weightage in %
On the successful completion of the course, students will be able to		
CO1	Identify a specific social need to be addressed	20
CO2	Identify stakeholder's requirements for the societal Project	20
CO3	Develop measurable criteria in which design concepts can be evaluated	10
CO4	Develop prototypes of multiple concepts using user's feedback	30
CO5	Select the best design solution among the potential solutions with its functional decomposition	20

Table 8. Course Mapping with CDIO Curricular Component and TCE Proficiency Scale

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1.1, 3.1.2, 3.2.3, 3.2.6, 4.1.2
CO2	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1.2, 2.5.1, 2.5.2, 3.1.2, 3.2.3, 3.2.6, 4.1.2
CO3	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1.3, 3.1.2, 3.2.3, 3.2.6, 4.1.2, 4.3.1
CO4	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1.4, 3.1.2, 3.2.3, 3.2.6, 4.1.2, 4.4.1
CO5	TPS5	Evaluate	Organize	Adaptation	1.1, 1.2, 2.1.5, 3.1.2, 3.2.3, 3.2.6, 4.1.2, 4.4.1

CO to PO Mapping with three correlations levels are shown as follows:
It can be observed that almost all the program outcomes are addressed with a significant correlation level. Similar observations were found in the so for conducted CDIO courses, and the same will be done for higher semester CDIO courses. The involvement of students in CDIO courses was really encouraging. They demonstrated their design thinking skills and showcased their work in exhibitions and conferences, for which they won awards and laurels. The summary of the course exit survey of students for this CDIO course is shown in Figure 1.

CONCLUSION

In TCE, CDIO curricular education framework is adapted for seven undergraduate engineering programs, namely Civil Engineering, Mechanical Engineering, Electrical and Electronics Engineering, Electronics and Communication Engineering, Computer Science and Engineering, Information Technology, and Mechatronics in alignment with guidelines by the Indian regulatory authorities. The new curriculum, introduced in the academic year 2018-19, gives more choices to choose the courses as per the student's preferred area of specialization. The courses in this program have been developed using the TCE Proficiency scale and CDIO curricular components. A new proficiency scale is defined by combining knowledge, skills, and affective domain learning. Also, the mapping of COs with CDIO curricular components are included in the course syllabus. In the proposed curriculum, a new specialized course was introduced at each semester of the program to improve the personal, interpersonal, and system building skills of the students, in addition to the disciplinary knowledge and reasoning. The courses are namely Engineering Exploration, Lateral Thinking, Design Thinking, Project Management, System Thinking, Engineering Design Project, Capstone Design Project, and major project. Designing and adapting the CDIO curriculum framework has helped us in significantly addressing all the three domains of learning, thereby strengthen the mapping between course-level learning outcomes and all 12 graduate attributes.

Figure 1. Course exit survey

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REDESIGN OF A FRESHMAN ENGLISH COURSE FOR COMMUNICATIONS ENGINEERING FRESHMEN

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ABSTRACT

This paper reports results of the Freshman English course redesign for Department of Communications Engineering (DCE), Feng Chia University. Skills of teamwork, active learning, creative thinking, critical thinking, and communication in English as a foreign language were particularly emphasized in the redesign endeavour. In recent years, DCE has incorporated CDIO in its curriculum renovation by launching freshman projects, deep-bowl and capstone courses to continuously advance the quality of engineering education. Positive results of DCE's curriculum reform in developing students' disciplinary knowledge and competences are evident. Nevertheless, DCE still considered room for improvement, especially in students' personal and interpersonal skills. Therefore, in 2017, DCE started seeking cross-disciplinary collaboration with Foreign Language Center with keen determination to enhance, from the onset of college education, Freshman students' personal and interpersonal skills. With such an unprecedented collaboration, an integrated Freshman English program (DCEFE) was launched in Fall 2018 with distinctive features of learning English through active learning in the communication engineering context. Implementation and results of students' perceptions of the intended learning outcomes are presented for future applications of CDIO syllabus.

KEYWORDS

active learning, personal and interpersonal skills, Standards 2, 7, 8

INTRODUCTION

As the only CDIO initiative member in Taiwan, Feng Chia University (FCU) has been actively implementing CDIO at the university level by integrating the CDIO syllabus into the departmental curriculum design of all academic disciplines (Jai, Chou, & Chen, 2016; Lee, Jai, & Lee, 2019). This report focuses on why, how, and how effective from student perspectives the Freshman English course for Communications Engineering students was redesigned. The primary aim of the course redesign was to develop students' personal and interpersonal skills as delineated in the CDIO approach. By redesigning class activities based on the CDIO syllabus and Stanford University's design thinking methods (Kelley & Kelley, 2014), it was anticipated that engineering students' active learning, creative thinking, critical thinking, communication in English as a foreign language, and teamwork skills will be enhanced to reach expectations of their future employers.

In recent years, Department of Communications Engineering (DCE), an IEET (The Institute of Engineering Education Taiwan) accredited department, has further incorporated CDIO in its curriculum renovation by launching freshman projects, deep-bowl and capstone courses to continuously advance its engineering education to meet the trends and needs of global industries. Positive results of DCE's reform in developing students' disciplinary knowledge and competences are evident. Nevertheless, DCE still considered room for improvements in personal and interpersonal skills to gain a more in-depth implementation of the CDIO syllabus.

Therefore, in 2017, DCE started seeking cross-disciplinary collaboration with Foreign Language Center with a keen determination to enhance integrated and active learning of freshmen. The redesign effort of the Freshman English course for the Department of Communications Engineer (DCEFE) was based on the CDIO Standards 7 and 8 (Crawley, Malmqvist, Ostlund, & Brodeur, 2014), integrated learning experiences and active learning, respectively. Rooted in the standards, the DCEFE redesign was set to achieve simultaneous development of disciplinary knowledge and professional skills, i.e., personal and interpersonal skills. Individual student's engagement, creative thinking and critical thinking skills are keen to personal development. In particular, the DCEFE course were to meet the CDIO syllabus items 2.4: attitudes, thought and learning, 3.1: teamwork, 3.2 communication, and 3.3. communication in foreign languages. Teamwork and communication skills, especially communication in English as a foreign language, are keen to the enhancement of effective interpersonal development. Moreover, about Standard 8, active learning, the course featured learning activities which foster student engagement and interaction. With such an unprecedented collaboration at Feng Chia University, DCE was able to infuse into its mindset of engineering pedagogy with language teaching activities inducing to student engagement, interaction, and communication.

THE DCEFE COURSE DESIGN

The existing university-wide Freshman English course of Feng Chia University follows a unified syllabus which aims to strengthen students' reading and communication skills. Its class activities are primarily based on conventional English teaching methods such as Grammar Translation and Communicative Language Teaching, which feature predominantly lectures and exercises for preparing for exams. Paper-and-pencil midterm and final exams for summative assessment weigh 40% of the semester grade.

To turn learning from passive to active, from surface to deep, and from summative to formative, it is necessary to redesign the existing university-wide Freshman English course to better fit the needs of engineering students. Thus, a major purpose of the DCEFE course design was to infuse the CDIO approach, active learning, and design thinking (Kelley & Kelley, 2014) methods into the class activities to engage students directly in thinking, teamwork, and communication. In light of the aforementioned teaching and learning approach and methods, the DCEFE employed collaborative project-, problem-, and task-based activities in the communications engineering context, which are aligned with intended outcomes and assessment. Examples of active learning activities including World Café, Gallery Walk, mind mapping, posters, elevator pitch speeches, and other student-centred activities are shown in Table 1 and Figure 1.

Table 1. Sample Topics of the DCEFE Learning Activities

Topic	Group Task	Intended Outcome	Relates to CDIO Syllabus
Driverless Cars	Help wanted! Please use words, sketches and illustrates to help me understand better what they are and how they function on driverless cars. • Lidar • Bumper mounted radar • Ultrasonic sensors	Explain the technical terms orally and graphically	2.4.3 creative thinking 3.2.5 Graphical communication, 3.2.6 Oral presentation, 3.3.1 English
Battling Smartphone Zombies	What do you think? 1. Why do people engage in unsafe smartphones use while walking in public? 2. How to prevent pedestrian injuries and fatalities from happening?	Report your responses both in drawing and in writing	
Internet of Things	Gallery Walk 1. Kevin Ashton and the groundwork 2. Solved obstacles 3. What is IoT and what can IoT do? 4. Connecting industrial equipment 5. Sharing communication 6. IoT vs. traditional computing	Your group is the teacher who should instruct the assigned paragraph to other groups. Illustrate your understanding in multiple modes of communication.	2.4.4 critical thinking 3.2.5 Graphical communication 3.2.6 Oral presentation and Interpersonal communication 3.3.1 English
The future of communication	World Cafe Everyone should attend all five tables and contribute your thoughts and ideas on the table theme.	Present your thoughts and ideas clearly to the table master. An accepted idea is the one which is creative, innovative, and convincing.	2.4.3 creative thinking 3.2.5 Graphical communication 3.2.6 Oral presentation & interpersonal communication 3.3.1 English

Figure 1. Active learning activities in the DCEFE class

METHOD

Participants

Two classes of DCEFE with a total of 56 students were surveyed in the final week of the Fall semester, 2019. There were 11 females and 45 males. 53.6% of them started learning English as a foreign language at kindergarten, 26.8% at Grades 1 to 2, 12.5% at Grades 3-5, only 7.1% at a later time. 57.1% of the students believed that they can cope with daily communication functions in English. Moreover, concerning learning preferences, 50% of the students considered lecturing as their preferred learning approach.

Measure and Procedure

To gain an in-depth understanding of student perspectives on the course design of DCEFE, a survey instrument was developed by the authors with a primary aim to measure students' perceptions of intended outcomes of personal and interpersonal skills development. It is a Likert scale instrument with response options between 1 to 5 with 1 being strongly disagree, 2 disagree, 3 neutral, 4 agree, and 5 strongly agree. As for data analysis, a description design was used to examine student' perceptions of the impacts of a resigned Freshman English course for communications engineering students on the personal and interpersonal skills of the CDIO syllabus, with special emphases on 2.4.3 Creative Thinking, 2.4.4 Critical Thinking, 3.1 Teamwork, 3.2 Communication, and 3.3 Communications in Foreign Languages.

RESULTS AND DISCUSSION

Two classes of DCEFE students with a total number of 56 participated in the survey in the final week of the Fall semester, 2019. As aforementioned, the course redesign effort was to integrate the CDIO syllabus in a freshman English course with special focuses on the development of personal and interpersonal skills. In addition to the descriptive statistics for students' perceptions of personal and interpersonal skills, perceptions of the overall development resulted from the integrated and active learning experiences by participating in class activities is also reported. Means, standard deviations, and frequencies and percentages of affirmative responses (i.e., strongly agree and agree) are reported in the tables below.

Development of Personal Skills

Four aspects of personal skills development were examined: initiating thoughts and ideas, engagement in class activities, increased creative thinking, and increased critical thinking (Table 2). As found in this study, the students positively responded that the redesigned DCEFE course provided more opportunities for them to initiate individual thoughts and ideas. They also expressed that by engaging more actively in learning tasks, it helped increase their creative and critical thinking skills. Moreover, it is worth noting here that relatively fewer students (n = 38, 67.9%) agreed that their critical thinking skills had been enhanced in the class. Such a result might have been caused by two reasons. First, being exposed to learning English through the grammar translation method for purposes of memorization and passing exams, students tend to be used to passive and surface learning from lectures. As a result, they were more hesitant when being asked to pose personal points of view in class. Second, it takes time to change students' learning habit from passively receiving knowledge to actively expressing personal views. Such a radical change of learning habits could cause uneasy and intimidating feelings on the freshman students, especially in adapting to a new learning context of the university. As also suggested by Crawley, et al, (2014), students' resistance to change to the way they are accustomed to teaching and learning is a challenge in implementing active learning.

Table 2. Perceptions of Personal Skills Enhancement (*N* = 56)

Item	Mean	SD	Freq.	%
Initiating thoughts and ideas	4.12	.79	44	78.6
Active engagement	4.13	.74	44	78.6
More creative thinking	4.21	.68	48	85.7
More critical thinking	3.91	.79	38	67.9

Note. Frequencies and percentages are of affirmative responses: strongly agree and agree.

Development of Interpersonal Skills

Regarding teamwork of interpersonal skills, it can be seen that the students had noticed their progress in collaborative learning, brainstorming with peers, asking for help, working with others for clarification of instructor's questions, solving problems collaboratively, and actively helping others (Table 3). Being used to passive learning for memorization and passing exams, it can be easily assumed that the communications engineering freshmen had preferred working and solving problems individually. In general, they would rather resolve learning difficulties by "studying harder" then by consulting with others. After experiencing active learning in the DCEFE course, the students effectively deepened their teamwork and collaboration competencies.

In terms of the development of communication skills, the students saw their improvement in expressing personal ideas more often in class and in the ability to present ideas in multiple modes of graphic, oral, sketching, and written communication. As aforementioned, face-to-face communication is not easy for students who are accustomed to traditional ways of teaching and learning. Undoubtedly, it would require a giant leap for the students to step out from their “comfort zone” and step in a communicative and interactive learning environment. Although adapting to active learning can be challenging to students, it can be confirmed here that it works to change students’ learning habits and, at the same time, to improve their communication skills.

Table 3. Perception of Interpersonal Skills Enhancement (*N* = 56)

Item	Mean	SD	Freq.	%
Teamwork				
More collaborative learning	4.39	.62	52	92.9
Would brainstorm with peers to complete tasks	4.23	.66	51	91.1
More problem solving opportunities for group problems	4.16	.76	49	87.5
More collaboration for clarifying questions	4.25	.64	50	89.3
Would help solve peers’ problems	4.16	.56	48	85.7
Would ask for help from peers	4.25	.67	51	91.1
Communication				
Would express ideas more often	4.25	.64	50	89.3
Would express ideas in multiple modes	4.23	.76	50	89.3

Note. Frequencies and percentages are of affirmative responses: strongly agree and agree.

Overall Development of Professional Skills

The DCEFE course aimed to infuse the CDIO approach and integrate the CDIO syllabus items of 2.4: attitudes, thought and learning, 3.1: teamwork, 3.2 communication, and 3.3. communication in foreign languages to enhance students’ personal and interpersonal skills. It is thus crucial to examine whether the redesign effort effectively achieved the intended goal. Undoubtedly, students’ perspectives play an indispensable source of feedback in the redesign and implementation process. The students’ feedback, as shown in Table 4, indicated that they reacted positively to the key aspects of professional skills development, which helps validate that the course redesign by integrating the CDIO syllabus is in the right direction. Also, it is worth noting that not only that the students found their teamwork skills were improved, they would also continue to apply the skills developed from DCEFE to other classes. Likewise, class engagement and active thinking were also responded positively by the students and will impact other areas of disciplinary and professional development. Most importantly, motivation for learning (M = 4.32) resulted from the active learning was also highly rated. Such a result strongly validates the effectiveness of CDIO standard 8, active learning and is aligned with Crawley, et al. (2014):

“CDIO programs integrate the learning of professional engineering skills with disciplinary knowledge through active and experiential learning methods. Through the implementation of the CDIO approach to learning, engineering programs become more attractive to students. Students find meaning, motivation, ad personal development in learning experiences that result in conceptual understanding, in developing engineering skills and attributes, in working with real problems in context, in aligning education with professional practice, and in a purposeful approach to engineering in society.” (p. 146)

Table 4. Perceptions of Overall Development of Professional skills (*N* = 56)

Item	Mean	SD	Freq.	%
Higher motivation for learning	4.32	.69	49	87.5
Higher comprehension of content	4.29	.62	51	91.1
Change of habitual learning styles	4.27	.82	48	85.7
Using more creativity in completing group work	4.29	.76	51	91.1
Would apply cultivated engaging attitudes to other classes	4.21	.80	48	85.7
Would apply cultivated teamwork skills to other classes	4.34	.77	48	85.7
Would apply cultivated active thinking skills to other classes	4.13	.76	45	80.3

Note. Frequencies and percentages are of affirmative responses: strongly agree and agree.

CONCLUSION

This study aims to understand from student perspectives results of a redesigned Freshman English course, DCEFE, for communications engineering freshmen. Rooted in the CDIO approach, an important purpose of the redesign was to provide English language training in the engineering context through integrated learning and active learning methods. That is, students were required to apply disciplinary knowledge in communicating technical ideas and in English as a foreign language. In partaking in problem- and task-based learning activities, the students described, argued, reasoned, and planed with their team partners to complete group projects. It showed that through active learning, the students were effectively enhancing their motivation, personality, and interpersonal skills in addition to reinforcing disciplinary knowledge. Such positive results are aligned with previous studies (Edstrom, Tornevik, Engstrom, & Wiklund, 2003) that students are more likely to achieve intended outcomes and more satisfied with the learning outcomes when they are engaged in integrated and active learning. Such results further help validate the appropriateness and necessity of implementing the CDIO approach in training engineering students' communication in English, along with other intended development of teamwork, creative and critical thinking skills.

In conclusion, in contrast to traditional approaches to English language training and engineering education which are mostly rooted in teacher-centeredness and knowledge-based instruction, active learning works to enhance personal and interpersonal skills, and motivation as well. Motivation is relatively low when students do not know the reasons why they should engage in learning. On the other hand, when students perceive clear intended outcomes relevant to the real world and when they find meaning and personal development, they start to appreciate the relevance and worth of learning. And when students start to appreciate the relevance and worth of learning, they will discover their potentials in accomplishing any challenges that will lead to a successful future as engineers.

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USING LEARNING ANALYTICS IN MOULDING STUDENTS TO BECOME SELF-DIRECTED LEARNERS

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ABSTRACT

The twenty-first century workers need to be able to constantly keep abreast with changing technology and possess the desired behavioural competencies to have a long, rewarding career. To help the students of the School of Electrical and Electronic Engineering (SEEE) of Singapore Polytechnic, to grow, serve and thrive in the new norm in this VUCA world, an enhanced engineering education model is needed, which incorporates lifelong learning, addressing the demands of deep skills, versatility, entrepreneurial vigour and a global mindset for the betterment of Singapore. This paper shares the comprehensive approach taken to refine the current holistic education model that incorporates the polytechnic's Self-Directed model, into its CDIO-based curriculum for the diploma programmes, and extending into the co-curricular activities (CCAs) offered by the School and the polytechnic. Cognizant of the challenges of the SDL initiative, the different workgroups within the School, articulate how their respective work areas contribute towards helping students to become self-directed learners. This helps to surface academic staff's understanding of the notion of self-directed learners, how their work areas are already contributing, and where these actions can be further improved, to achieve the common goal. With this in place, the school hopes to gauge whether the whole school approach has contributed towards students' progress in becoming self-directed learners. For this purpose, the School plans for what is termed provisionally, the Self-directed learning (SDL) index, to add to the commonly used Grade Point Average (GPA). This requires that students provide their self-assessment on various aspects of self-directed learning. Although it is a three-year project, this paper aims to share the work progress, learning and findings at the end of its first year. Learning analytics will be used to provide feedback on the progress of the students at appropriate stages and the end of their three-year-long study.

KEYWORDS

Self-Directed Learning, Learning Analytics, Whole-school, Standards 2, 10

INTRODUCTION

Technology disruption is the new norm in this VUCA (Volatile, Uncertain, Complex, Ambiguous) world of the 21st century. Today's graduates can no longer expect that the knowledge and training acquired through completing formal academic programmes in institutions of higher learnings (IHLs) like the polytechnics or the universities, are enough and able to see them through their entire working lives.

To be able to meet the challenges of technology disruptions, they will need to become self-directed learners, with the ability to continually upgrade their skills and knowledge through a life-long endeavour to learn, unlearn and re-learn throughout their career, as pointed by Medel-Añonuevo, Ohsako & Mauch (2001) that “Today it is no longer enough to have the same living and working skills one had five years ago”.

An enhanced engineering education model can help the students of the School of Electrical and Electronic Engineering in the Singapore Polytechnic to meet the challenges of the the 21st century workers, as shown in the Integrated Engineering Experience – Education for the Future” model of Figure 1, which incorporates lifelong learning, addressing the needs of deep skills, versatility, entrepreneurial vigour and a global mindset for the betterment of Singapore. In short, the focus is to nurture and develop students in three areas - academic, technology and leadership & service.

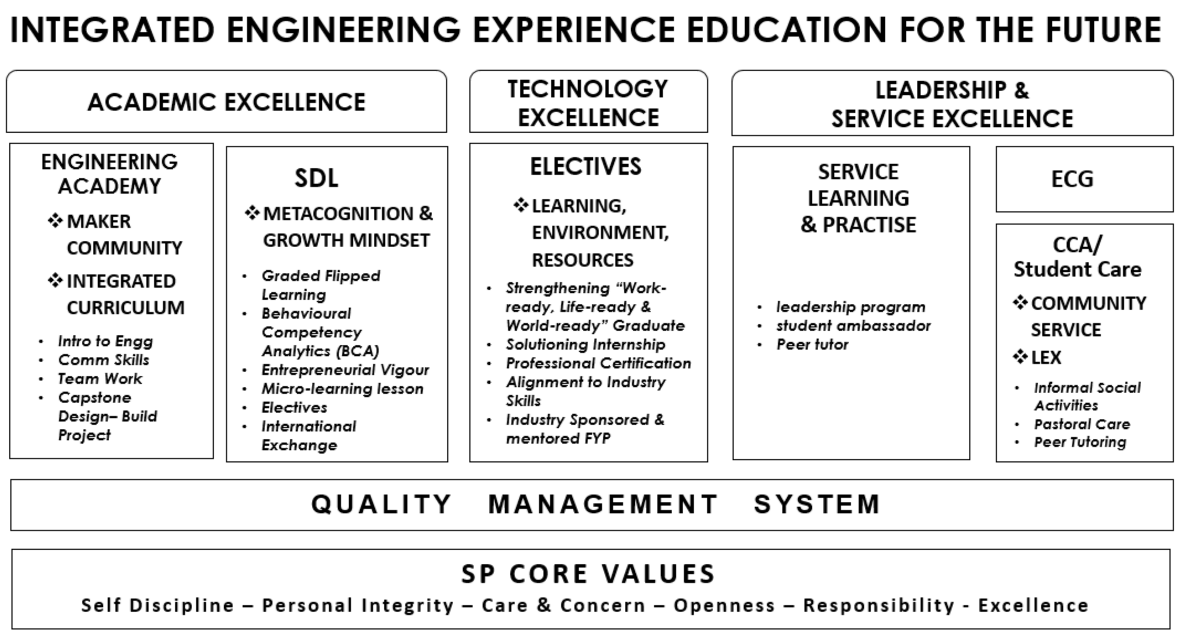

Figure 1. SEEE’s enhanced engineering education model

The model is a comprehensive approach to enhance the current holistic education model that incorporates the polytechnic’s Self-Directed Learning framework, strengthening the School’s’ CDIO and Design Thinking (DT)- based curriculum for the diploma programmes, and extending into the co-curricular activities (CCAs) offered by the School and the polytechnic.

SEEE values every student who invests three years to pursue a highly recognised engineering diploma qualification in SEEE. What will make the SEEE graduate more successful as compared to his or her peers, is that the person must display a set of highly valued and observable behaviours or traits which all employers will look for in a 21st century employee. SEEE terms this set of behaviours, the EEE DNA (Figure 2), comprising of ten key traits, namely Constantly Curious, Communicate with Impact, Be Versatile, Growth Mind-set, Global Mindset, Entrepreneurial Spirit, Deepen Skills, Give Your Best, Be Lifelong learner, and

Passionate in Engineering. The DNA elements were developed after many rounds of conversations involving teaching staff and students. SEEE is arguably possibly the largest and leading engineering education provider in Singapore with about 2600 full-time students enrolled.

This is mirrored to some extent by Vest (2005) who remarked that “students are driven by passion, curiosity engagement and dreams” and further added that “making universities and engineering schools exciting, creative, adventurous, rigorous, demanding, and empowering milieus is more important than specifying curricular details.”

Through different platforms such as co-curricular activities, national and international competitions, community service projects, leadership development, overseas attachment or exchanges developed within the School, as well as through collaboration with other stakeholders, SEEE aims to maximise the potential of every student that comes through its doors, thereby nurturing these curious minds and producing passionate engineers for the nation. Not limiting its students to teenagers but extending to working adults as well, the polytechnic for all ages aims to produce graduates who are work-ready, life-ready and world-ready. Such a highly-skilled engineering workforce will then able to support Singapore’s economic growth and aspiration towards transforming the nation to meet future challenges. (Smart Nation: The Way Forward, 2018).

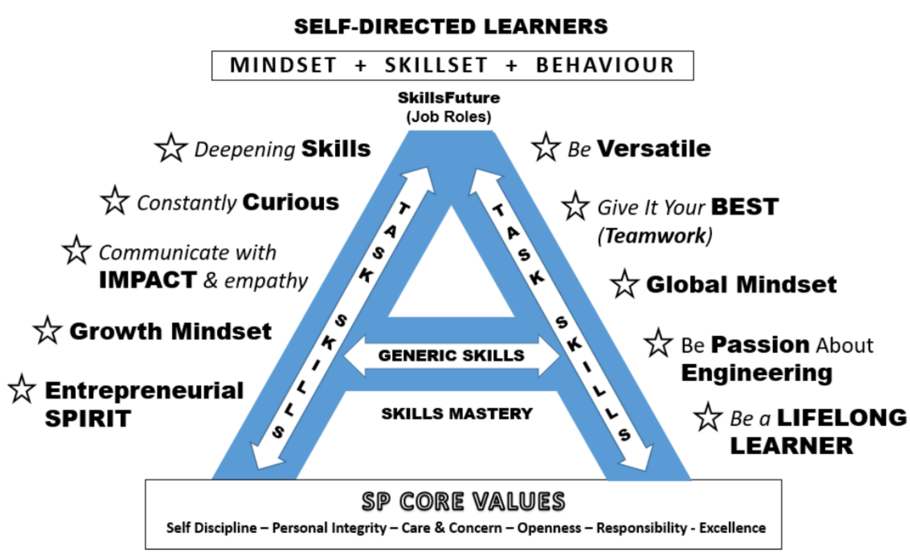

Figure 2. Desirable traits and EEE DNA

SELF-DIRECTED LEARNING IN SINGAPORE POLYTECHNIC

One of Singapore Polytechnic’s collective aspirations is then, that beyond just imparting knowledge and skills, it reiterates the academic staff’s role in the holistic development of the students, necessarily including that of shaping them to become self-directed learners. This was through the implementation of a Self-Directed Learning (SDL) Framework as shown in Figure 3 (Leong, Chan, & Chong, 2019) as a key initiative at the institutional level in 2018.

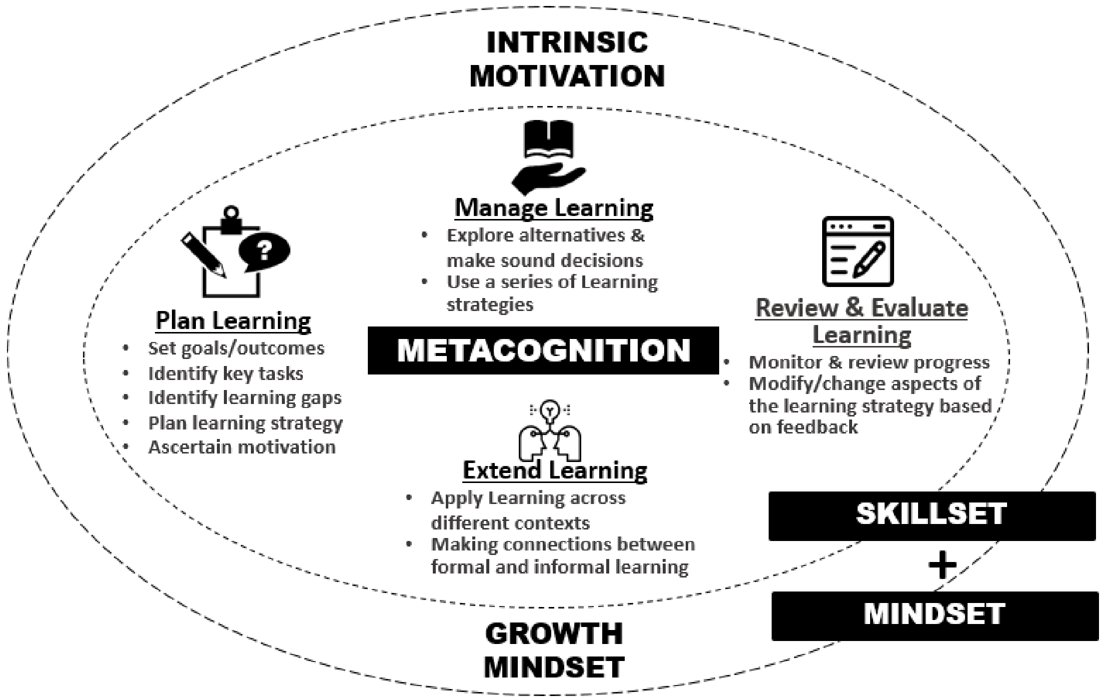

Figure 3. SP Self-Directed Learning (SDL) framework

The SP's SDL framework makes explicit the stages of planning, managing, reviewing and extending learning for the learner, echoing the definition offered by Knowles (1975) for self-directed learning as a process where the individual learner takes the responsibility and accountability for one's learning. This process essentially comprises the following: diagnose one's learning needs, formulate learning goals, identify resources to meet these goals, opt and put in place learning strategies and evaluate outcomes of the learning goals.

Gibbons (2002) reminds on the importance of the learner taking personal ownership of the learning, and the motivation to pursue and persist in the learning process by the learner, including that of extending learning, by making links, including those within formal and informal educational settings.

Tan and Koh (2014) suggested that self-directed learning could be better understood as occurring on a spectrum, ranging from the lowest level of SDL readiness to that of the highest; the lowest being incidental self-directed learning, and that of the highest, with high ownership of the various aspects of SDL.

For SEEE, the need to incorporate the SDL framework is aligned with its adoption of the CDIO framework for the implementation of the curricula of the various diploma courses that it offers. In the CDIO Syllabus, Part 2 covers the personal and professional skills and attributes expected of the engineering graduate, and the stages identified in SP's SDL model are reflected in 2.4.5, 2.4.6 and 2.4.7 of the CDIO syllabus.

DEVELOPING SELF-DIRECTED LEARNERS THROUGH A WHOLE-SCHOOL APPROACH

Figure 4 shows SEEE's whole-school approach to mould its students towards SDL, throughout the students' three-year-long studies. The journey begins during the freshmen orientation programme to welcome new students whereby the communication between the School management, comprising the Director, Course Managers and Pastoral Care Tutors, and the new students take place. The whole-school approach is conveyed to the students, alongside the school's goal and mission to imbue and nurture the new students towards becoming self-directed learners by the time they graduate from the diploma courses at the end of their studies, including the EEE DNA shared earlier.

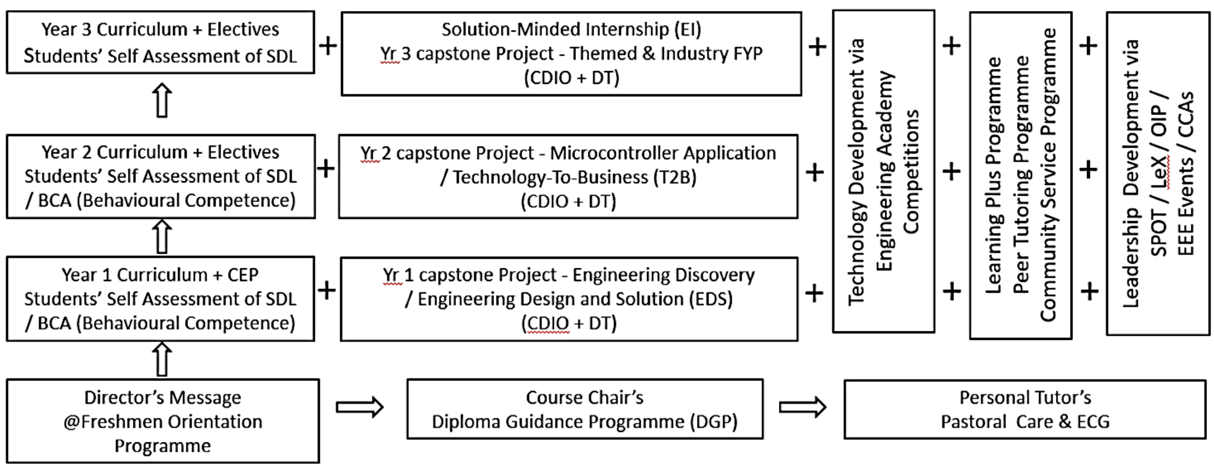

Figure 4. Whole-school approach to develop self-directed learners

The curriculum in all the three years of study is designed to build up their independent, meta-cognitive learning skills through flipped learning with self-assessment analytics of SDL. Also, integrated projects in each of the three-year course of study help to develop the students in two areas – to apply the theoretical knowledge they have learnt into practice, and to improve on their personal and interpersonal skills including teamwork and communication skills which are key employability criteria (Part 2 and 3 of the CDIO syllabus). Community service programmes and other events such as overseas immersion programme, service-learning experiences in overseas rural communities and CCAs all seek to transform them to become work-ready, life-ready, empathetic in their outlook, generous and caring towards the less fortunate.

The School also further translates SP's SDL framework and contextualized the framework for the engineering curriculum as shown in Figure 5. This modified framework was the result of several discussions between teaching staff and students.

Based on the school's interpretation, students who become self-directed learners possess a growth mindset together with the metacognition ability. To have a growth mindset, they need to be intrinsically motivated in their outlook coupled, underpinned with a passion for engineering. With a growth mindset, these will spur students to be innovative, looking at challenges from a wider perspective and always searching for creative solutions to existing or future challenges, helped by their ability to plan, manage, review and evaluate and extend their learning. With this ability, it helps in the acquiring of new knowledge that is indispensable in facing the unknown challenges of the future.

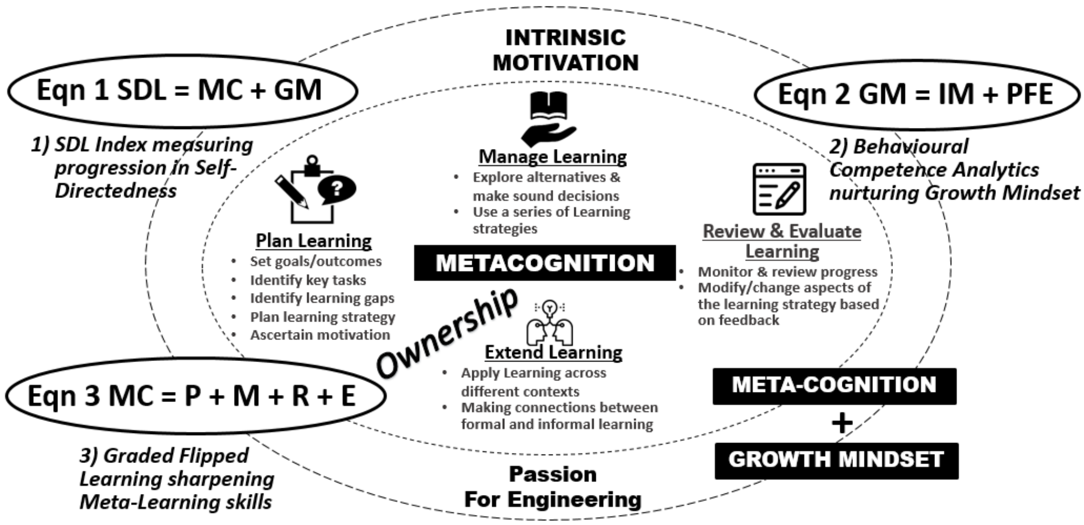

Figure 5. SEEE's SDL Framework, contextualizing SP's SDL Framework for an engineering curriculum

SDL ECOSYSTEM

For a School with a staff strength of 180 staff, there are various divisions, sections and staff workgroups, each with its objectives, and within the respective spheres of influence. However, collectively, the ultimate goal is to mould the students to become self-directed learners.

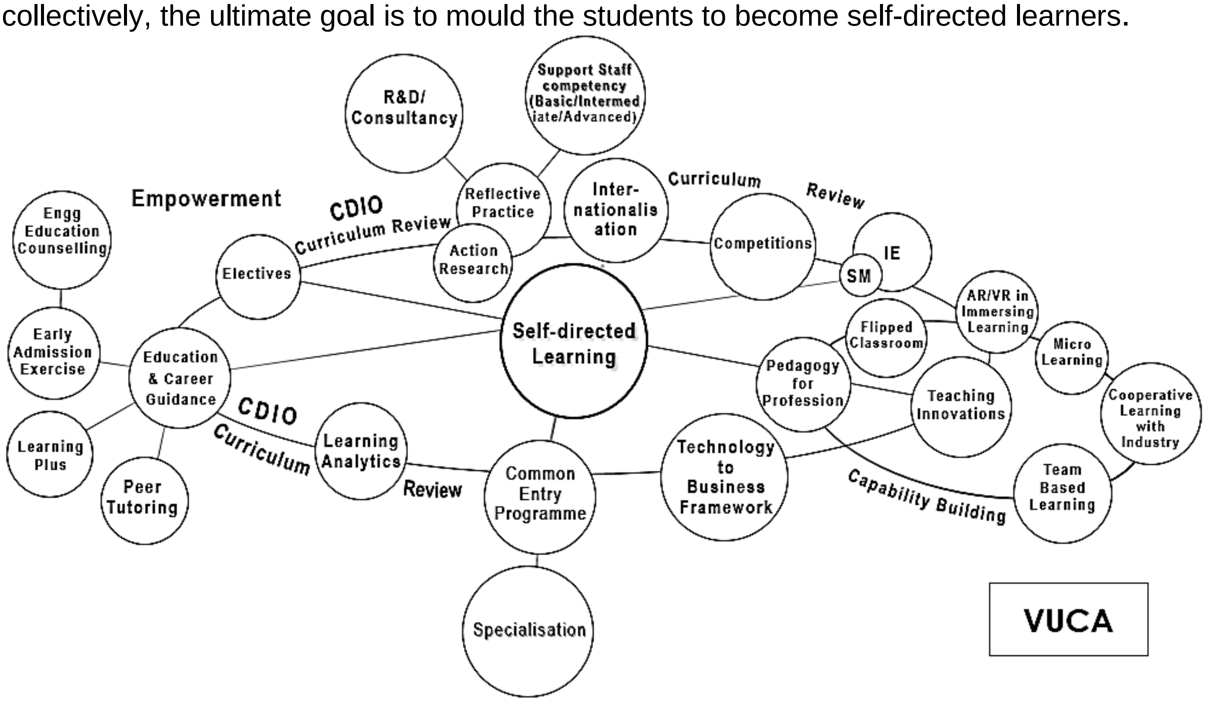

Figure 6. SEEE's SDL ecosystem

Figure 6 shows the SDL ecosystem detailing the interconnection of the different work areas that contribute towards the goal of SDL after a comprehensive review of the prevailing workflow in the entire school. The SDL ecosystem espoused by the School is in line with the notion that self-directed learning can take place in various contexts, and the essential role of the academic staff is to put in place by design so that self-directed learning can take place within these contexts.

The kind of ecosystem that the School posits is suggested in the work done by Tan & Koh, 2014, which considers self-directed learning as taking place both within and outside the formal school setting, with students potentially benefiting from both structured and unstructured learning experiences. Essentially, these broad contexts of learning are as follows: both in-school and out-of-school settings with structured learning experiences, led by academic staff; and in-school and out-of-school settings with unstructured learning experiences primarily carried out by the students.

For both in-school settings, examples of academic staff undertaking reflective practise and teaching innovation exemplify the in-school settings with structured learning experiences for the learners. To further illustrate, one example of this out-of-school setting, would be the solution-minded internship undertaken by all students in Year 3 of the studies, with a structured internship programme offered by the companies. The experiential learning experiences of learners through such out-of-school or out-of-the-classroom settings may offer scope to prepare students to be self-directed (Jiusto & Dibiasio, 2006).

In the following sections, several aspects of the whole-school approach outlined in the SDL ecosystem in figure 6 above are shared and how the learning experiences garnered in the settings, as articulated by the various workgroups, help shape the students towards being self-directed in their learning.

Reflective Practice (RP) & Action Research (AR)

Through RP, academic staff question their long-held assumptions of students' learning challenges, and their usual teaching practices, to help their students learn better. This extends beyond content and assessments, intending to get their students to think about their learning. Through AR, teaching staff take their reflective practice further. They critically examine their own accepted usual teaching approaches and practices, systematically and carefully collect data, analyse the data, and act on what they learn and work collaboratively with fellow teaching members on implemented interventions. These are shared with colleagues and papers proposed on the action research undertaken. Teaching staff look for evidence-based T&L interventions and approaches, including technologies that push the boundaries of how students learn, and how these are used in the changing educational landscape. They explore and adapt these to their teaching practices to help their students towards being self-directed learners. Sharing of reflective practices amongst teaching members and publication of action research work are testimonies to the good work achieved. Ultimately, improved teaching practices will help students to become SDL.

Teaching Innovation (TI)

Lecturers take on "deepening pedagogy" goals which allow them to review and implement innovative pedagogy or technology, to improve the students' learning experiences. They are also involved in "reflective practice", whereby there is intentional and regular reflection on the effectiveness of teaching and learning interventions, strategies, pedagogy or technology used in the classroom. Academic Mentors (AMs) research teaching innovation and present their findings at international and regional conferences (e.g. CDIO, ISATE, IEEE etc). Currently, engaging content is effectively delivered to full-time and adult students over the Internet. Flipped teaching is progressively implemented over the three years for all courses to train the students to become independent learners and sharpen their metacognitive attributes. Data-driven approaches in teaching and learning, using analytics will be increasingly leveraged to enhance SDL.

R&D / Solution-minded Internship

Students as interns take charge of their learning as they manage and deliver industry project/s within the 22-week-long internship in an assigned company. Using CDIO/Design Thinking (DT) approach, the interns sharpen their skills in planning, managing, reviewing and evaluating, and extending their learning in their internship. This contributes to the sharpening of their metacognitive skills that is part of SDL. The technical outcomes of their industry projects demonstrates their R&D skills.

Pieces of evidence pointing to the successful completion of the internship are from internship journals that capture the interns' SDL journey; feedback from the employers highlighting the value of the work tasks and/or projects created and deployed, and possible scholarship awarded to the interns as well as employment opportunities for the interns.

Competitions

Students competing in international and local competitions sharpen their skills through training where they plan, manage, review and evaluate and extending their learning based on a set of competition criteria. The training under the guidance of academic staff as competition coaches and experts, provide opportunities for self-directed learning, given the open nature of competitions. Such highly charged and competitive environments drive the students in such programmes to take charge of their learning, giving them many opportunities to be self-directed especially since it is necessary to think on their feet in response to unexpected developments. The shortlisting for final rounds of competitions as well as the many prizes and awards won by the students are testaments to the students successfully embracing and developing the SDL qualities.

Internationalisation

This provides many opportunities for the students to benefit in the following ways: broadening and developing global perspectives, social and cultural interactions and exchanges, networking and building global friendships and learning to be independent and self-sufficient while living and learning in a foreign environment.

Students on an international programme will have to take ownership of their learning by engaging in a project and/or completing a structured learning in different socio-cultural environments. In this way, they learn to adapt and thrive in an international environment, pushing their limits and gaining skills beyond the classroom. The students' global experiences captured in the students' reflective journal give details of their achievements and the value of the projects deployed in foreign settings gives a measure of how successful the outcome is. Internationalisation will help the school to produce graduates who are culturally sensitive and possess a global outlook with the ability to operate within multi-national and cultural settings.

Electives

Students take charge of their learning by shaping their learning paths and pursuing their passions. They have a choice of electives that allow them to broaden, deepen or further knowledge and skills. The polytechnic's Elective Framework is designed to provide the students with educational experiences aligned with the aspiration of developing self-directed, versatile and lifelong learners.

Common Entry Programmes & Specialisation

The common entry programmes offer a pathway for the students to spend one semester taking both electrical & electronic engineering and mechanical & aerospace engineering modules so that they can make informed choices in choosing their preferred courses that are aligned with their interest. Before making the decision, they exercise self-directedness by exploring online resources and getting advice from seniors and lecturers on the courses offered.

Technology to Business (T2B) Framework

It aims to inspire Diploma in Engineering Business (DEB) students to be technology entrepreneurs by providing a hands-on introduction to the entrepreneurial process of discovering, evaluating, exploiting and implementing the opportunities with existing and/or emerging technologies and develop them into potentially viable businesses. Students will apply CDIO and Design Thinking to conceive the solutions/services and finally operate on them. Furthermore, they will learn to create value propositions, assess risks and develop project plans as an integral part of their projects by developing the entrepreneurial mindset and attitude to bring their solutions/services to the next level. With the training, this group of students will develop the confidence to work in start-up companies or MNC with start-up venture activities. Others will acquire the conviction to spin-off their solutions/services to start-up companies. This enterprising opportunity further develop the students' self-directed learning.

Education & Career Guidance (ECG)

The ECG platform provides students opportunities in discovering and understanding their values, interests, personality and strengths and creating their brand. The Learning Plus programme complements by helping students to understand the kind of skills and competencies required in the workplace through industry exposure, workshops and exhibitions. Personal Tutors help to motivate and inspire students to meet their full potential. In this way, the soft skills nurtured in the students, industry and academia exposure and social community engagement will serve to enrich the students holistically in their development. Together with their academic results and imbued with the school's DNA, the graduates can apply for university places or jobs with a good resume and portfolios.

Student Leadership Development

As the students lead, plan and execute events from school to international level, the network and learn how to communicate, help each other and work together in a team. They also volunteer, serve, and contribute back to school and social community through various activities. The rigorous and intensive Singapore Polytechnic Outstanding Talent programmes and SEEE Ambassadors activities nurture and develop the selected group of students to become more confident and competent in dealing with social challenges. Service-learning in the peer tutoring program provides an opportunity for the weaker students to learn good learning strategy from peer tutors who are senior students. The peer tutors have leaders who will mentor and guide other tutors on commitment, responsibility, patient and caring in carrying out their duties to help the weaker students. Another area for leadership development is in community service. It provides the students with the learning opportunity in planning and coordinating as they work as a team to implement interactive activities with the community. As they engaged the community during the activities, student learn better to be more empathetic in their approach and outlook.

USING LEARNING ANALYTICS TO MEASURE SELF-DIRECTED LEARNING

Learning Analytics is defined as " the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs" by the Society for Learning Analytics Research. The use of learning analytics in education and the actual outcomes and impact are somewhat varied and could be clearer as suggested in the literature review (Viberga, Hatakkab, Bältera, & Mavroudia, 2018) (Wilson, Watson, Thompson, Drew, & Doyle, 2017). The need for effective leadership for the development and deployment of learning analytics is also recommended by Andre, Le, & Webster, 2019. The kind of use of the learning analytics in the School's case would be akin to the lifelong learner modelling proffered by (Kay & Kummerfeld, 2012), through on a very modest scale. This refers to how data gathered from different learning environments will be archived as the learner's learning activities that can provide an image of the learner's learning journey in life.

Here the School hopes to use learning analytics to address the question of whether and how effective the whole-school approach has achieved its intended objectives. To address this issue, the school decides to look into the students' SDL readiness at different stages of their courses through self-assessment by the students. This consists of 14 statements, using a 7-point Likert scale, as shown in Figure 7. The set of statements can be divided into three groups, the first two groups relating to intrinsic and extrinsic motivations respectively, and the remaining ten on SDL readiness, adapted from the work by Tan, Divaharan, Tan and Cheah (2011) on students' assessment of their SDL.

The first self-assessment was conducted when the students enrolled into the polytechnic. Based on the roadmap, the subsequent assessments are targeted for implementation when the students complete their Year 1 in April 2020, Year 2 in April 2021 and Year 3 in April 2022. The results obtained each year would be compared to see whether the trainings received have made a positive impact on the students' self-directed learning.

The first survey was conducted in April 2019 and the results are shown in figure 7 below. About intrinsic motivation, 47% indicated that they prefer challenging learning materials and another 56% prefer learning materials that arouse their curiosity even if they are difficult to understand. For extrinsic motivation, 59% would like to do well in their studies so that others would have a favourable image of their abilities. A high percentage of 68% agreed that getting a high grade is a most satisfying personal experience. Trying to understand where mistakes were made in their learning to improve garnered the highest percentage of 71%. When it comes to seeking out what is required beyond the syllabus of the module, a low percentage of 38% was registered. As the favourable response ranged from 38% to 71%, this shows that there is room for the school to sharpen their SDL skills during their course of study.

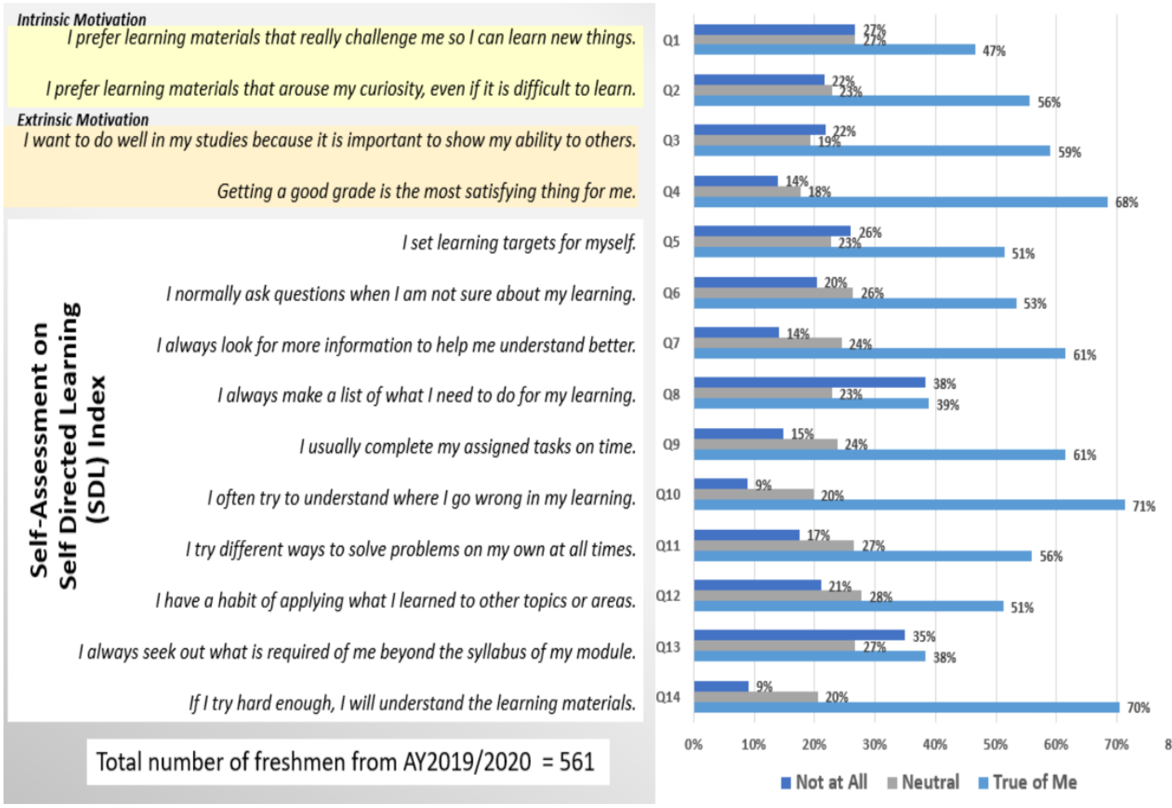

Figure 7. Self-assessment on SDL Readiness and Results of Survey of Year 1 Freshmen

Through the data obtained at different stages of the students' journey, the use of learning analytics intended for use up to this point is more like a tool for quality assurance and quality improvement of the whole-school approach as put across by Sclater, Peasgood, & Mullan, (2016). The term SDL index, mooted by the School, represents a score indicative and derived from the responses of the students, though its actual form may be considered in conjunction with other information.

Going forward, it could be possible that the data collected could also be used to show the progression of students in being SDL, vis a vis students' record of CCAs and other out-of-classroom settings achievements, recorded under the Student Administration System (SAS). This may contribute towards providing students with the profile of the success story of a self-directed student, along the lines suggested by Sclater, Peasgood & Mullan, 2016, to help encourage the right behaviours of the students.

LIMITATIONS

The approach outlined thus far, has possible limitations. The need to validate the student self-assessment questionnaire on SDL is recognised. For the self-assessment by the students, there could be situations whereby some of the high-achieving students place higher demands on themselves and rate themselves lowly on the self-assessment, and some of the low-achieving students may have a blind spot in terms of their capabilities and thus rate themselves highly on the self-assessment. This issue will be addressed by another ongoing project called

“Behavioural Competency Analytics” that seeks to gather feedback from teaching staff for correlation with the students’ self-assessment. To date, the first stage of the study is completed based on the roadmap. As more results will be received, compiled and analysed in subsequent years, it would then be possible to identify specific areas of the whole school approach, which contributes positively or otherwise, towards shaping students to become self-directed learners.

CONCLUSION

The paper presented the school of EEE’s SDL framework with the ecosystem established and the adoption of the whole-school approach. The first set of data in figure 7 showed there is great potential in the students to become more self-directed. Using learning analytics and with more progressive data to be collected in the coming years, the effectiveness of the whole-school approach would be reviewed and assessed and for taking appropriate actions where required. This would provide the impetus for the school to continuously shape the students towards being self-directed learners and prepare them for the workplace of the future.

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BIOGRAPHICAL INFORMATION

Toh Ser Khoon is currently the Director, School of Electrical & Electronic Engineering, Singapore Polytechnic. Under his leadership, the School continues to be a strong advocator and practitioner for CDIO, Design Thinking and FabLab-based curriculum for the Engineering diploma programmes. His current focus is on nurturing and preparing learners to be self-directed and work-life and world-ready. In the area of teaching innovation, the emphasis will be on the use of educational technology and the application of learning analytics for engineering education.

Chia Chow Leong is a Deputy Director at the School of Electrical & Electronic Engineering, Singapore Polytechnic. His current portfolio is in Course Management and Student Development. He oversees the planning, development and implementation of full-time courses and continuing education & training (CET) courses in his school. He has a strong interest in conducting action research to enhances students' learning and strengthen staff pedagogical competence. He also plans programmes to nurture students and develop them to become self-directed learners.

Tan Hua Joo joined the Singapore Polytechnic in 1991, serving in various portfolios such as Academic Resource & Development Manager, Course Manager and Head of Teaching & Learning (T&L) Unit. As a senior lecturer, his interest is in T&L matters particularly in nurturing and developing students to become independent learners. He is also passionate about using educational technology in his teaching to help the students in their learning.

Safura Anwar has been with Singapore Polytechnic as a lecturer since 1986. As a senior lecturer, she has served various portfolios. Her appointment as an academic mentor since 2012 sees her working with students and colleagues alike to help students learn better.

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EDUCATION FOR ENGINEERS OR RE-ENGINEERING EDUCATION? CDIO IN NON-ENGINEERING PROGRAMMES

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ABSTRACT

The CDIO Initiative aims to equip the next generation of engineers with relevant knowledge, skills, and attitudes. As an educational framework, it still resides largely within the purview of engineering education. However, because it employs active learning tools such as group work and project-based learning, the applicability to curricula and programs outside of the engineering field has become a topic of discussion. In general, benefits of employing the CDIO approach include stronger connections to professional contexts, enhanced programme development and quality assurance, and a higher commitment to the continuous improvement of educational quality. This paper surveys the application of CDIO to one such non-engineering educational environment at a private university in Japan. We review the rationale behind the university's joining the CDIO Initiative, outline four non-engineering adaptations of CDIO standards, and highlight several changes in curriculum design using the CDIO self-evaluation rubric. Implications for future modifications based on these outcomes are also discussed.

KEYWORDS

Non-engineering programmes, self-evaluation rubric, curriculum design, best practices, Standards 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

INTRODUCTION

The CDIO INITIATIVE is an innovative educational framework for producing the next generation of engineers (CDIO, 2020). While it was developed for the context of engineering education, there has been significant discussion concerning the application and implementation of CDIO to non-engineering programmes. Reported benefits have included better educational design, better meeting of stakeholders' needs, improved quality assurance and a stronger connection to the professional context (Crawley et al., 2014; Malmqvist et al., 2016; Tangkijviwat et al., 2018).

The authors discuss the original motivation of Hokkaido Information University (HIU), a private Japanese non-engineering institution, for joining the CDIO initiative, and look at how the curriculum has changed as a result of applying CDIO standards. The notion of "best practices" – some techniques, strategies, technologies and relationships used to improve learning outcomes – employed before joining the CDIO initiative, is also discussed. Successful programmes resulting from implementing the CDIO framework are briefly outlined, and the progress of the university, two years after joining the initiative, is evaluated.

THE UNIVERSITY

HIU, founded in 1989, is part of the eDC group (Electronics Development group Company). The group is comprised of five closely meshed entities; a university, a string of technical colleges, a software development corporation, a space development company and a research institute. These five entities interconnect to form an institution that focuses on learning, industry and research. HIU is the primary learning institution in the group, and the faculties and departments that comprise it adhere to the group's vision; namely, providing information-based knowledge and skills. HIU applied and was accepted into the CDIO Initiative in March 2018. As HIU is not an engineering university, polytechnic or institute of technology, its involvement with the initiative is, perhaps, somewhat special.

RATIONALE FOR JOINING THE CDIO INITIATIVE

The founding principles of HIU state:

"In the spirit of academia-industry cooperation, we seek to nurture advanced information and communication technology professionals, instilling them with an understanding of the value of internationalization, cultivating their innovation and sense of humanity, and ensuring they are capable of contributing to the development of our information-oriented society through a specialized education based on solid practical groundwork" (HIU, 2020).

These principles and the language that expresses them are similar to the CDIO Initiative's vision of CDIO-based education, which stresses activities that are "rich with student design-build-test projects, integrating learning of professional skills such as teamwork and communication, active and experiential learning, and a quality assurance process (CDIO, 2020)."

If HIU's founding principles are referenced with CDIO Standards, similar objectives become apparent: For example:

"In the spirit of academia-industry cooperation **(Standard 3)**, we seek to nurture advanced information and communication technology professionals **(Standard 2 & 5)**, instilling them with an understanding of the value of internationalization **(Proposed Standard - Internationalization & Mobility)**, cultivating their innovation and sense of humanity **(Standard 7)**, and ensuring they are capable of contributing to the development of our information-oriented society **(Standard 12)** through a specialized education based on solid practical groundwork **(Standards 1 & 7)**".

Further, the CDIO programme is appropriate for information-oriented education and can be applied to skills that are taught at HIU. For example, **Conceiving** may refer to defining customer needs, applying the requisite skill and considering the appropriate technology (such as in network design or programming); **Design** involves constructing the necessary scaffolding for a system, network or game; **Implementing** means realising the design in a working system, process or model (such as a game, database, website, or network), and **Operating** entails maintaining, adjusting and evolving the product (games, networks, websites) as needed.

CDIO IN NON-ENGINEERING PROGRAMMES

More than a decade of collaboration with Thailand's Rajamangala University of Technology Thanyaburi (RMUTT), one of the earliest adopters of the CDIO initiative in Asia, has helped fuel interest at HIU in learning more about, and ultimately joining, the CDIO Initiative. This interest is due in part to RMUTT having effectively applied CDIO-based curriculum development to non-engineering programmes in their Mass Communication Technology Faculty. RMUTT faculty members have reported that there has been a continuous improvement in the quality of education since they applied CDIO standards to design and develop their curriculum (Tangkijviwat et al., 2018).

More recently, this broader adaptation of CDIO has been followed up with RMUTT's application to Digital Media, Hotel Management, Health & Beauty and Thai Traditional Medicine courses, amongst others. The same is apparent at the Mongolian University of Science and Technology (MUST), which has used the framework to enhance creativity and communication through project-based learning, with a special emphasis on English education (Sangijantsan, 2019).

Already sharing common CDIO objectives, and with over 30 percent of the tenured faculty having engineering backgrounds or graduating from engineering faculties (including the current president), HIU saw value in joining the CDIO Initiative, becoming the third tertiary institution in Japan to be accepted.

INITIAL SELF-EVALUATION OF HIU

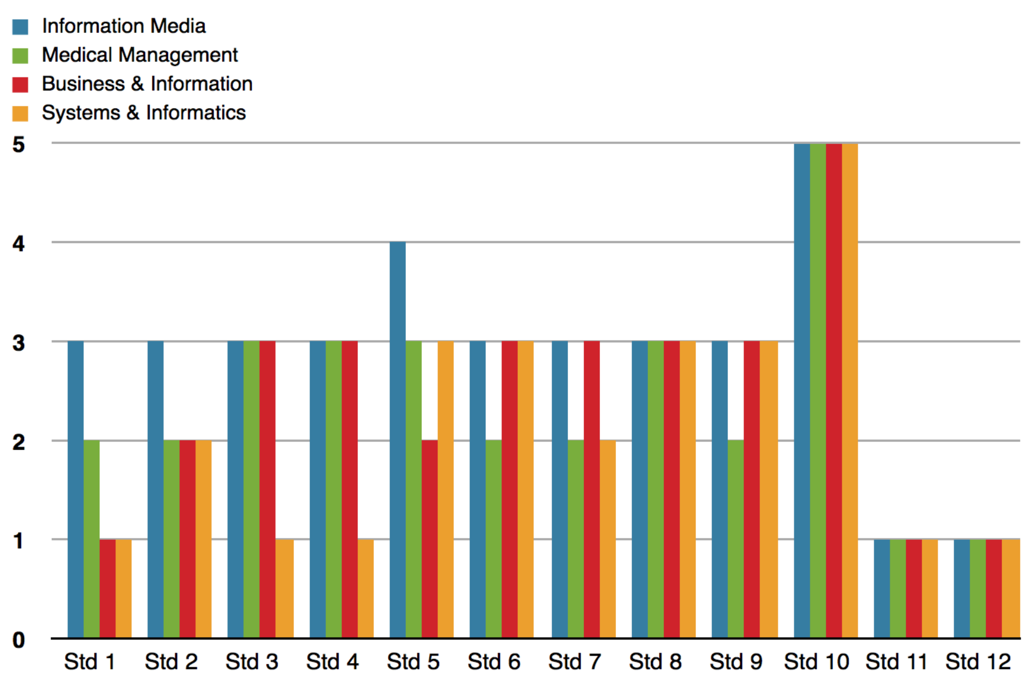

FIGURE 1: Self-evaluation by CDIO Standards, December 2017

Excluding the School of Distance Learning (off-campus students), and the General Education Group (whose teachers are formally affiliated with other departments), teaching faculty at HIU belong to one of four departments: Information Media, Systems & Informatics, Business &

Information, or Medical Management. Figure 1 shows an initial self-evaluation for each of the four departments carried out at the end of 2017. Involvement on a scale of zero to 5 is shown for each of the 12 CDIO Standards.

The initial self-assessment revealed that the Department of Information Media was more advanced than other departments in terms of the self-assessment rubric. There are several reasons why this may be the case. These include the fact that Information Media was the only department that had already been conducting project-based learning (Standard 5), one of HIU's best-practices, on a regular basis for several years. Similarly, CDIO as context (Standard 1) – also a best practice - was more advanced because Information Media put effort into connecting the educational context to what is needed in the professional world. The best-practice that equates to Standard 2 - review and validation of learning outcomes, by faculty and industry - was also perceived to be progressing well. Due to a robust Faculty Development programme that has been in place since 2010, enhancement of faculty teaching competence (Standard 10) was evaluated as high for each department. Conversely, program evaluation and assessing student learning (Standards 11 and 12) were generally assessed as being poorly undertaken. The Department of Systems and Informatics, which involves programming and system design, rated their progress significantly lower than other departments. This assessment is a little surprising, as programming and system design skills have a clear overlap with engineering education (hence, system engineer, network engineer), and therefore lend themselves more readily to adoption of the CDIO framework. If the university is regarded a whole, and the self-evaluation is viewed as a totality by averaging departmental rubric scores, a clearer picture of the general progress of the university becomes apparent. This is expressed by the line superimposed on the bar graph in Figure 2.

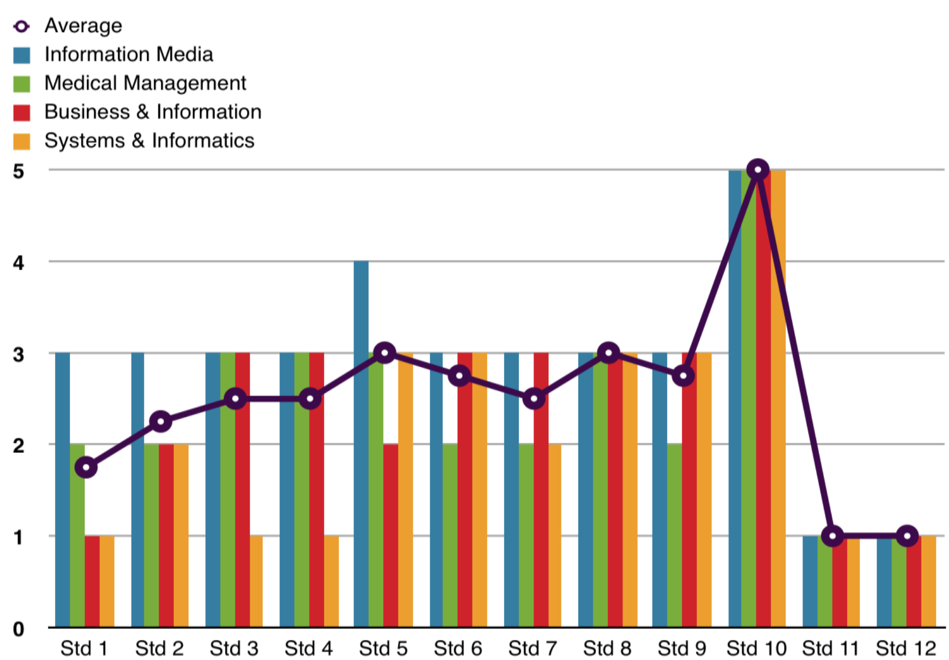

FIGURE 2: Self-evaluation by CDIO Standards, showing average rubric score, December 2017

Despite higher self-evaluations by Information Media, and lower evaluations by Systems & Informatics, if the assessment is viewed as an average, extreme scores cancel each other out.

On average, then, these results show the university in 2017 as having a moderate adherence to CDIO standards, hovering just below an average of 3.

TOWARDS MORE ADOPTION OF THE CDIO FRAMEWORK

Over the last two years, since joining the CDIO Initiative, many faculty members in HIU have undertaken efforts to improve curriculum design, learning outcomes, and faculty skills, while attending to stakeholder needs, through the application of CDIO standards. As noted, while Information Media tends to fit the CDIO framework more effectively than other departments because of its employment of project-based learning, active learning, and a revised curriculum, other departments have been targeting their own weaker points in an effort to improve learning outcomes. These efforts are depicted in Figure 3.

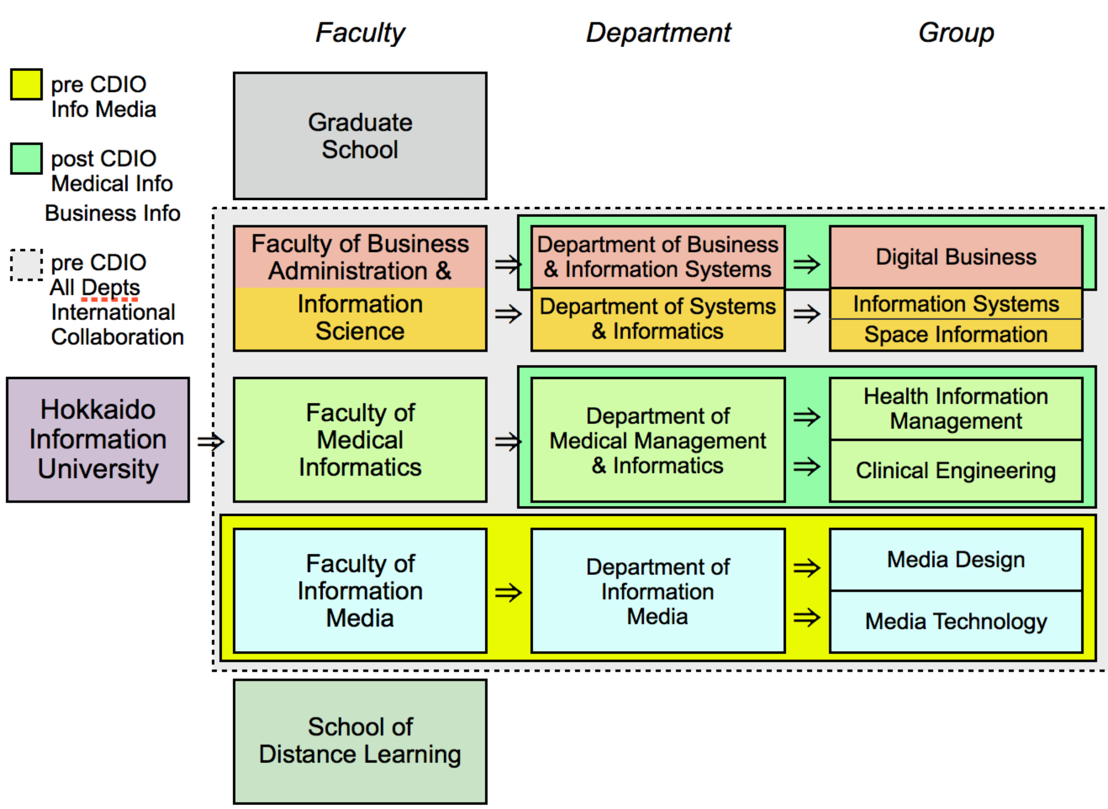

FIGURE 3: Application status of CDIO standards to programmes, by faculty, department, and group, before (yellow) and after (green) joining the CDIO Initiative.

As we mentioned above, the Department of Information Media was already somewhat aligned with CDIO Standards before HIU's acceptance into the Initiative in 2018. This is indicated by yellow (pre CDIO Info Media) in Figure 3. The areas in green depict more recent, post-2018 efforts by both the Clinical Engineering group in the Department of Medical informatics, and the Digital Business group, in the Department of Business & Information Systems, to incorporate the CDIO framework into its existing programmes (post CDIO Medical Info, Business Info).

The larger grey (broken-lined) rectangle signifies an international student collaborative exchange workshop which already existed before the CDIO initiative, and was not originally designed with reference to CDIO standards. Except for post-graduate studies (Graduate School) and the distance-learning program (School of Distance Learning), it can be seen that CDIO standards now apply to most of HIU's curriculum.

A brief discussion of some of the programmes within the curriculum follows.

CDIO APPLICATION: FOUR CASES

The Application of CDIO Standards to Clinical Engineering Education

Shimizu et al. (2018) discusses the task of clinical engineers as the operation, monitoring and maintenance of medical equipment in hospitals. Shimizu, a tenured faculty member in the Department of Medical Management & Informatics, discusses the importance of practical training rooms and medical simulators in providing the necessary skills to perform tasks required of medical engineers working in Japan. In particular, Shimizu focuses on Standard 2 - Learning Outcomes - what Crawley et al. (2014) refer to as setting "specific, detailed learning outcomes for personal and interpersonal skills, . . . (encouraging) product, process and system building skills, . . . (and ensuring) disciplinary knowledge, consistent with program goals." There is also a clear focus on the importance of the Integrated Curriculum (Standard 3), where off-campus clinical practice in a controlled environment at a hospital is undertaken after on-campus programmes, leading to a more effective education. This also ties into Standard 4 (introductory courses – as reworded by Malmqvist et al., 2016). Standard 6, the provision of an Engineering Workspace, is evidenced in the clinical engineering practice room at HIU, which simulates an actual hospital environment, and is essential in helping students develop the appropriate operating skills. These facilities also allow active learning (Standard 8) through teamwork and a heavy emphasis on the practical operation of simulators and related devices.

A Practical Application of Business Systems in enPiT2

Myojin et al. (2018) discuss the application of the CDIO framework to enPiT2. enPiT2 (Education Network for Practical Information Technologies) is a nationwide cooperative effort between multiple universities and industries, under the auspices of the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT). Its goal is to develop human resources who can maximize information technology in practical contexts, with specific respect to four themes; big data, security, embedded systems, and business system design.

Myojin is a tenured professor in the Department of Business & Information Systems. Much of what is covered in Myojin et al. (2018) centres on the efficacy of using active learning techniques (Standard 8) to promote student learning, and addressing challenges through a task-based learning approach, or a design implement experience (Standard 5). Looking at the business system contextually -- as being conceived, designed, implemented and operated -- are the essence of Standard 1.

Boosting Foreign-Language Communication Confidence Through a Short-term ICT-based International Workshop

Rian et al. (2019) and Anada et al. (2018) refer to a short-term ICT-based international exchange programme between HIU and RMUTT. The main part of the programme consists of two 8-day workshops, held at each university. Throughout the workshops, students work in small groups to produce web sites, short films and computer programs, all in English. There are 4 stages to the programme; selection, competition, collaboration, and sharing.

The programme involves conceiving, designing, implementing, and operating ICT-based projects, primarily in English, which is a foreign language to both Japanese and Thai students. Not only does the programme focus on design implement experiences (Standard 5) through a collaborative teamwork approach using active learning strategies (Standard 8), it also relies upon learning outcomes (Standard 2) and integrates personal skills with disciplinary knowledge (Standard 7). The programme also pays attention to the syllabus, with students communicating and presenting in non-native languages (CDIO Syllabus 3.2 & 3.3) and completing pre-programmed design seminars (CDIO Syllabus 4.3.4). It also references the proposed CDIO Standard of Internationalisation and Mobility (Campbell & Beck, 2010).

Availability of CDIO as a Driver of Creating Shared Value

Fukuzawa (in press), a tenured faculty member of the Department of Business and Information Systems, examined whether the CDIO framework could be successfully applied to teaching the business concept of Creating Shared Value (CSV). Students were assigned a task, and in collaboration with a company, completed a complex design and creation project. Based on results obtained from the class, which was conducted as a project-based learning (PBL) project (Standard 5), Fukuzawa noted that students working in conjunction with companies (CDIO Syllabus 4.2) in a workspace appropriate to their needs (Standard 6), we're able to create, design and implement a business system (Standard 1). It was also noted, however, that the learning assessment (Standard 11) was more difficult than expected, making an objective programme evaluation (Standard 12) hard to implement. The conclusion was that a more rigorous application of Standards 11 and 12 may yield better results.

EVIDENCE OF IMPROVED CURRICULUM DESIGN

The four cases outlined above show that most of the CDIO standards and some of the syllabus have been considered concerning improving curriculum design. This is summarized in Table 1.

As Table 1 shows, most CDIO Standards were referred to in designing the above-mentioned programmes or projects. While the table lists only the Departments of Medical Management & Informatics, and Business & Information Systems, some other faculty members were also involved in the programmes discussed by Rian and Myojin, making them more interdisciplinary than the table may imply. However, it should also be noted that the Department of Systems & Informatics had the lowest self-evaluation by CDIO standards, indicating that a more proactive approach would be beneficial. Conversely, despite having had the highest initial self-evaluation in 2017, the Department of Information Media is conspicuously absent. This does not mean that Information Media did nothing; rather that the authors are not aware of new programmes designed using CDIO standards. It should also be noted that the proposed optional CDIO Standard 13 (Campbell & Beck, 2010) has been included. Further, while both Fukuzawa and Rian noted the relationship of their programmes to the CDIO syllabus, the main focus of this paper is to show how curriculum design has improved by paying closer attention to CDIO standards and the accompanying rubric.

TABLE 1: Standard focused on, in relation to faculty member, department(s), and initial self-evaluation score. MMI = Dept of Medical Management & Informatics, BIS = Dept of Business & Information Systems. Information Media Department and Systems & Informatics Department not directly involved in the programmes. *Standards 4, 5 and 6 are reworded according to Malmqvist's application of CDIO standards to non-engineering courses (2016). Self-Evaln refers to the Self-Evaluation by CDIO standards conducted in 2017 before joining the CDIO initiative. Optional Standard 13 has been proposed by Campbell & Beck (2010).

Std #	Standard	Faculty Member	Dept	Self-Evaln
1	The Context	Fukuzawa	MMI	1
2	Learning outcomes	Shimizu, Rian	MMI, BIS	2, 2
3	Integrated Curriculum	Shimizu	MMI	3
4	Introductory course*	Shimizu	MMI	3
5	Professional practice experiences*	Myojin, Rian, Fukuzawa	BIS	2
6	Workspaces for professional practices*	Shimizu, Fukuzawa	MMI, BIS	2, 3
7	Integrated learning experiences	Rian	BIS	3
8	Active learning	Shimizu, Myojin, Rian	MMI, BIS	3
9	Enhancement of faculty competence	0		2, 3
10	Enhancement of faculty teaching competence	Shimizu, Fukuzawa, Rian	MMI, BIS	5
11	Learning assessment	Fukuzawa	BIS	1
12	Programme evaluation	Fukuzawa	BIS	1
Opt 13	Internationalisation and Mobility	Rian	BIS	N/A

In December 2019, departments were again asked to perform a self-evaluation using the CDIO rubric. This was conducted 2 years after the initial self-evaluation, and departments were asked not to refer to the earlier self-evaluation. The results can be seen in Figure 4.

The 2019 results for both the Departments of Medical Management & Information, and Business & Information Systems, are more conspicuous here (Figure 4) than they were in 2017 (Figure 3). The Department of Systems & Informatics self-evaluation remains, meanwhile, virtually the same as in 2017.

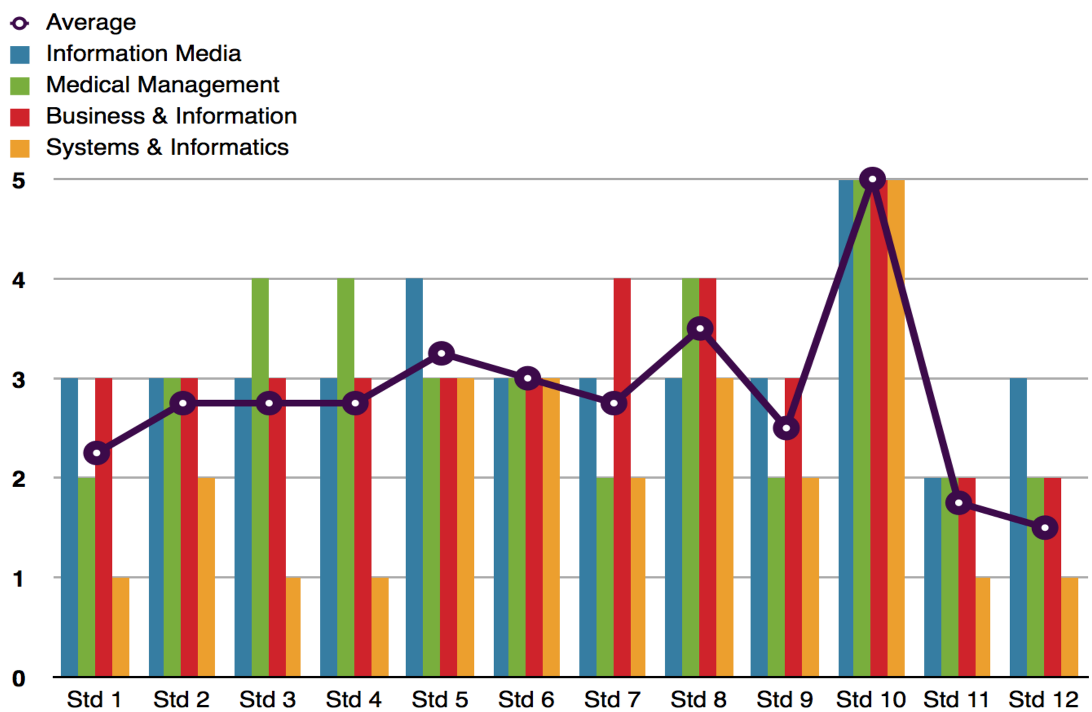

FIGURE 4: Self-evaluation by CDIO Standards, showing average rubric score, December 2019

As with the 2017 self-evaluation (Figure 3), the combined departmental average (Figure 4) is shown as a line graph. Compared with the earlier graphs (Figure 1 and Figure 2), it may be difficult to see any changes. It is not the authors' intention to compare departments in terms of CDIO adoption progress. Rather, the intention is to show that the university as a whole is progressing, and that some departments are progressing more quickly than others. A visualization of the progress might become more evident if the two line-graphs representing self-evaluations before and after CDIO adoption are compared (Figure 5).

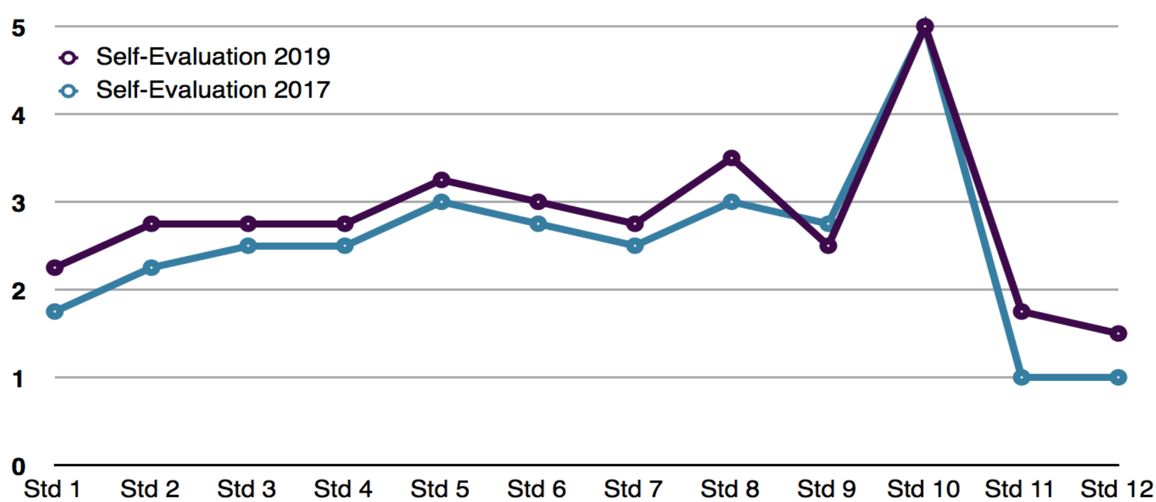

FIGURE 5: Comparison of self-assessment using CDIO assessment rubric; 2017 - 2019

A comparison between the two self-evaluations, taken two years apart, does not show as big a change as might have been expected. Standard 10 (Enhancement of Faculty Teaching Competence) remained the same. This may be due in part to a robust, ongoing Faculty Development programme that has resulted in faculty confidence in terms of relevant knowledge and skills. It may seem unusual that Faculty Teaching Competence (Standard 10) has remained at the top, while the Enhancement of Faculty Competence (Standard 9) was scored lower. The data showed that Systems & Informatics rated themselves lower than before. This may be because of an increased awareness of how to self-assess accurately, or perhaps the department may have felt that there were obstacles such as personal, interpersonal, or system-building skills problems. In either case, the evaluation itself is not at the bottom level, but it should be addressed. Other gradual increases may have resulted from other departments, especially Medical Management & Information, and Business & Information Systems, feeling more confident in their curriculum design procedure. Change has been gradual, as noted by the similarity in shape of the two lines in Figure 5.

OVERALL PROGRESS

If the progress of HIU in terms of adopting the CDIO initiative is to be analysed based on self-evaluations, these results suggest that the university is moving – at least, incrementally – towards better curriculum design. More programmes and projects are being designed with conscious reference to CDIO Standards, more attention is being paid to stakeholders in the education process, and a general interest in improving the relevance and quality of education has been increasing. The number of faculty taking part in CDIO events – such as workshops, regional meetings and annual meetings – is rising, as is the number of students taking part in the CDIO Academy. There has also been an increase in integrated learning experiences and design-implement experiences. Additionally, the curriculum demonstrates better integration than it did previously, with some cross-departmental subjects having been approved. Learning assessment and programme evaluation are still areas that need improvement, and progress is expected in these areas by continued application of the appropriate standards.

LIMITATIONS

The authors were interested in trying to objectively evaluate how well HIU, as a non-engineering university, has been adopting the CDIO framework. Specifically, we looked at an average change in self-evaluation responses in terms of adherence to CDIO standards in designing and realizing projects, programmes and the curriculum. Case-study reports on programmes designed around CDIO standards, such as the four outlined in this paper, provide a good way to evaluate change. Despite reference to the CDIO Syllabus by both Rian et al. (2019) and Fukuzawa (in press) in their programmes, it might be viewed as a statement of goals for engineering education. The main focus of this paper was on the application of CDIO Standards to non-engineering programs. Developing a sustained awareness among faculty members of CDIO concerning the design and structure of department curricula, and how that awareness can help improve educational outcomes, was and remains an objective.

The conclusion that HIU appears to be slowly but soundly adopting the CDIO initiative is based on self-evaluations conducted over two years, and evidence of application of the CDIO standards in recent programmes offered by several departments. The authors plan to conduct another self-evaluation based on the implementation of newer programmes designed around CDIO Standards in another two years.

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STRENGTHENING CDIO IN B.ENG. FINAL PROJECTS WITH AN INDUSTRY ROADMAP

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ABSTRACT

The increasing demands from industry present students undertaking their internships and final projects with a correspondingly steepening learning curve. Upon completion of internships and final projects, when the student may leave the company, the true potential value of the activities is often not fully realized due to the limited exchange of information between the company, the university and the student. This paper presents a roadmap for improving knowledge dissemination and value creation for both university and industry along with developing the engineering competencies of the student. Regular evaluations of the design-build experiences with the students, industry and academic supervisors (CDIO Standard 5) are essential elements in the process along with the revision of outcomes according to industry stakeholders' needs (CDIO Standard 2). The process establishes a continuous flow of students undertaking internships and subsequent final projects. An overlap of students, i.e. an intern along with a final project student, combined with strategic meetings ensures knowledge transfer and continued value creation. Furthermore, upon completion of the final project, the student is encouraged to propose a technical profile status report for development efforts for the coming years for the company, including the most important technical elements to support this. This proposal is also used as reference material for the subsequent internship and/or final project. The roadmap has been successfully applied for several semesters within a company producing polymer products for the medical industry and is further detailed in the paper. Students who have undertaken their industrial placement and B.Eng. final project following the roadmap have been required to communicate their findings and conclusions to their peers and supervisors to a greater extent than previously which has strengthened the inherently integrated learning experience (Standard 7).

KEYWORDS

University-industry collaboration, R&D learning environment, B.Eng. final projects, internship, Standards 2, 5, 7, 9

INTRODUCTION

The Centre for Bachelor of Engineering Studies at the Technical University of Denmark (DTU Diplom) has implemented the CDIO framework and standards in all B.Eng. programs offered since 2008. Close collaboration with industry has always been an essential element in providing the design-implement experiences (Standard 5) and the integrated learning experiences (Standard 7). The B.Eng. programs consist of seven semesters (3.5 years in total) and all students undertake a full-time 20-week industrial placement during their 5th or 6th semester. In their final semester, the students complete a 20 ECTS point B.Eng. project in industry. The primary learning outcome of the B.Eng. final project is defined as the practical application of technical knowledge concerning innovation, development and solution of technical problems including all the CDIO phases.

The benefits of close collaboration between academia and industry are well described and documented in the literature. These include enhancing the employability of graduates and faculty development (Tiewtoy, Krusong & Kuptasthien, 2019) and developing interpersonal skills (Säisä, Määttä, Roslöf, 2019). Establishing and maintaining close cooperation with companies is not without challenges as Male et al. (Male, King, Hargreaves 2016) describe. Companies can experience a lack of a clear, convenient and coordinated system of contact in universities. Time and other resources required for student supervision can also provide a barrier to collaboration. Having been the academic supervisor for many student final projects over many years, the authors have also observed other additional factors which also act as barriers and limit the desired outcomes of the industrial collaboration when considering industrial placement and final projects. These problems are described below and an industry roadmap is presented which has been demonstrated to be effective in addressing these problems as well as those as described by Male et al. (Male, King, Hargreaves 2016).

Challenges within Small or Medium-Sized Enterprises

In Denmark, 99.7% of public and private companies are classified as being small or medium-sized enterprises (SME) since they have fewer than 250 employees (European Commission, 2019). Danish companies' expenditure on research and development is 2.0% of the Gross Domestic Product (GDP) which is significantly higher than the European average of 1.4% (Statistics Denmark, 2020). This means that the B.Eng. students at the Technical University of Denmark typically undertake their industrial placement and B.Eng. final project in highly specialized small or medium-sized companies and work on highly specialized projects.

The specialized nature of companies and projects presents several challenges relating to the individual student and also any subsequent students who may follow and undertake their final project within the same company. The timescale for the project is 12 weeks. Therefore, when the student initially starts working on their final project within the company, they are faced with a very steep learning curve in terms of acquiring specialized knowledge of e.g. the technical domain, technology, equipment, standards and company procedures etc. This also requires a high initial investment of time and resources from the technical supervisor within the company. This investment by the company supervisor must be repeated for each subsequent student starting their final project within the company. This is both inefficient and expensive and may prevent companies from offering projects.

Upon completion of the final project at the end of the 12 weeks, it is not uncommon for the student to be offered employment within the company. This is a desirable outcome and proves the benefits of integrated learning experiences (Standard 7). What can also happen though, is that the student after handing in their final project report and attending their final examination, finds employment elsewhere. This can have several negative outcomes. Due to time and resource limitations, the company supervisor may not be fully briefed about all aspects of the project before the student leaves the company. This means that the company does not obtain the full potential value of the project and may need to use unnecessary resources to continue developing the project. If for some reason there are no students following immediately within the company, the continuation of certain research and development activities within the company may not be continued due to lack of resources. The lack of final project students within the company may also potentially result in a decrease in communication and collaboration between the company and academic supervisors.

The industry roadmap described below for strengthening CDIO in B.Eng. final projects has shown to solve these problems and enhance university-industry cooperation.

INDUSTRY ROADMAP FOR STRENGTHENING CDIO

The objective of the roadmap is to strengthen the implementation of the relevant CDIO standards concerning industrial placement and the final project in B.Eng. programs at the Centre for Bachelor of Engineering Studies at the Technical University of Denmark (DTU Diplom), in particular concerning validating learning outcomes (Standard 2), evaluating the design implement experiences (Standard 5) and the integration of learning experiences (Standard 7) with SMEs as stakeholders. The involvement and benefits of SMEs as stakeholders in CDIO projects has been described by Nordfalk et al. (Nordfalk, Bridgwood, Nyborg, 2018). A process for the longer-term involvement of SMEs in taught courses has also been described by Bridgwood et al. (Bridgwood, 2017).

The objective is achieved by establishing strategic collaboration with companies and defining research and development projects which require more resources than an individual final project or industrial placement. A flow of students undertaking industrial placement and subsequent final project is achieved and most critically, the exchange of knowledge acquired is ensured. The roadmap steps involved in the process are described below:

1. An initial discussion is undertaken between DTU Diplom and the relevant company where the company's requirements and areas of interest for research and development are identified and documented. This is done for both short- and long-term timeframes.
2. DTU Diplom publishes the available position(s) for industrial placement after an agreement with the company.
3. The company selects the appropriate candidate(s) who then undertakes and completes their industrial placement which is subsequently documented by a report.
4. Having completed their internship, the student then commences their B.Eng. final project within the company. The topic for the final project is established and agreed upon towards the end of the internship.
5. At the same time as the student commences their final project, another student commences their internship within the company.
6. When the student completes their final project, they are required to submit a technical profile status document along with the compulsory final project report. The technical profile status document is described below.
7. The above steps are repeated such that at any one point in time, a student is undertaking an internship along with a student undertaking their final project. This overlap is one of the essential elements in ensuring that the transfer of knowledge is maximized. This is illustrated in Figure 1.

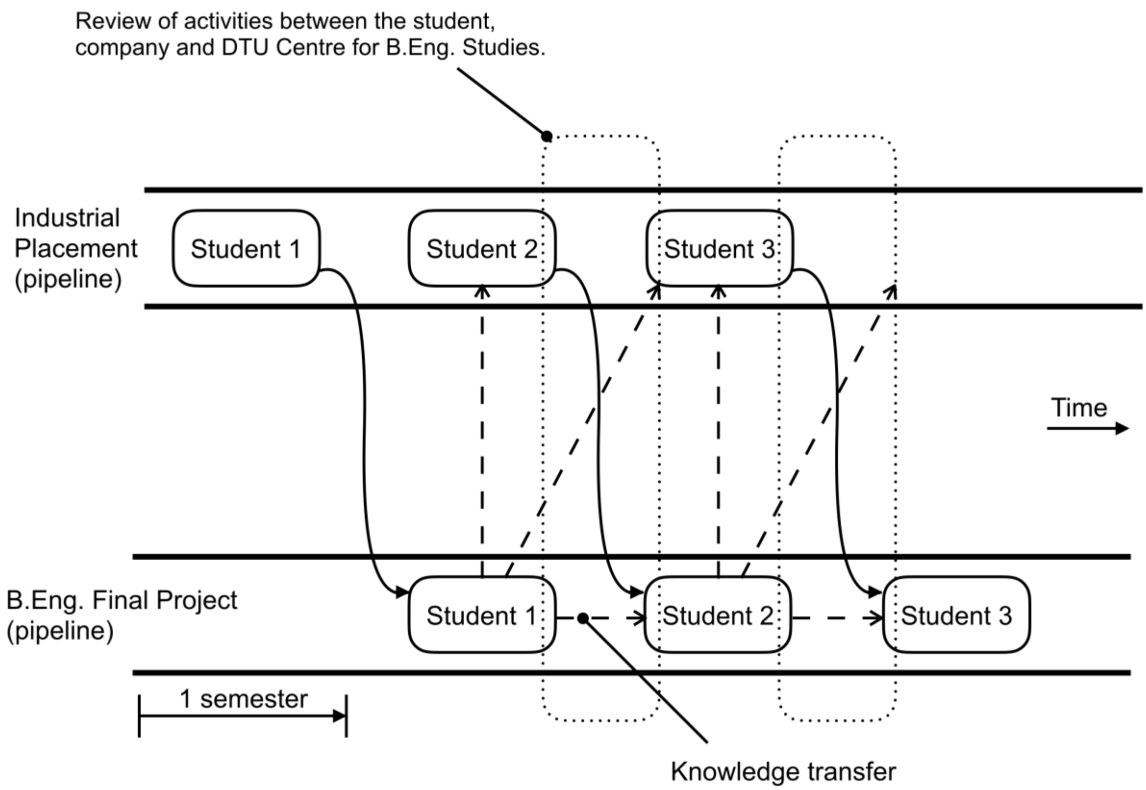

Figure 1. Flow and interaction of students within a company

Figure 1. illustrates the continuous flow and interaction of students within a company, represented by two pipelines. The industrial placement pipeline shows how a student e.g. Student 1, at the end of their 20-week internship, is followed by another student e.g. Student 2 who will eventually be followed by another student e.g. Student 3 and so on. At the end of their internship, the student will then progress to the B.Eng. final project pipeline and be part of the continuous flow of students subsequently undertaking their final project. In Figure 1, the dashed lines emanating from each student in the final project pipeline represent communication and knowledge transfer between students at various levels and stages. In Figure 1 above, consider e.g. Student 1 in the B.Eng. final project pipeline:

- Having completed their internship and now undertaking their final project, Student 1 can provide valuable knowledge and advice for Student 2 who is undertaking their internship.
- Upon completion of their final project, Student 1 can provide valuable knowledge and advice for Student 2 who is about to commence their final project and also to Student 3 who is about to commence their internship.

At the end of a B.Eng. final project period, a status review meeting is held between the company, DTU Diplom and the current and prospective students in the industrial placement and B.Eng. final project pipelines. The purpose of the meeting is to undertake a retrospective review of the research and development activities completed and to plan future short- and long-term activities. An input to the review is the technical profile status (TPS) document which the student generates in cooperation with the company and DTU Diplom, in addition to the student writing their final project report. The TPS document includes short- and medium-term recommendations for the following B.Eng. final project period along with literature, software and equipment references. Furthermore, the TPS also contains checkpoints for ensuring that the DTU Diplom information channels to the students, announcing the internships together with the technical contents of these are updated in agreement with the decisions made between the student, the company and DTU Diplom at the review meeting. In Figure 1 above, the status review is illustrated by the dotted rectangle bridging the two pipelines. This communication ensures that the knowledge sharing between the company, DTU Diplom and the students is maximized whilst also strengthening the students' interpersonal and operational skills. Furthermore, it is recommended to carry out the TPS review at the same meeting between the student, the company and DTU Diplom, where the assessment of the B.Eng. final project is carried out, thus avoiding spending additional overhead time in the final project supervision process.

RESULTS

The industry roadmap described has been successfully implemented since 2018 in a continuing cooperation with Dansac A/S (Dansac 2020), a leading manufacturer of stoma products. A series of industrial placements and B.Eng. final products have been undertaken and completed in collaboration with Dansac's Business Improvement Division. The students' research and development activities have primarily been focused on manufacturing process characterization and quality control and have been very varied. Projects have included, for example, measuring and analysing the cooling profiles of polymer products in a manufacturing line and utilizing a 3D scanner to access the criticality of component dimensions in composite structures. The varying short- and long-term areas of interest for investigation have had the added benefit that the students are working on multidisciplinary projects with the students themselves coming from a variety of B.Eng. degree programs. The programs have included B.Eng. Healthcare Technology, B.Eng. IT Electronics, B. Eng. Electronics and B.Eng. Mechanical Engineering.

Continuity is a fundamental aspect of the industry roadmap and this continuity between the company and the same university faculty members acting as the academic point of contact and supervisor has also contributed to the enhancement of faculty competence (Standard 9) in the setting of Dansac A/S.

CONCLUSIONS AND FINAL REMARKS

An industry roadmap for strengthening CDIO in B.Eng. final projects has been presented. The results of having implemented the roadmap since 2018 have demonstrated an increased level of collaboration and communication between the university and industry. As part of the roadmap, regular biannual reviews held between the university, company and students enable the program learning outcomes to be revised based on changes in the stakeholder's, i.e. the company's needs (Standard 2). Similarly, the meetings also provide a forum for the evaluation of the design-implement experiences of the B.Eng. final projects
based on feedback from the students, academic supervisor and company supervisor (Standard 5). The students undertaking their industrial placement and B.Eng. final project are required to convey their findings and conclusions to their peers and supervisors to a greater extent than previously which strengthens the inherently integrated learning experience (Standard 7).

Adoption of the roadmap does not involve any contractually binding obligations for the company involved, the agreements are based upon informal declarations. The long-term cooperation is often driven by enthusiastic individuals within the company and is therefore potentially vulnerable to staff turnover. Similarly, undertaking an industrial placement and B.Eng. final project in the same company is not required by the academic regulations and a student may choose to undertake their B.Eng. final project in a different company.

The longer-term collaboration concerning industrial placement and B.Eng. final projects has reinforced the implementation of CDIO standards and provided additional benefits for the companies involved. DTU Diplom is currently actively engaged in establishing cooperation with additional companies for them to adopt the roadmap.

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DESIGN THINKING COURSE IMPLEMENTATION IN CDIO BASED UNDERGRADUATE PROGRAMMES

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ABSTRACT

Thiagarajar College of Engineering (TCE), Madurai, India has adapted CDIO curriculum for all undergraduate Engineering programmes in 2018 to address the increasing gap between scientific and practical engineering demand and to meet the global requirements of professional Engineer. In alignment with CDIO syllabus goals and mission of the institute, new courses, namely Engineering Exploration, Lateral Thinking, Design Thinking, Project Management, System Thinking, Engineering Design Project, Capstone Project and major project were introduced in the CDIO curriculum. The objectives of these courses are to improve creativity, critical thinking, collaboration and communication among the millennial learners. The course on 'Design Thinking' offered at third semester aims to provide a conceive-design experience. The course provides an experiential learning to understand the requirements of users, to challenge assumptions, to redefine problems, to create innovative design solutions, to prototype and to test. In this paper, we present the pedagogical framework, evaluation and grading methods developed for the 'Design Thinking' course. The evaluation was carried out based on design quality and the demonstration of the prototype considering both individual cognitive development and collective team effort. From the formal course exit survey and informal interviews with the students, significant students' engagement was observed in the course through teamwork. Students have experienced design-build-test process with a customized design thinking approach through periodical project review and poster presentations in oral and written forms. Performance analysis on course implementation has confirmed significant improvement in technical, personal and interpersonal skills of learners. Inclusion of community projects in project-based learning served as an efficient pedagogical method to promote students' engagement in self-learning.

KEYWORDS

Design Thinking, CDIO Curriculum, Critical Thinking, Collaboration, Communication, Standards 1, 2, 4, 5, 7, 8, 9, 10, 11

INTRODUCTION

The major objective of any engineering program is to produce graduating engineers with ability to conceive-design-implement-operate complex value-added engineering systems in a modern team-based environment (Crawley, 2001). Graduating Engineers should be able to appreciate the process of engineering and contribute to the development of engineering products and systems for the betterment of humanity. However, the recent report on the National Employability Skills Report (Aspiringminds, 2019) reveals that 80% of engineers in India are not employable for any job in the knowledge economy. The employability trends in India have shown no significant change over the past nine years. Annual reviews of Internal Quality Assurance Cell in our institute have revealed that, in the past two decades, 90% of our graduates have been offered placement only in software industries. The percentage of graduates getting employment in core companies is low. Graduates are not able to meet the stringent requirements of core engineering industries such as practical skills and system thinking skills. Quality of the curriculum has a significant impact on employability. Though engineering in an applied discipline, the increasing gap between engineering education and engineering practice has ended up in making engineering education more theoretical. Learners are not sufficiently exposed to design implement experiences during the period of graduation.

As only a few faculty members have industrial experience, adopting industrial practices was restricted to a few academic courses and projects. Though we have been following outcome-based education framework, practical skills, design thinking skills, system thinking skills, personal and interpersonal skills have not been much emphasized in the curriculum. Further, many of the graduate's who have been placed in software industries also want to switch over to core engineering jobs. They come back to the college seeking support for postgraduate studies in their respective disciplines in higher learning institutions. In summary, the challenges namely Poor employability rate in core companies, Insufficient exposure to design implement experiences during graduation, Lack of faculty competence in design and product building skills and Minimal emphasis on personal and interpersonal skills in the curriculum have enforced us to adopt CDIO curriculum framework to bring in systemic changes in the curriculum.

In the earlier curriculum of TCE, 'Engineering Design' and Capstone Courses were offered in fourth and seventh semesters respectively to promote design thinking among the undergraduate students. Only a few faculty members who handled these courses had exposure on design thinking and hence the effectiveness of the courses was not up to the expected levels. Also, identification of real-world complex engineering problems for all the students in the class was difficult. On the other side, learners gave promising and positive feedback that these courses have provided them with a platform to innovate and try something new as an engineer. Hence, a new series of courses with appropriate refinements which includes Engineering Exploration, Lateral Thinking, Design Thinking, Project Management and System Thinking have been introduced in TCE CDIO curriculum since 2018. This article reports an experimental study on the impact analysis of the Design Thinking course offered at TCE in promoting creativity, critical thinking, collaboration and communication. The impact of using community-based projects for Design Thinking for Problem based Learning on student engagement and self-learning is presented. The impact of training programs in enriching faculty competence related to design thinking and product building skills has also been analyzed.

The rest of the paper is organized as follows: Section 2 explores the various pedagogical approaches for design thinking courses reported in the literature. The research questions formulated for the present experimental study are presented in Section 3. Section 4 describes the course structure, content delivery methods and assessment plan adopted for design thinking. Section 5 presents the impact of the course in achieving the desired learning outcomes. Summary of the research findings and the scope for refinements are presented in Section 6.

LITERATURE STUDY

Literature study on the various pedagogical approaches for Design Thinking course practised at various institutions has been conducted. A human-centred design thinking approach has been adapted to a design course at MIT D-Lab (Ranger, 2018). The course aimed at creating prosthetic and assistive devices for human support. The team comprised of learners with diverse background. Problem identification has been done in collaboration with international stakeholders and industry partners who supported with interactive lectures and workshops. The collaborative effort has resulted in long term benefits for projects and has created new career development opportunities. An exploratory analysis of the various dimensions of design thinking has been conducted by Dym et al. (2005). The study confirms that the most favoured pedagogical model for teaching design thinking is Project-Based Learning (PBL). Various sources of data on the assessment of learning skills confirm the success of the PBL approach. The possibility of extending Design Thinking to STEM Education has been investigated by Li et al, (2019). It could be inferred from the reported results that the design thinking approach has resulted in improved creativity and innovation in integrated STEM Education. The impact of design thinking pedagogy on student development specifically for Electrical, Computer and Software Engineering (ECS) students was investigated by Sarah (2019). The impact of the Design Thinking course in shaping the perceptions of what it means to identify as an ECS engineer has also been analyzed. The initial exploratory investigation of design and design thinking in higher education business programs were reported by Matthews et al. (2017). The article also guides potential directions for management education programs. Design thinking can also be extended to organizations in all sectors of the economy. Dunne (2018) conducted a qualitative study which explores the goals of an organization in adopting design thinking, challenges faced and actions taken to address the challenges. It has been reported that legitimacy, cultural resistance, and leadership turnover can compromise the work of design thinking programs.

It could be inferred from the literature that, an appropriate pedagogy for design thinking customized to the learning styles and learning environment results in significant improvement of technical, personal and interpersonal skills of the learners. Learners should not be made to memorize facts and repeat them on demand. They must be provided with opportunities to interact with content, think critically and generate new information. The course on Design Thinking aims to open up the opportunities for collaboration, communication, critical thinking and creativity for the students of TCE.

RESEARCH QUESTIONS

The motivation for the experimental study is supported by the following two Research Questions (RQ):

RQ1: What is the impact of the course on ‘Design Thinking in promoting the 21st century skills namely Creativity, Critical thinking, Collaboration and Communication?

RQ2: Does the inclusion of community-based projects under Project-Based Learning in ‘Design Thinking’ course promote student engagement and self-learning?

DESIGN THINKING COURSE AT TCE

In the view of students' engagement in solving challenging and real-world problems, the Engineering Design course was introduced in our earlier curriculum. With the use of design principles, students developed a prototype addressing a specified theme area like smart city. It was observed that students were enthusiastic and interested in developing innovative ideas. Besides, feedback was also obtained from the course handling faculty members and they expressed their need for training in handling project-based learning courses. As part of institutional capacity building, twenty faculty members have undergone a training programme on the Design Thinking course with the human-centred design approach offered by Purdue University in collaboration with Indo-Universal Collaboration for Engineering Education (IUCEE). Subsequently, our institute has been recognized as a member of the IUCEE-EPICS (IUCEE-Engineering Projects in Community Services) consortium. To improve the students' involvement in community-based projects and addressing technical, personal and interpersonal skills, the previous Engineering Design course was modified as the Design Thinking course with three credits. This course is a customized version of the EPICS design process by adopting the first three of its phases namely problem identification, specification development and conceptual design phases.

Course Design

The expectations of the course are conceived as identification of a societal problem, problem formulation, specification development through the interactions with stakeholders, identification of multiple solutions, selection of best solution with defined measurable criteria, the use of the systematic approach in evolving product architecture using a functional decomposition and development of a conceptual prototype. With these requirements, the Course Outcomes (COs) were formulated for the students' engagement in managing community-based projects. The Course Outcomes (COs) of this course are listed in Table 1. To deliver the course effectively, fourteen faculty members were further trained in the Design Thinking course offered by the IUCEE-EPICS consortium to deliver and mentor the projects of this course. Besides, an industry-experts' led training programme on Product Design was also facilitated to disseminate the industrial practices and tools used in managing the projects.

Table 1. Course Outcomes of Design Thinking Course

CO Number	Course Outcome Statement
On the successful completion of the course, students will be able to	
CO1	Identify a specific social need to be addressed
CO2	Identify stakeholder's requirements for the societal project
CO3	Develop measurable criteria in which design concepts can be evaluated
CO4	Develop prototypes of multiple concepts using user's feedback
CO5	Select the best design solution among the potential solutions with its functional decomposition

Course Content

The content has been evolved from the defined course outcomes. The concept map of this course is shown in Figure 1. Table 2 depicts the relationship established with the TCE proficiency scale and CDIO syllabus version 2.0 (Crawley, 2001).

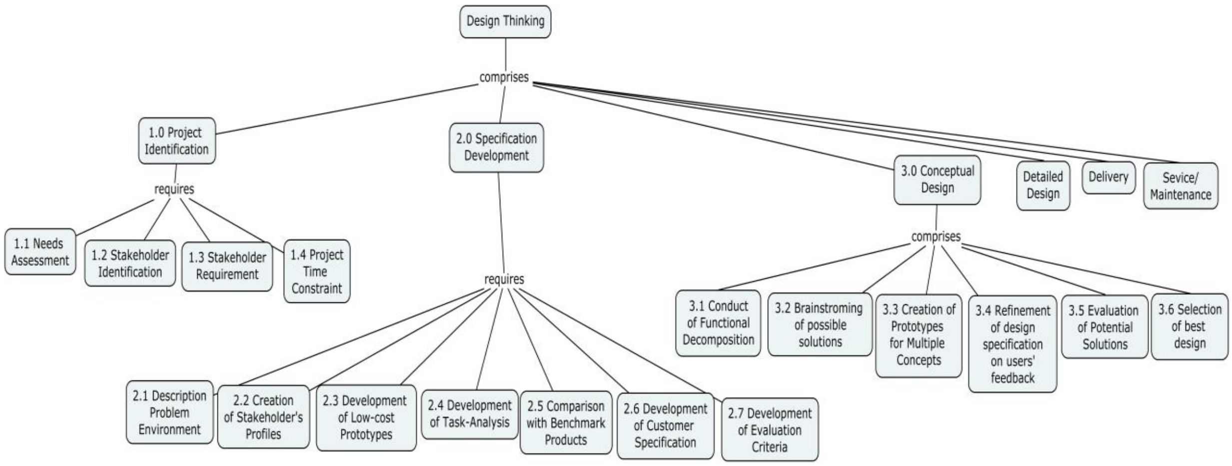

Figure 1. Concept Map of Design Thinking Course

Table 2. CO Mapping with TCE Proficiency scale and CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1.1, 3.1.2, 3.2.3, 3.2.6, 4.1.2
CO2	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1.2, 2.5.1, 2.5.2, 3.1.2, 3.2.3, 3.2.6, 4.1.2
CO3	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1.3, 3.1.2, 3.2.3, 3.2.6, 4.1.2, 4.3.1
CO4	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1.4, 3.1.2, 3.2.3, 3.2.6, 4.1.2, 4.4.1
CO5	TPS5	Evaluate	Organise	Adaptation	1.1, 1.2, 2.1.5, 3.1.2, 3.2.3, 3.2.6, 4.1.2, 4.4.1

Assessment Plan

The previous Engineering Design course was designed as a theory-cum-practical course. Based on the feedback received from course handling faculty members and students, the assessment plan of Design Thinking has been defined as a project-based course to enhance the design-build experience to the students. The detailed assessment plan is presented in Table 3.

Table 3. Detailed Assessment Plan

Phases	Deliverables	Marks	Course Outcomes
Continuous Assessment			
Review 1 – Problem Identification	Technical Report	10	CO1 and CO2
Review 2 – Specification Development	Technical Report	20	CO3
Review 3 -Conceptual Design	Technical Report	20	CO4 and CO5
End-Semester Examination			
Demonstration	Prototype	60	CO1, CO2, CO3, CO4 and CO5
Poster Presentation	Poster	40	

- Reports are to be submitted at each review. The report and presentation will be evaluated based on customized Rubrics for periodic reviews.
- Demonstration and Poster presentation will be evaluated by two faculty members nominated by their respective Head of the Department.

As per the assessment plan, rubrics are developed and implemented in reviewing the progress of students' design thinking projects. Reviews are conducted at the end of Project Identification, Specification Development and Conceptual Design Phases. The rubrics for three phases of evaluation are presented, in Table 4, Table 5 and Table 6 respectively. Further, adherence to the project plan and communication skills are also assessed during the review process.

Table 4. Assessment Rubric for Review-1 (Problem Identification Phase)

Descriptors	**Exemplary (4)**	**Proficient (3)**	**Partially proficient (2)**	**Incomplete (1)**
Need Assessment	Clearly stated the motivation and need of the project with appropriate evidences and data	Clearly stated the motivation and need of the project with enough evidences and data	Stated the motivation and need of the project with minimum evidences and data	Lack of clarity in the statements for the need of the project with no or inappropriate evidence and data
Identification of Stakeholders	All the stakeholders are identified with their roles and responsibilities.	All the stakeholders are identified and the roles and responsibilities are identified for a few stakeholders	All the stakeholders are identified but their roles and responsibilities are not defined.	Few Stakeholders are identified. Roles or responsibilities are not defined.
Definition of basic stakeholder requirements	Excellent and clear understanding of the scope of the problem and its objectives. Identifies and list constraints and able to correlate with the problem	Sufficiently states the scope of the problem and can identify and list the objectives. Identifies and list constraints but unable to correlate with the problem.	Able to identify the scope and objectives with discrepancies. Understands few constraints.	Unable to identify the scope and objectives. Little understanding of the problem constraints
Project Plan	Clearly stated stages of the project with the project charter and appropriate timelines.	Clearly stated stages of the project with appropriate timelines. Project charter is not presented.	Clearly stated stages of the project with inappropriate timelines. Project charter is not presented.	The stages are not identified with timelines.
Presentation Slides	Slides support the presentation, are easy to read and understand, keywords are used effectively.	Slides are easy to read and understand	Slides are easy to read and understand in most of the slides.	Slides are difficult to read and understand spelling/grammar errors evident.

Table 5. Assessment Rubric for Review-2 (Specification Development Phase)

Descriptors	**Exemplary (4)**	**Proficient (3)**	**Partially proficient (2)**	**Incomplete (1)**
Problem Environment and Stake-holders' profile	Clear specific details of problem environment and stakeholders' profiles with suitable evidences	Adequate details of problem environment and stakeholders' profile with supporting evidences	Adequate Details of problem environment and stakeholders' profile with minimum supporting evidences	Unclear on problem environment and inadequate stakeholder's profile with weak supporting evidences.
Mock-ups or prototypes	Presented low-cost mock-ups or prototypes with revisions based on customer feedback.	Presented low-cost mock-up or prototype with customer feedback but without any further revision.	Presented low-cost mock-up or prototype without any revision or customer feedback	Presented inappropriate mock-up or prototype without any revision or customer feedback
Customer Specifications and Evaluation Criteria	Clearly stated the final specifications and evaluation criteria with consensus from project partner. Presented and recorded the appropriate evidences for the revisions	Clearly stated the revised specifications and evaluation criteria with consensus from project partner. Presented the adequate evidences for the revisions	Clearly stated the specifications and evaluation criteria with minimal feedback from project partner. No evidences of revision of specification with consensus from project partner.	Not clearly stated the specifications and evaluation criteria and no feedback from project partner.
Adherence to Project Plan	Completely executed the individual's role and responsibilities in accordance with the code of conduct Clearly defined appropriate project timelines.	Partially executed the individual's role and responsibilities in accordance with the code of conduct Clearly defined project timelines.	Clearly stated the roles and responsibilities of team members in demand of the project Partially defined project timelines	Inappropriate roles and responsibilities of team members Inappropriate project timelines

Table 6. Assessment Rubric for Review-3 (Conceptual Design Phase)

Descriptors	**Exemplary (4)**	**Proficient (3)**	**Partially proficient (2)**	**Incomplete (1)**
Functional Decomposition	Identified all the functions of the proposed product and presented in a clear visual representation	Identified all the functions of the proposed product with adequate visual representation	Identified only few significant functions of the proposed product with inadequate visual representation	Few significant functions are not identified. No visual representation of functions
Alternate solutions and their evaluation	Identified potential alternate solutions and adopted a systematic procedure in evaluating the best solution	Identified potential alternate solutions and adopted a procedure in evaluating the best solution	Identified potential alternate solutions and not adopted any procedure in evaluating the best solution	Identified few alternate solutions and not adopted any procedure in evaluating the best solution
Prototype	Demonstrated a working prototype and its functions	Demonstrated a prototype/model with few of its functions	Presented a visual representation of product with few of its functions	Presented an inappropriate model/sketch of the product
Adherence to Project Plan	Completely executed the individual's role and responsibilities in accordance with the code of conduct Clearly defined appropriate project timelines.	Partially executed the individual's role and responsibilities in accordance with the code of conduct Clearly defined project timelines.	Clearly stated the roles and responsibilities of team members in demand of the project Partially defined project timelines	Inappropriate roles and responsibilities of team members Inappropriate project timelines
Communication Skill	Effectively and creatively delivers the information while staying on the topic and considering the audience, uses voice variations, seems confident and delightful ending on time.	Adequately delivers the information while staying on the topic, considers the audience, speaks clearly and ends on time	Delivers the information while staying on the topic, considers the audience, speaks somewhat clearly, trying to end on time	Demonstrates inconsistent command of the English language

Course Delivery Plan

Students were identified location-specific community problems and were mapped with one of UN Sustainable Development Goals (SDG). The students were instructed to follow the steps in the human-centric approach which is delineated in Figure 2. The course outcomes, assessment plan, assessment rubrics and course delivery plan were obtained approval in the academic council. The scheduled activities for each phase of design thinking are given below.

PROJECT IDENTIFICATION PHASE

- Team Formation and Roles Assigned
  - Roles such as Project Manager, Project Partner Liason, Project Archivist, Financial Officer, WebMaster
- Brainstorming/ Focus Group Discussion
  - Requirements - 5W-1H technique, Photos, Videos and Report prepared
- Code of Cooperation Discussion
- Stakeholders Interview Question and Survey Question Preparation
- Voice of Customer Report
- Requirements identified with priorities

PROJECT SPECIFICATION DEVELOPMENT PHASE

- Low – Cost – Model Preparation: Materials identification, Stakeholder Profile and Model Preparation Phase
- Low-cost model demo – video
- Opportunities identified to showcase the idea
  - All teams are presented their models in Intra department Association Event
- Received Feedback in the models and requirements from stakeholders, experts etc.

PROJECT CONCEPTUAL DESIGN PHASE

- Functional Decomposition
  - 10 important functions are identified in each team
- 5 possible ideas for each function
- Preparation of idea evaluation parameters
- Best Idea identification – Document submission
- Demonstration of working project/ product video submission

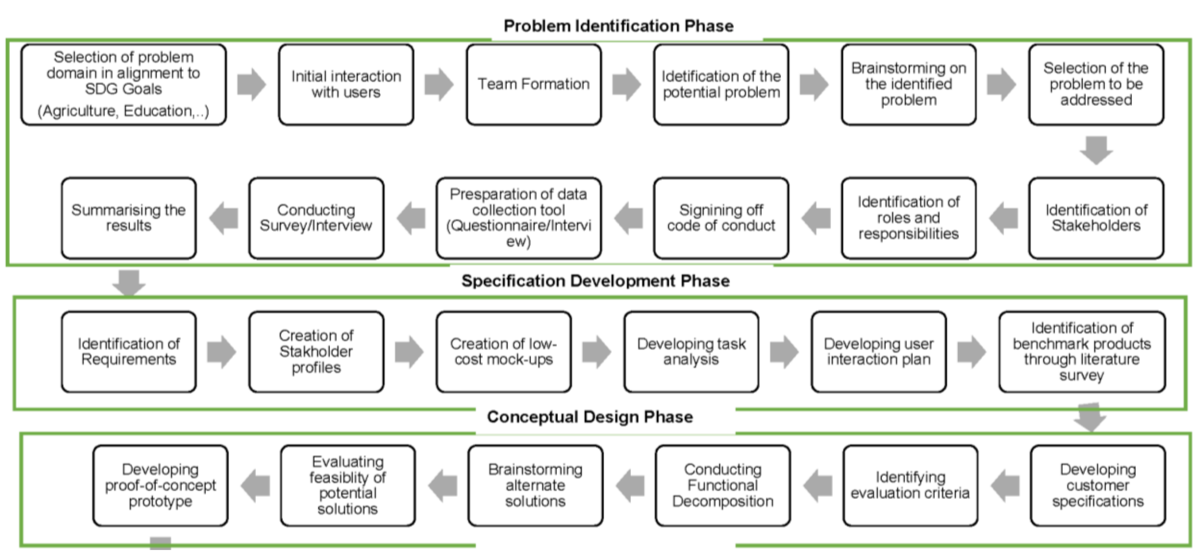

Figure 2. Steps involved three phases of Design Thinking course

IMPACT ANALYSIS

The Design Thinking course was first offered to 880 undergraduate students belong to civil, mechanical, electrical and electronics, electronics and communication, computer science and engineering, information technology and mechatronics programmes. A study was conducted to analyze the students' engagement in this course and in addressing community-based projects influences their perceptions on learning experiences and professional skills of 21st century learning skills (creativity, critical thinking, collaboration, and communication).

An institutional survey with a 4-point Likert scale has been conducted to determine the effectiveness of the course. Students' learning experiences in the Design Thinking process, team experience, professional communication and assessment were performance measures of this online survey. 530 (out of 880) responses were received The distribution of the responses according to the programmes is presented in Figure 3.

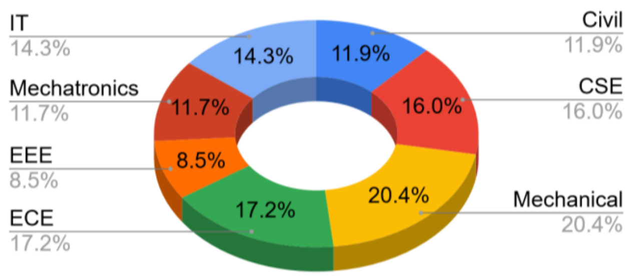

Figure 3. Distribution of students' responses in percentage

The students' responses on overall experience on the course, and opportunities in addressing creativity, critical thinking, collaboration and communication are presented in Figure 4 (a-e) respectively. Photographs taken during brainstorming sessions, exhibition of low-cost prototypes, project reviews are shown in Figure 5 (a-d). The performance measures are consolidated in Table 7.

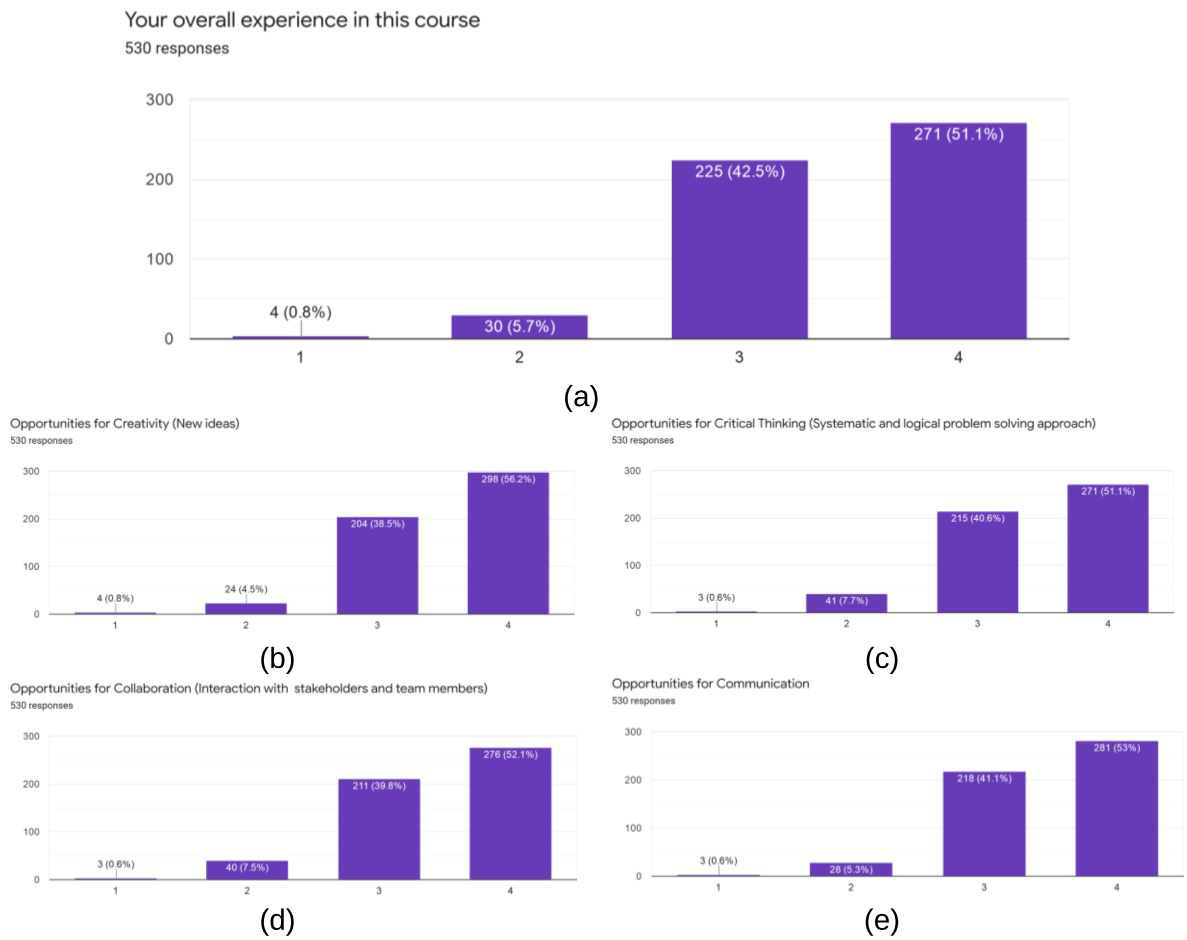

Figure 4. Students' Satisfaction Level on 21st century learning skills

(a) Brain-storming Session

(b) Low-cost prototype Preparation

(c) Inter-departmental open house

(d) Periodic Project Review

Figure 5. Sample Photographs of Students' Activities

Table 7. Students' Response on Institutional Survey
**Values are in percentage*

Description / Response Scale	4 (Excellent)	3	2	1 (Fair)
1.0 Learning Experience on Design Thinking Process				
1.1 Identification of Societal Problem	44.7	48.5	6.4	0.4
1.2 Formulation of the problem	39.1	51.9	9.1	0
1.3 Literature Review (Research Articles, Patents, Existing products, etc)	35.7	48.9	14	1.5
1.4 Identification of Stakeholders of your project	50.8	41.3	7.4	0.6
1.5 Identification of Stakeholders' specification	48.1	42.8	8.5	0.6
1.6 Specification Development process	39.4	50.8	9.4	0.4
1.7 Functional Decomposition	39.2	47.9	12.3	0.6
1.8 Prototype Development	47.4	44	8.3	0.4
2.0 Team Experience				
2.1 Roles and responsibilities assigned	48.9	39.8	9.6	1.7
2.2 Opportunities to contribute individually	49.8	39.4	7.9	2.8
2.3 Contribution of other members	46.6	35.8	14	3.6
3.0 Experience in professional communication				
3.1 Oral Presentation	48.1	42.3	8.5	1.1
3.2 Report writing experience	43.6	46	9.1	1.3
3.3 Poster Preparation and Presentation	56.4	35.8	6.6	1.1
3.4 Drawings/sketches in idea generation and communication	55.7	36.4	7.2	0.8
4.0 Assessment				
4.1 Guidance of Assessment rubrics in the execution of the project	41.9	46.8	9.6	1.7
4.2 Satisfaction level in assessment	42.5	46.8	9.1	1.7
4.3 Periodic Reviews - Continuous Assessment	47.2	42.8	8.7	1.3
4.4 Poster presentation - Terminal Examination	52.8	39.1	7.2	0.9
4.5 Confidence in the presentation in common forum like an open house, hackathon	52.6	40.2	6.4	0.8

CONCLUSION

A significant outcome of the design thinking course includes 164 conceptual prototypes of real-world location-specific community problems. Satisfaction index of the students is improved mainly because of experiential learning. Use of the rubrics for periodic reviews served as an effective instrument for assessing personal and interpersonal skills of the students. Opportunities provided for promoting 21st-century skills namely creativity, critical thinking, collaboration and communication have motivated the students to take up the prototypes to the next level of its implementation. Many of our students have extended their projects of design thinking and exhibited their implementations in a national level contest like Smart India Hackathon and IUCEE-EPICS Design contest and received good recognition and rewards. The training programs on Design Thinking have enriched the faculty competence in mentoring the students with a human-centred approach to solve real community problems. The outcome of this training resulted in faculty awards for their posters in Design Thinking training programme. The course coordinator has been rewarded with the IUCEE- Transformational award for the year 2019 under the category of Leadership in Community Project-Based

Learning (CPBL). Based on the feedback from faculty and students and as a part of continual improvement, few refinements in the pedagogy of Design Thinking course are in progress. Based on the experience gained in its initial attempt and the feedback from the faculty & students, the implementation process for managing an interdisciplinary team is under development.

LIST OF ABBREVIATIONS

Abbreviation	Expansion	Abbreviation	Expansion
CO	Course Outcome	PBL	Project-Based Learning
CPBL	Community Project-Based Learning	SDG	Sustainable Development Goals
ECS	Electrical, Computer and Software Engineering	STEM	Science Technology Engineering and Mathematics
EPICS	Engineering Projects in Community Services	TCE	Thiagarajar College of Engineering
IUCEE	Indo-Universal Collaboration for Engineering Education	TPS	TCE Proficiency Scale

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Baskar Subramanian holds a Doctoral Degree in the field of Hybrid Genetic Algorithms. He has carried out postdoctoral studies at Nanyang Technological University, Singapore in the area of Evolutionary Computation under BOYSCAST Fellowship, DST, India. He has completed three research projects in the area of Sensors and Evolutionary Computation. 16 students were awarded a Doctoral Degree under his supervision. He has completed the IUCEE Engineering Education Certification Programme with Distinction.

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CREATION AND USE OF LOW-COST LEARNING COMPONENTS

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ABSTRACT

This paper presents the creation of an e-learning ecosystem for the course Instruments and Measurements, taught in the Electronics Engineering undergraduate program at Pontificia Universidad Javeriana in Bogotá, Colombia. The ecosystem consisted in a set of virtual learning objects including 95 tutorial videos, 20 simulation scenarios, interactive class notes and assessment material, all available online. The created material received high acceptance from the students while showing great potential as combined tools to reinforce the learning process.

KEYWORDS

Virtual Learning Objects, E-learning, Video-tutorial, laboratory, Active learning, Standards 8, 9

INTRODUCTION

Since the adoption of the CDIO initiative in the Electronics Engineering program at the Pontificia Universidad Javeriana in Bogotá, Colombia, different implementations and innovations have been carried out to stimulate active learning in the students within the subjects that compose the curriculum. One of the courses that have been extensively subjected to a set of innovative strategies is Instruments and Measurements. This course is responsible for providing the students with the technical skills for operating electronic measurement equipment. Some of the topics taught during one semester are: apply measurement methods, techniques for presenting experimental results, analysis techniques to interpret experimental information, operation and use of instruments in the development of laboratory measurements and theoretical validation of knowledge acquired in previous courses about electrical circuits and signals. Since electronic design is a fundamental part of our program, working in the laboratory is a permanent activity and therefore the operation of equipment for the realization of measurements are skills and knowledge that our students must acquire and maintain thanks to the practice and the bibliographic material, which includes equipment manuals, class notes made by teachers, guided laboratory practices, and online self-assessment.

An extensive search was carried out throughout Internet to find potential tutorial videos available that deal with the operation and management of the laboratory equipment to offer the students complementary material to the topics seen in the theoretical part of the course. Unfortunately, the available material did not meet the expectations in terms of production quality in both image and sound, clarity and development of concepts, security, specificity, shallow depth, even including strong conceptual errors, and finally, language – Spanish in this case.

For this reason, a project to create video tutorials was proposed, and a first pilot was developed with a further assessment of the acceptance of the students. The positive opinion received from the pupils in this first stage, motivated a larger project dedicated to producing e-learning tools to complement and enhance the theory of the course. This paper presents the creation of an e-learning ecosystem consisting of a total of 95 tutorial videos, 20 simulation scenarios, and assessment material. As an additional strategy, the students were prompted to produce their video tutorials presenting the use of a specific equipment or conducting a particular experiment. In this manner, the students took the role of prosumers, i.e. producers of the content of which they are also users (Sarsa, 2014).

The paper is structured as follows: the first section shows previous work in VLOs. The following section details of implementation and operation of our VLOs, technical production of them, including some examples of final products. Then we present the results about student perception and use of the VLOs and finally, in the last section, we provide the conclusions and future work.

RELATED WORK

Virtual Learning Objects (VLO) emerged during the 90s decade, because of the need to share and reuse content in any area of knowledge (Colomé et al., 2012). VLOs is defined as "digital or non-digital" tools supported by technology (Wiley, 2000), that can be used, reused and referenced to facilitate the learning process, encouraging the student autonomy throughout self-learning, while at the same time shifts the role of the teacher to a "mentor, guide and evaluator" of the process (Montagud et al., 2013). VLOs help to develop and expand the landscape of active learning (CDIO Standard 8), including self-assessments and formative assessments with real-time feedback. The emergence of different technologies such as Internet, tablets and digital blackboards, have opened the door for a change in traditional models of teaching inside a classroom to a model based on self-learning using VLOs as new educational tools (Arango et al., 2014). In this new paradigm, it can be observed a convergence of didactic theories, methods, technologies and services intertwined to facilitate and enhance the learning process.

Most online learning environments available can be related to an "information warehouse", where users can browse and retrieve information from a repository without any learning support. VLOs can facilitate significative e-learning if they are oriented to construct learning ecosystems, where the participation of users is part of an instructional strategy in which not only the learning objects and digital repository are available to share and reuse, but also the system can keep learner profiles to achieve personalized learning experiences. In this case, the instructional paradigm shifts from instructor-centred to learner-centred (Lin & Kuo, 2005).

Several reports have shown that video becomes a highly effective educational tool (Allen and Smith, 2012; Kay, 2012; Stockwell et al., 2015). Arango, et al (2014) proposed a set of VLOs to teach Differential Calculus that includes two elements: a video-lesson where the contents are presented systematically and comprehensively, and a motivational program as a video-support material, where the authors claim that the learning occurs. This video-support is a set of interactive material that demonstrate the verbal speech to stimulate student participation during and after the viewing. It is important to remark that authors recognize the necessity of supplementary tools add to the audio-visual lessons to assure a significative learning process. Rodriguez and Romero (2019) go further in the creation of VLOs proposing a model where the students take the role of prosumers, producing video-lectures for their classmates as mean to report a research assignment of a particular topic in the course of History of the English Language. With this approach, the authors claim that students reach a higher level of autonomous learning since they know in advance that the objective of the course is to produce high-quality videos for their peers, in addition to the widely discussed advantages of peer instruction model (Mazur, 1997). Finally, in a more qualitative evaluation, the students manifested high satisfaction with the course after the participation in the video projects. Similar approach was attempted in this project, where the students generated video tutorials to be added to the course repository.

Another interesting approach of the use of VLOs is their use for teaching technical skills as operation of equipment in virtual scenarios. Lin and Kuo (2005) discussed a learning environment prototype called Best Virtual Worlds (BVW), where learners are immersed in a virtual world, where they can manipulate the VLOs while the learning scenario can be created instead of simple static information browsing. Similar concept was presented by Lazarou, et al. (2019) using VLOs for teaching technical skills as operation of equipment in virtual laboratories where objects can be experienced by the students in a realistic and user-friendly way, using virtual and augmented reality. Authors report that this kind of environment, allow the students to accelerate the learning and working process while simultaneously learn a large amount of information involving all their senses and react to it with “language, actions and body language”. Following this idea, a total of 20 oscilloscope simulation scenarios were developed, including control, manipulation and measurement of signal parameters.

IMPLEMENTATION AND OPERATION

As the intention was to have a set of VLO’s available to students, the first step was to create a visual identity to give a consistent image and format to all the material that was planned to be created. In addition to easily identifying the material, a visual identity gave a sense of belonging to the students. Figure 1 shows the banner and logo created to brand the tools developed for e-learning ecosystem.

Figure 1. Image of the visual identity of the VLO’s set. “Electronics Engineering. Instruments & Measurements”

All the material created incorporated the logo observed in Figure 1, including the videos, the simulation scenarios and the tests and written information such as the class notes and the laboratory guides. Figure 2 presents a screenshot of one of the class notes with the corresponding logo that identifies it.

Figure 2. Class notes with the visual identity of the VLO's. "Vertical Sensitivity"

The second stage consisted in the production of 95 video tutorials. A joint work was developed with an audiovisual team to plan the pieces, 60 of them between 2 and 5 minutes long, 26 between 5 and 10 minutes long, and 9 between 10 and 20 minutes long. The videos were produced with the help of a technical group specialized in audiovisual production and with the appearance of professors and laboratory technicians. All of the videos are available both in the digital learning space of the class, and in a YouTube channel, called "*Instrumentos Lab 101*". The tutorials cover different topics regarding the work in the laboratory such as safety standards, handling equipment, methodology for performing measurements in the laboratory, etc. The topics covered by the tutorials are distributed as follows: 10 videos on metrology, 36 on oscilloscopes, 40 on multimeters and 9 on welding. The main objective was to maintain the safety of the people who handled the equipment, since improper use could cause accidents such as electrical shock or fires. Likewise, guarantying the integrity of the equipment and reducing the probability of damage due to misuse. Finally, to reduce the number of working hours in the laboratory for students due to an incorrect measurement process as a result of a lack of knowledge of equipment management. As an additional strategy, students where encourage to produce their video tutorials. The videos are also available on a free access YouTube channel: "*Instrumentos Lab 101*". Although the videos were initially created for internal consumption, the channel has about 200 subscribers and the videos have reached a combined audience of more than 16,000 views. Figure 3 shows one frame of a single video, incorporating the visual identity.

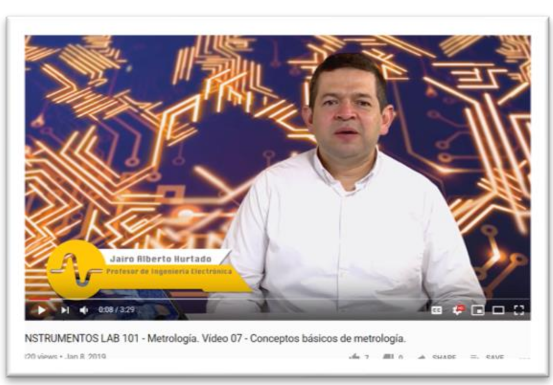

Figure 3. Image of a video tutorial on YouTube channel "*Instrumentos Lab 101*"

To complement the videos, 20 simulation scenarios were designed with an analogue oscilloscope, in which the students had to move the controls to answer the questions of each scenario as seen in Figure 4. Similarly to the videos, the simulation scenarios are available on a freely accessible web page. The rest of the information and the material created is placed on the learning management system belonging to the course, hosted in this case in the platform Blackboard. In addition to indicating if the answer of a particular problem has been answered correctly or not, the software issues a feedback that indicates if that a possible mistake could have been made if that is the case or in turn, it explains why the provided answer is indeed correct. Each session includes a set of videos regarding a topic, interactive class notes, exercises and the use of simulation scenarios. Once completed, students are assessed through a formative evaluation, so that they monitor their level of learning.

For the production of the videos, professional help was received provided by the centre of technical resources of visual audio production within the University, called the *Centro Ático*. The realization of the videos was staged at the "*Sala Ágil*" (Agile Room) within *Centro Ático*. This is a space created to make low-cost videos at an accelerated pace so that professors can create their content simply and efficiently without the need to cover advanced technologies, while at the same time, maintaining product quality.

The room was adapted as a small TV studio of approximately 20 m^2. This studio is equipped with a 21" IMac computer with an Intel Core i7 3.1 GHz processor and an NVIDIA GeForce GT 650M graphics card, a 512MB hard drive and a 2TB backup hard drive, 16 GB of Memory MHz DDR3. A second integrated 21" screen complements this system so that the teacher can observe in real-time the process what is being recorded as seen in Figure 5. Thus, in this small space, it is now possible to make audiovisual products almost in real-time with only the help of a technician who guides the capture process by operating the software and subsequently the final edition of the product made by placing banners, music and input and output messages.

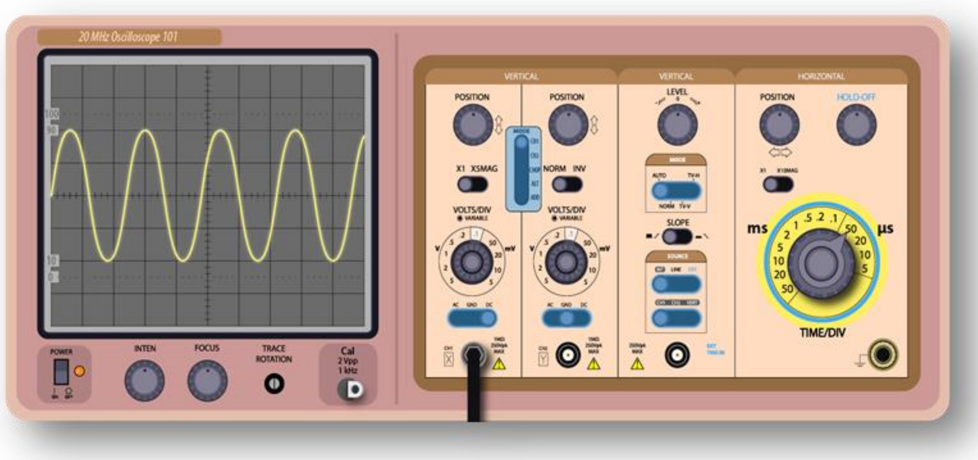

Figure 4. Analog oscilloscope of simulation scenarios

Figure 5. Equipment and physical space of the agile room.

As part of the classwork, students were asked to make a video regarding laboratory equipment management or measurement methods. The purpose of this assignment was for the student to become an expert in the management of a specific equipment or the realization of the specific measure, so that he could create the video accordingly. This goal was achieved, but additionally, it worth to mention that the videos produced by students were made with high technical quality and appropriate academic content. Several of these videos have been selected to be part of the YouTube channel.

RESULTS

Students were asked to fill out an online survey, which had 20 questions about the content of the VLOs, their relevance, their usefulness and about the process of creating videos made by themselves. Around 83% of the students agreed that the videos were clear and less than 20% of them consider that the new concepts presented in the videos were difficult to understand. Nevertheless, 100% of them considered themselves prepared to address the topics shown in the videos. More than 85% of the students agreed that the VLOs helped them to understand the management of the equipment, to make better measurements, to complement the class learning and to promote their autonomous learning. Regarding the preference of videos as bibliographic resources, more than 85% consider that it has been more useful than other types of resources and about 96% of them prefer the videos as study material.

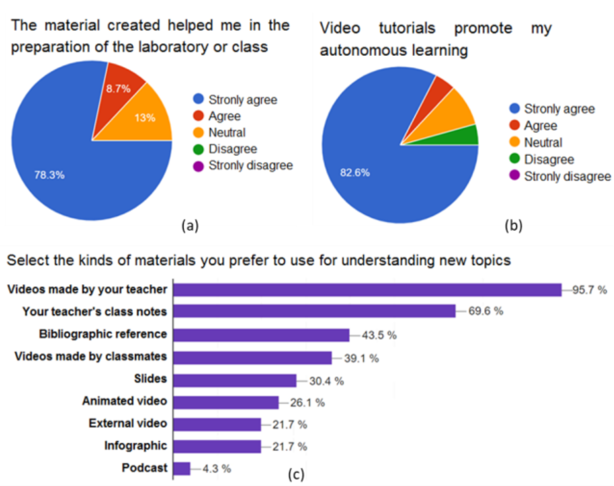

Figure 6. Sample result from survey of Instruments and measurements students

Only 25% of the students consider that making a video tutorial is easy, but about 70% of them felt qualified to do it and more than 80% felt they had the academic as well as technological mastery to do it. About 80% consider that videos should be considered as a percentage of evaluation within the class as seen in Figure 6(a)-(b).

Regarding to the material they prefer to study, there is a strong tendency to choose the material made or recommended by the teacher (Videos 96%, class notes 70%, course guidebook 43.5%). Then comes in the preference the videos created by classmates and later the teacher's slides, all of them well above the material created by external people, animations with Powtoon or Podcasts, as reflected in Figure 6(c).

Worth to mention that the efforts and the amount of work necessary for the creation of VLOs, tend to be much more demanding than preparing a traditional course in a classroom. Behind each new object, some extra work is required that involves among others: identification of the object in the syllabus of the course, the definition of the object, design, creation, realization and testing. A suitable approach consists in to gradually generate each VLO along the semester, and even in consecutive versions of the course. In our favour, the professor in charge of the course invested time during a sabbatical semester to carry out this work. Despite the extra effort involved in the preparation of the material, this is a one-time endeavour, and at the end, the reward is observed in the improvement of the learning process and comments from the students.

CONCLUSIONS

Lecture classes correspond to traditional teaching model, although some modifications and innovations have been incorporated, including active learning, providing tools that expand the offer of content flipped classroom, blended and online classes (Brame, 2016). This paper has discussed the creation of an e-learning ecosystem for the course Instruments and Measurements, a course taught in the Electronics Engineering undergraduate program at Pontificia Universidad Javeriana in Bogotá, Colombia. The ecosystem consisted in a set of VLOs including a total of 95 tutorial videos, 20 simulation scenarios, interactive class notes and assessment material, all available online.

The tools were highly valued by the students, who manifested high acceptance of the material. The highest rating received is for the videos, however, they indicate that the material created has helped them to improve their learning process and it has promoted self-learning practices. On the other hand, the experience of creating their videos, helped the students to increase their self-confidence in their academic capabilities and technological knowledge to perform the videos, becoming prosumers. These exercises, in addition to promoting the deepening of concepts in the development of video, strengthen communication and teaching skills, increasingly demanded in the workplace. Improvement in the communication skills of engineers must be monitored as part of future work.

Finally, results have shown the feasibility of producing videos tutorials at a reduced budget. However, the authors of this paper recommend that professors in charge must be released in time to develop quality material. The generation of this type of tools is demanding in terms of time and resources. For instance, the team in charge of the project reported in this paper was granted with incentives in time by reducing teaching and administrative hours, and nevertheless, only around 50% of the syllabus of the course is covered with the material currently produced. The time invested in the production of the tools was one semester.

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EDUCATIONAL ROBOTICS PROJECTS THAT PROMOTE INNOVATION AND SOCIAL COMMITMENT SKILLS

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ABSTRACT

The course of the University Social Project (PSU) of the Pontificia Universidad Javeriana in Colombia, provides spaces for undergraduate students of electronic engineering, in which they can articulate and implement the relationship between their profession and social challenges in the country. At PSU, students apply their disciplinary knowledge in training activities and technical advice, which contribute to the transformation of the context in which they carry out their social practice. In recent years, some students have had the opportunity to carry out projects where they must conceive, design, and implement a product that solves one of the problems of vulnerable communities. These projects have initially focused on generating new products or prototypes of educational robotics for students and teachers of low-income schools. Through the development of this project using the CDIO initiative, students can apply their existing knowledge in real-life problems or real-life situations. They also can learn about how to carry-out a user-centred design, how to apply an Iterative and incremental development methodology, and how to perform a rigorous user validation. This kind of project fosters the acquisition of skills such as innovation and social engagement skills. This paper shows the methodology used for the development of these educational robotics products and some examples of products developed by students. We also discuss how this type of project can promote innovation and social engagement skills. Finally, the new perspectives and lessons learned are detailed.

KEYWORDS

Educational robotics, Engineering Education, Social Commitment, Innovation and Creativity skills, Standards 5, 7

INTRODUCTION

University Social Project (Proyecto Social Universitario - PSU) is a mandatory theoretical-practical course for final year engineering students of the Electronics Engineering Program at the Pontificia Universidad Javeriana, Colombia. This course provides students with the opportunity of knowing part of the social reality of the country and apply their knowledge and skills to contribute to the solution of problems faced by communities and institutions in situations of economic and social vulnerability.

Students in the PSU course have 60 hours of fieldwork at a beneficiary institution during the academic semester. In addition to this fieldwork, they have a two-hour weekly meeting with the course professor. During these meetings, students participate in workshops and conferences that invite them to reflect on social responsibility (Lopez et al., 2011).

The activities of electronic engineering students during their fieldwork have mainly focused on training and technical service activities. However, the development of projects where students conceive, design, and implement products that solve the problems or needs of the beneficiary institutions or communities has recently been explored. This kind of project provides students with the opportunity to apply their knowledge and skills to solve real-life problems and validate their ideas with end-users and potential clients. Besides, these projects foster the development of 21st-century skills such as creativity, innovation, and social commitment.

The projects carried out in the last two years have focused on the development of educational robotics products that contribute to educational innovation in low-income educational institutions. The purpose of this paper is to present how the CDIO philosophy was adapted to guide the work of students in the development and validation of robotics educational products. We also present how the use of strategies such as user-centred design and incremental and iterative development methodology help students achieve the development of products that meet the educational needs of teachers and students of low-income institutions.

This paper is structured as follows: first, the methodology based on the CDIO initiative used in product development projects is introduced. Then, examples of students' projects in the field of educational robotics are presented. Later, the challenges and potential of these projects are also discussed. Finally, lessons and new perspectives are given.

METHODOLOGY TO DEVELOP EDUCATIONAL ROBOTICS PRODUCTS

Recently, in the PSU course, a new line of work has been created in which senior students of electronic engineering can propose innovative solutions to problems or needs in institutions or communities in vulnerable conditions. The projects that have been developed have focused on the development of educational robotics products that facilitate educational innovation in low-income educational institutions (Bravo et al., 2018).

Students who choose this line of work, have 60 hours in the semester to conceive, design and implement and validate with end users a prototype of educational robotics product that supports the teaching and learning processes. This product must be designed so that it can be easily adopted by low-income educational institutions. Therefore, the product developed by students should be low cost and easily replicable.

For the development of the product, the user-centred design approach has been adopted in such a way that the solution developed satisfies the need of the users (Institute of Design Stanford, 2010). For this reason, the students must involve the end-users and potential customers at all stages of product development.
Students are assigned one or more mentors who provide advice on the different stages of product development and validation. This mentor is usually a volunteer professor who is an expert on the subject of the project, in this case, an expert in educational robotics or educational technology. Students also have the support of a schoolteacher for the validation of ideas and the product developed in a real context. As for the PSU course professor, its role in the project is to find the mentors and schoolteachers who will support students in project

development. This professor is also responsible for verifying that students comply with the proposed work plan.

Based on the CDIO approach, the methodology used in the PSU course to develop innovative solutions in educational robotics involves the following stages:

Stage 1: Conceive

Due to time constraints, students are informed about what the problem is or the need they must solve. They are asked a guiding question that describes a design challenge. This guiding question will guide the students' work throughout the product development process. An example of a guiding question is the following: *As an engineer, how would you design an educational robot that helps sixth-grade students in low-income schools understand mathematical concepts such as the Cartesian plane, angles, and geometric figures*.
At this stage, students should carry out a consultation process with end-users, potential clients, experts, and bibliography sources to understand the challenge they are trying to solve. This consultation process involves conducting interviews, focus groups, observations, and a comparative evaluation process.

To guide students in the student research process, they are asked a series of essential questions. For example, what difficulties do students have in understanding the problem of the Cartesian plane? What difficulties does the teacher have to present the theme of the class? What tools does the teacher use to present the topic? What teaching method does the teacher use to explain the subject? How can an educational robot help the teacher explain the issue? Have the students or the teacher used educational robots?

Once the students have understood the challenge and have observed it from the perspective of the end-users, the next step is to define the functional and non-functional requirements that the product to be designed should have. Due to time constraints, mentors give students basic project requirements. Students along with the mentor must refine and prioritize these requirements according to the lessons learned from the performed inquiry process.

Then, an agreement is reached with the student on which of these requirements he will implement and validate during the course. The student will generate a work plan with the activities to be carried out and the delivery dates. To achieve a functional prototype for schools, the following semester another student will resume the project and implement other functionalities. This process is repeated until a prototype is developed that can be taken to schools.

Stage 2: Design

The iterative and incremental development methodology was selected to design the product prototype. Students begin with the grouping and prioritization of the requirements to be implemented. Then they select the first set of requirements and generate possible design solutions. After that, they select the best solution and include it in the design. Subsequently, students perform design verification with end-users using rapid and low-cost prototypes (e.g., paper prototypes). Next, students choose a new set of requirements and the process is repeated until all the requirements are included in the design.

Stage 3: Implementation

In this stage, the prototype of the educational robotics product is built and validated (Daniela, 2019). Students are provided with craft materials, electronic components (for example, microcontrollers, motors, sensors), mechanical parts, and 3D printers to build the product prototype. Once the prototype is finished, students validate it with end-users and potential customers.

The validation process includes the design of a learning experience that uses the designed prototype. It also involves the design of the data collection instruments. The designed learning experience is implemented in a school under real conditions. The results of this stage are possible improvements to the design. It is also possible that new design requirements may be identified (Mikropoulos, 2013).

At this stage, students must generate a detailed document of the work done in the semester. Also, technical manuals, source codes, and learning experience guides are generated. This documentation is essential for the continuity of the project.

EXAMPLE OF DEVELOPED EDUCATIONAL ROBOTICS PRODUCTS

In this section, two projects carried out during the PSU course are described. These projects arise from the need to promote educational innovation in low-income institutions. In the first project, students were asked to develop a robotic arm to teach mathematical concepts. The project requirements were to design a low-cost robotic arm that is easily replicable by teachers and students. Also, the robot should have the option of being teleoperated through mobile devices or via wired control in case students do not have access to a mobile device or computer. Figure *3* shows the result of the engineering design process of the robotic arm. Students validated the designed arm robot and generated a report with improvements in design.

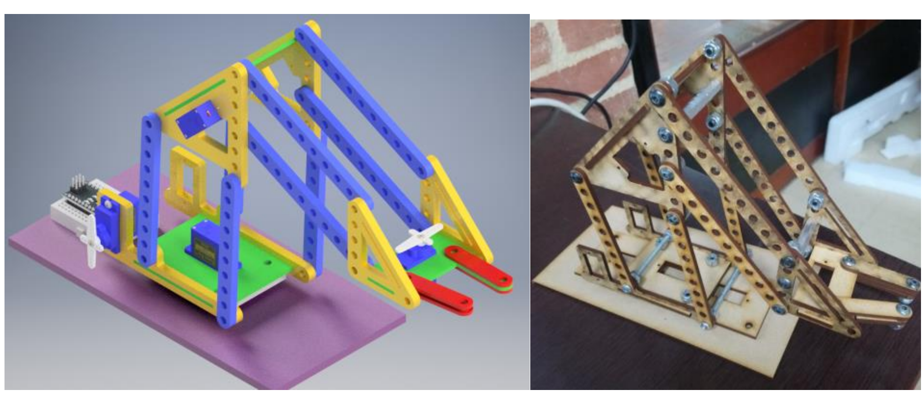

Figure 3. Arm Robot to teach mathematics

This project continued in the following semester with another group of electronic engineering students. These students were asked to improve the design of the robotic arm and to develop robotic educational activities based on the robotic arm that supports the teaching of the Cartesian plane and geometric figures. Two examples of designed learning experiences are:

- **Activity 1 - Reveal the riddle**: The activity consists in strengthening the knowledge of geometric figures in students between 5 and 7 years old. The designed activity proposes that students use the robot to join the points of a given numerical sequence. Next, students must determine what geometric figures they drew.

- **Activity 2 - Find the treasure:** This activity, designed for students between 8 and 11, seeks to strengthen the theme of operations with vectors in the Cartesian plane. Students use the robot to mark certain points on the Cartesian plane. Then, they must do some geometric and vector operations to find out where the treasure is on the Cartesian plane.

In the second project, students were asked to design an expressive robot for the implementation of storytelling activities in non-technical school subjects. The requirements given to the students were that the robot must be inexpensive, play audio files, and be able to express emotions such as happiness, sadness, calm, and anger. Engineering students carried out a consultation process with students and teachers at the school to obtain other design requirements and validate possible solution ideas. The result of the engineering design process was the development of a prototype robot actor that is capable of expressing emotions through faces projected on an LED matrix and an intuitive interface for the teleoperation of the robot actor (see Figure *4*). In the designed interface, the user can choose emotional faces, play audios, and control the movement of the robot.

Figure 4. Expressive robot actor prototype and its control interface

The students carried out a validation of the prototypes developed with children between 4 and 6 years old (see Figure *5*). This validation allowed them to identify possible improvements in the design of the robots and the interface.


Figure 5. Storytelling activities with children

DISCUSSION

Product development projects provide students with rich contexts to apply their knowledge and skills in solving real problems facing vulnerable communities. The development of these product prototypes not only promotes social commitment but also fosters creativity and innovation skills in students.

This new line of work has pleased the students of the course because they are having the experience to design a user-centred product. They have the opportunity to validate most ideas with the user through rapid prototypes. This allowed them to realize that many times what they imagined did not work and needed to rethink their idea. This interaction with users also allowed them to discover new design requirements and restrictions.

Students also value the support they have during the execution of the project. They had one or more expert mentors on the subject of the project, the support of a schoolteacher to perform validations, and the accompaniment of the course teacher. The mentor's role is key to the development of the project. The mentor is the person who guides the student through the entire product development process. The fact that the mentor is an expert in the subject of the project makes the product development process quick and successful. For example, the mentor is that he is already clear about the basic requirements of the product to be developed and students can start from those requirements. The inquiry process that students have helps refine these requirements so that they adapt to the context and the target users. In addition to the training that social responsibility students have, the mentors provided students with training on user-centred design, design thinking, incremental and iterative product development, innovation process, design of data collection instruments, among others.

Something interesting about the projects proposed to the students is that many of them are linked to research projects that are being carried out in the engineering faculty. For example, the low-cost expressive robot actor project arose from the robotic theatre research project for educational purposes. This makes many of the solutions students develop innovative in the market. For example, an educational robot that allows to easily implement robotics storytelling activities in the classroom has not been identified. That is why the projects developed in the course can become an entrepreneurial project for students and teachers. We also hope to link people from the university's innovation department to the course. They will be able to support accompanying teachers and students to mature the idea and achieve a product that can be transferred to the market.

NEW PERSPECTIVES AND LESSONS LEARNED

The activities that students do in the PSU course have been limited to training and technical support activities in beneficiary institutions. Recently a new line of work has been created in which students develop prototypes of products that seek to solve a need or problem faced by vulnerable communities. Currently, product development has focused on educational technology solutions for low-income educational institutions. It is expected to expand this work area to other fields.

A limitation of this proposal is that the number of students who can participate in product development projects is limited. It depends on the number of volunteer professors that are available to accompany students in product development. We are dedicating efforts to increase the number of volunteer mentors participating in the course. For example, we are planning to link graduates and entrepreneurs to advise the students' work on the project.

The time constraint in the course for the development of a product prototype was resolved by dividing the project into different stages of development. In one semester, a student is responsible for implementing a set of requirements and the following semester another student implements the pending requirements. The process is repeated until a functional and validated prototype is achieved. To ensure the continuity of the projects, students must document their work well.

Our strategy to bring the prototypes of products developed to the school is through the students of the courses that develop training activities. These students help generate didactic material and carry out teacher training and implement learning activities that use the developed prototype.

Finally, it is expected to find resources to be able to donate prototypes developed together with educational material (e.g., booklets) to schools. Also, providing schools with an accompaniment for the appropriation of this educational technology through the students of the PSU course.

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FRAMEWORK FOR AN INTEGRATED LEARNING BLOCK WITH CDIO-LED ENGINEERING EDUCATION

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ABSTRACT

As a CDIO collaborating member, Sheridan's School of Mechanical and Electrical Engineering Technology (MEET) maintains a curriculum that is deeply rooted in skills-based learning, experiential learning, and engineering design. To ensure our graduates are consistently agile and ready for the workforce, we are taking proactive measures to further improve their learning experiences. An important challenge still impeding our students' knowledge acquisition is the perception that program courses have disjointed learning outcomes. In reality, the course map of programs is carefully designed in such a way that technical skills acquired in particular courses gradually build on each other. Despite the traditional existence of prerequisites and co-requisites, the inaccurate view that courses function independently persists among students and, occasionally, among faculty members. One feasible approach to tackle this pedagogical challenge is to combine various courses into an integrated learning block (ILB) having a unified mission and objective. In general, an ILB is formed by the interconnectivity of at least two courses. At Sheridan's School of MEET, we are applying an ILB with three engineering courses offered within the same semester for all of our Bachelor's of Engineering degree programs. The ILB deliverables are based on the design of a chosen engineering system or subunit in a project-based learning (PBL) environment. The rationale of this paper is to share Sheridan's framework for implementing an ILB in engineering programs and to examine the opportunities and challenges related to this type of curriculum design. In particular, we will discuss the methodology by which courses are selected to form an ILB while taking into account their appropriateness for an industry-driven PBL. This will be followed up with some of the strategies that are proposed to evaluate the performance of students in an ILB through formative and summative assessments based on CDIO competencies.

KEYWORDS

Integrated Learning Block, Active Learning, Project-Based Learning, Curriculum Design, CDIO, Standards 1, 2, 3, 5, 6, 7, 8, 9, 11, 12

INTRODUCTION

In Canada, a Bachelor's of Engineering (B.Eng.) degree is obtained once students successfully complete a specialization program of choice over a duration that is typically four years of full-time education. In the Greater Toronto Area (GTA), four comprehensive research-based universities offer this degree: the University of Toronto, York University, Ryerson University and Ontario Tech University. As of recently, Sheridan is the latest school to offer a B.Eng. degree within this region. As a first step, the Mechanical Engineering (PEQAB, 2014) and the Electrical Engineering (PEQAB, 2017) degree programs were proposed to the Postsecondary Education Quality Assessment Board of Ontario for consideration in 2014 and 2017, respectively. Today, both of these engineering disciplines have obtained Ministerial consent to offer the B.Eng. degree programs at Sheridan.

What is unique about both of these degree programs is that they were developed with the Conceive, Design, Implement and Operate (CDIO) Initiative (Crawley, Malmqvist, Ostlund, Brodeur, & Edström, 2014) in mind. Sheridan is the only engineering school within the GTA where CDIO is explicitly embedded in its degree programs (Abdulla, Motamedi, & Majeed, 2019). Practically speaking, this means that our students will focus on analytical skillsets while also devoting nearly half of their education time working on hands-on projects in state-of-the-art labs that are equipped with industry-standard advanced technologies. Setting Sheridan apart from other local universities is the fact that, as a polytechnic, the school focuses on active skills-based learning, experiential learning, project-based learning (PBL), problem-solving techniques, and applied and experiential research. Also, both Mechanical and Electrical Engineering students are expected to complete a mandatory four-month internship with industrial partners following their second year of study, with the option to complete an additional co-op experience following their third year.

Overall, the B.Eng. degree programs at Sheridan consist of fundamental, discipline-related and elective courses in Mechanical and Electrical Engineering. Irrespective of the chosen discipline, enrolled students will have the option to specialize in either power and energy or mechatronics. The overall duration of the program spans four years that are split into eight semesters. Throughout the program, students are expected to complete 48 courses or the equivalence of 176 credits. It is interesting to highlight that among the Mechanical and Electrical Engineering disciplines, nearly half of the courses in the program map overlap. To be precise, there are 27 common courses across the two disciplines related to fundamental engineering topics, electives and capstone projects. Moreover, within a specific discipline, roughly 82% of courses are identical between the two possible specialization streams. A summary of the B.Eng. programs offered at Sheridan is outlined in Table 1.

Table 1. Macroscopic view of B.Eng. degree programs offered at Sheridan

<table>
<tr><th colspan="2">Degree Program</th><th colspan="2">Bachelor's of Engineering (B.Eng.)</th></tr>
<tr><td colspan="2">Discipline</td><td colspan="2">Mechanical Eng. or Electrical Eng.</td></tr>
<tr><td colspan="2">Specialization Stream
within a discipline</td><td colspan="2">Power and Energy or Mechatronics</td></tr>
<tr><td colspan="2">Overall Duration</td><td colspan="2">4 years (8 semesters)</td></tr>
<tr><td rowspan="3">Overall Courses</td><td>across disciplines</td><td><u>common courses</u>
27 courses (92 Cr.)</td><td><u>discipline specific courses</u>
21 courses (84 Cr.)</td></tr>
<tr><td>within a discipline</td><td><u>common courses</u>
40 courses (144 Cr.)</td><td><u>specialization specific courses</u>
8 courses (32 Cr.)</td></tr>
<tr><td>total</td><td colspan="2">48 courses (176 Cr.)</td></tr>
<tr><td colspan="2">First Cohort</td><td colspan="2">Fall 2019 (Mechanical Eng.) and Fall 2020 (Electrical Eng.)</td></tr>
</table>

Excited by the unique nature of these programs, we are taking proactive measures to deliver an exceptional educational program to our learners. Extrapolating from related diploma programs, we foresee that B.Eng. students will fall into the trap of looking at the learning outcomes of each course offered in the program map in a standalone fashion. This compartmentalized perception of the curriculum is utterly problematic. In reality, the program maps are designed in such a way that skill sets, knowledge, and mindsets acquired in courses gradually build on each other. Building on the work of Pace (2017), who introduced the notion of learning bottlenecks – that is, areas where students tend to get “stuck” and “those places in courses where the stream of learning is particularly apt to be obstructed” (p. 19) – we systematically examined places that could potentially emerge as bottlenecks within the curriculum and identified a disjointed perception of the program as a potential challenge. This bottleneck could be addressed by deliberately integrating the curriculum of courses to explicitly pull course subjects that may appear disjointed into a cohesive learning block. Evidently, following many data-driven discussions from environmental scans of other programs and with a close examination of this potential bottleneck, we, identify the following interrelated curriculum development questions that are worthy of careful investigation:

- Beyond registration restrictions stipulated by prerequisites and co-requisites, do students understand the interrelatedness of courses from a technical viewpoint? Namely, what is the link among engineering courses and to what extent does the learning outcomes of one specialized course practically impact another?
- Do learners have an appreciation for and a grasp of the purpose of non-engineering courses (e.g. mathematics, probability and statistics, economics, technical writing) required in an engineering program map? In other words, do they see how these seemingly tangential subjects will inevitably support specialized discipline courses?
- Can students connect the relevance of the content acquired in courses to real-world engineering problems, hands-on scenarios and application use-cases? That is, do students know the reason and the practical benefit for taking a certain course and how it all fits in the larger scheme of training the engineers of the future?

One way to tackle these questions is by proposing the implementation of an integrated learning block (ILB) in the curriculum. This paper chronicles some of our experience in this initiative by describing Sheridan’s framework for implementing an ILB in engineering programs based on CDIO competencies as outlined in the standards in v2.0 (The CDIO Initiative, 2010) and the revisions proposed for v3.0 (Malmqvist, et al., 2019).

PEDAGOGICAL ACTIONS AND RATIONALE

A feasible way to tackle the conundrum of disjointed courses is to integrate various subjects into an ILB (Edström, Gunnarsson, & Gustafsson, 2014). ILBs have the advantage of having a unified mission and learning outcomes. Early work on ILBs can be traced back to nearly three decades ago, where integrating engineering curricula was considered to support students in connecting mathematics, science and engineering together (Froyd & Ohland, 2005). Although each course in an ILB is unique in scope, students engaged with the various courses will gain complimentary competencies across areas of study. In general, an ILB is formed by the interconnectivity of at least two courses. At Sheridan's School of MEET, we are applying ILBs with three engineering courses offered within the same semester (Rayegani & Ghalati, 2015). Since some courses can be integrated more easily than others, we specifically designed and developed courses that have synergies and interdependencies amongst them. Ultimately, the decisions involved in the selection of engineering courses to integrate and curriculum development were mutually agreed upon following careful intradepartmental discussions. In such a setting, an ILB committee is formed with multiple stakeholders, including (a) the course leads of target courses, (b) the ILB coordinator, (c) the Associate Dean, and (d) invitees from the industry.

Although in Figure 1, we show the course map for the B.Eng. degree program only in Electrical Engineering, a similar setup is also available for Mechanical Engineering. As is obvious, the program spreads over four years, during which time major group projects are undertaken. Indeed, these projects are conducted using CDIO guidelines, of which Sheridan is a member (Zabudsky, Rayegani, & Ghafari, 2014). However, the CDIO competencies are gradually acquired based on instructional scaffolding. To be precise, first-year courses will primarily focus on I-O; second and third-year courses on D-I-O; and fourth-year courses on C-D-I-O guidelines as a whole (Abdulla, Motamedi, & Majeed, 2019). Furthermore, we aim to form at least one ILB of 16 credits in each of the first three years, where the complexity of engineer design evolves from one CDIO-ILB project to another. To avoid overwhelming students with major hands-on group work, we decided to include a gap year between each CDIO-ILB project. As a result, these projects are respectively set in term 2 (highlighted in blue), term 4 (highlighted in orange), and in term 6 (highlighted in green). Granted, in the last year (i.e., terms 7 and 8), nine credits are allocated for the capstone project.

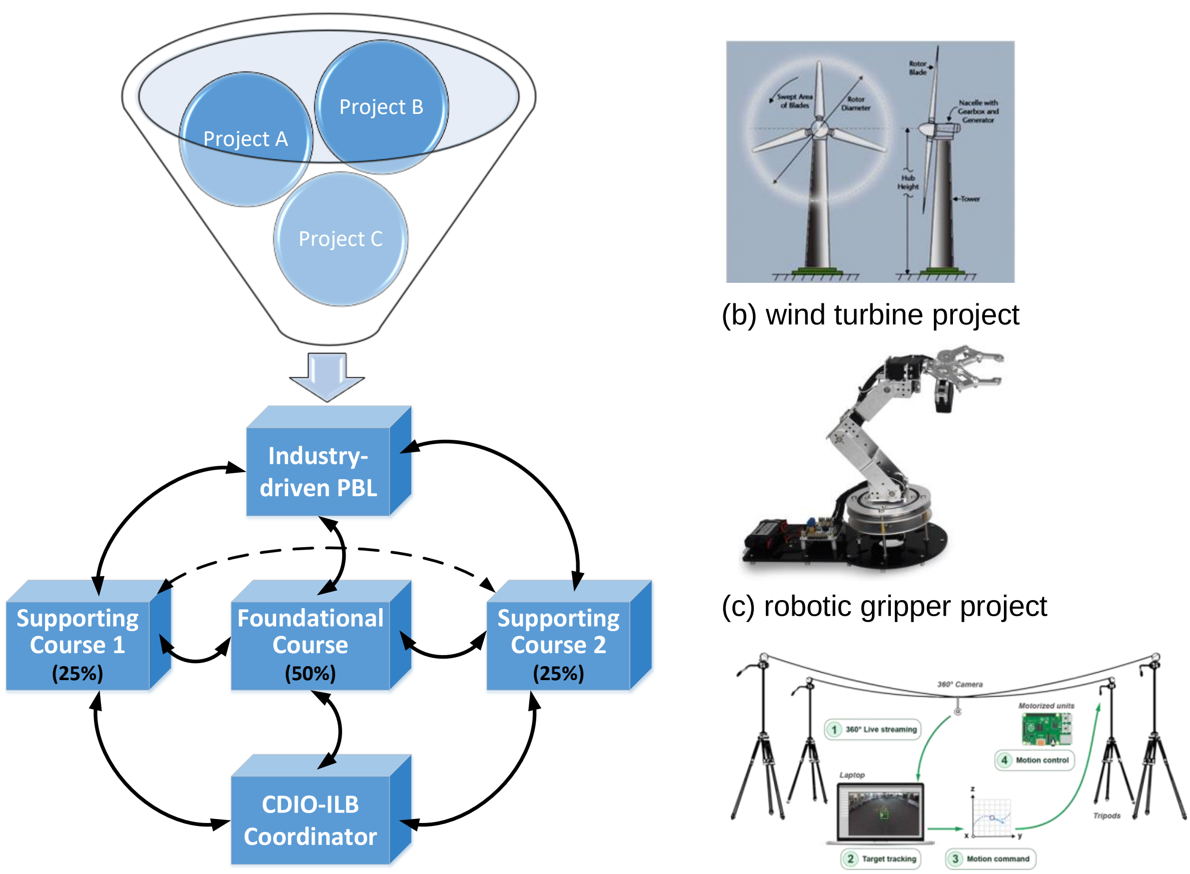
	Discipline Courses						**Breadth Courses**
Term 1 Fall Year 1	Calculus 1	Linear Algebra	Fundamentals of Physics 1	Exploring Engineering	Engineering in Society – Health & Safety		Composition & Rhetoric
Credits:	Credits: 4.0 (3-0-2)	Credits: 4.0 (3-0-2)	Credits: 4.0 (3-2-0)	Credits: 4.0 (2-2-2)	Credits: 3.0 (3-0-0)		Credits: 3.0 (3-0-0)
Term 2 Winter Year 1	Calculus 2 P: Calculus 1	Intro. to Chemistry for Engineers	**Fundamentals of Physics 2** P: Calculus 1 and Fund. of Physics 1	**Engineering Design and Problem Solving P: Exploring** Engineering	**Computer Programming**	1st CDIO-ILB Project	*Breadth Elective Course*
Credits:	Credits: 4.0 (3-0-2)	Credits: 4.0 (3-2-0)	Credits: **4.0** (3-2-0)	Credits: **4.0** (3-2-0)	Credits: **4.0** (3-2-0)		*Credits: 3.0 (3-0-0)*
Term 3 Fall Year 2	Differential Equations P: Calculus 2	Fundamentals of Digital Systems	Algorithms and Data Structures P: Computer Programming	Electronic Circuits 1 P: Fund. of Physics 2	Electrical Circuits and Power P: Fund. of Physics 2	2nd CDIO-ILB Project	*Breadth Elective Course*
Credits:	Credits: 4.0 (3-0-2)	Credits: 4.0 (3-2-0)	Credits: 4.0 (2-2-2)	Credits: 4.0 (3-2-0)	Credits: 4.0 (3-2-0)		*Credits: 3.0 (3-0-0)*
Term 4 Winter Year 2	Numerical Methods P: Differential Equations	**Signals and Systems 1** P: Diff. Equations	Fundamentals of EM Fields P: Fund. of Physics 2	**Electronic Circuits 2** P: Electronic Circuits 1	**Microprocessor Systems** P: Fund. of Digital Systems	Co-op and Career Preparation	*Breadth Elective Course* 1 year
Credits:	Credits: 4.0 (3-0-2)	Credits: **4.0** (2-2-2)	Credits: 4.0 (3-0-2)	Credits: **4.0** (3-2-0)	Credits: **4.0** (3-2-0)	Credits: 1.0 (1-0-0)	*Credits: 3.0 (3-0-0)*
Mandatory Internship Term (4 summer months)							
Term 5 Fall Year 3	Statistics and Quality P: Linear Algebra	Signals and Systems 2 P: Signals and Systems 1	Communication Systems P: Signals and Systems 1	Electric Power Gen. and Transmission P: Electrical Circuits and Power	Introduction to Energy Systems P: Fund. of Physics 2	**1 year gap**	*Breadth Elective Course*
Credits:	Credits: 4.0 (3-0-2)	Credits: 4.0 (3-2-0)	Credits: 4.0 (3-2-0)	Credits: 4.0 (3-2-0)	Credits: 4.0 (3-2-0)		*Credits: 3.0 (3-0-0)*
Term 6 Winter Year 3	**Design of Digital Systems** P: Microprocessor Systems	**Control Systems** P: Signals and Systems 2	**Electric Machines** P: Electrical Circuits and Power	Power Electronics P: Electrical Circuits and Power, and Electronic Circuits 1	Power Distribution System Design P: Electrical Circuits and Power	Engineering Internship Preparation	*Breadth Elective Course*
Credits:	Credits: **4.0** (3-2-0)	Credits: **4.0** (3-2-0)	Credits: **4.0** (3-2-0)	Credits: 4.0 (3-2-0)	Credits: 4.0 (3-2-0)	Credits: 0.0 (1-0-0)	*Credits: 3.0 (3-0-0)*
Optional Co-Op Term (8 to 16 months, year 4)							
Term 7 Fall Year 4	Capstone Project (C&D)	Micro-Controller Applications P: Design of Digital Systems	3rd CDIO-ILB Project	Power System Analysis P: Electric Power Gen. and Trans.	Alternative Energy Systems P: Introduction To Energy Systems	Engineering Economics and Entrepreneurship	*Breadth Elective Course*
Credits:	Credits: 4.0 (2-4-0)	Credits: 4.0 (3-2-0)		Credits: 4.0 (3-2-0)	Credits: 4.0 (3-2-0)	Credits: 3.0 (3-0-0)	*Credits: 3.0 (3-0-0)*
Term 8 Winter Year 4	Capstone Project (D, I & O) P: Capstone Project (C&D)			Power System Control & Protection P: Power System Analysis	Intelligent Power Systems P: Power System Analysis		*Breadth Elective Course*
Credits:	Credits: 5.0 (2-6-0)			Credits: 4.0 (3-2-0)	Credits: 4.0 (3-2-0)		*Credits: 3.0 (3-0-0)*

Figure 1. Program map for B.Eng. degree in Electrical Engineering for the Power and Energy specialization stream.

FORMATIVE AND SUMMATIVE FEEDBACK STRATEGY

In formative assessments, students' performance in a particular skill set emphasized in a specialized course is evaluated by the specific instructor of the course. This is, of course, conducted regularly using different techniques, including traditional written examinations, data collection through hands-on laboratory work, and group reports. On the other hand, the summative assessment of a learning block is evaluated by the ILB committee. This committee will take into consideration the amalgamation of the various acquired skills from the three target courses. They will also identify how these newly acquired skills have helped in the overall engineering design project. In this component, the ILB coordinator will have responsibilities quite similar to that of a project manager for an engineering design project. The coordinator will regularly meet with students to verify that periodic milestones are successfully met.

The approach by which we assess the performance of students in an ILB formation is structured systematically (see Figure 2). To be precise, the deliverables expected from an ILB will generally be based on the design of a particular engineering sub-system or system in a PBL environment (Kolmos, 2017). First-year projects, such as wind turbine, robotic gripper and spider cam (Germain, 2017), focus on I-O competencies. On the other hand, real-world system engineering design problems geared for D-I-O and C-D-I-O competencies are proposed through close consultation with industrial partners in advanced semesters.



(a) strategy for implementing CDIO-ILB

(b) wind turbine project

(c) robotic gripper project

(d) spider cam project

Figure 2. CDIO-ILB setup with three courses founded on PBL, and with sample projects.

Certainly, to ensure the success of an ILB, group formation and interaction is very important. To clarify, we should stress that the same group of students will be registered in similar sections of courses taking part in an ILB. The learners will be responsible to form their groups composed of either 3 or 4 students each. The groups will identify themselves with a name of their choice, and they will remain together across the ILB courses until the end of the semester. The groups will also elect a designated team leader to facilitate interaction with instructors.

Training students in group work is extremely important since effective group interaction is an integral element of a successful professional work environment, and, in general, group work enhances the overall deliverables assigned by a supervisor. Nevertheless, groups are always prone to some challenges. For instance, some group members may not actively participate in the engineering design project. Further, at times, group cohesion and coordination may be lacking and, as a result, efforts will be fragmented. Should this happen, groups will have an intervention with the ILB coordinator to suggest techniques to overcome challenges and resolve differences. One mechanism to minimize and safeguard against such possibilities would be to require that each group submit a team contract provided to them at the start of the semester. This is an effective and proven strategy for group harmonization applied in other engineering courses at Sheridan were teamwork is front and centre (e.g., COMM-16165, Technical Reports and Presentations course).

EARLY RESULTS IN IMPLEMENTING THE CDIO-ILB FRAMEWORK

As indicated in Table 1, the first cohort of B.Eng. students enrolled in Mechanical Engineering in the fall of 2019. The first CDIO-ILB project began soon after in winter of 2020 during the students' second semester. Meanwhile, in anticipation of the very first ILB experience at Sheridan, the faculty in the School of MEET had regular weekly meetings throughout the fall 2019 semester to put concepts of this important framework into action. These meetings were instrumental for promoting extensive exchanges, debates and brainstorming sessions where diverse viewpoints enriched the discussions related to organization and logistics, forecasting potential challenges, and managing and operating PBL activities arranged in an ILB setup. Moreover, in these meetings, we were able to effectively study, refine, and finalize several related aspects about (a) curriculum mapping to CDIO syllabus and Canadian Engineering Accreditation Board (CEAB) requirements; (b) evaluation plan and deliverables; (c) rubric design and performance assessments; (e) potential schemes for group size as a function of project complexity; and (f) defining the scope and description of the first set of projects compatible with the learning outcomes of the three courses within an ILB. Of course, estimating budget requirements and mobilizing faculty, engineering staff, and technologists to implement these CDIO-ILB projects was needed to assist our learners engaged in this unique, hands-on undertaking.

As shown in Figure 1, we formed a learning block by integrating the following courses: Engineering Design and Problem Solving (ENGR-18922D), Computer Programming (ENGR-11833D), and Fundamentals of Applied Physics (PHYS-15924D). As illustrated in Figure 2.a, the design course was the foundational course for the CDIO-ILB project, and the programming and physics courses were supporting courses in this PBL assessment. Furthermore, twelve design teams were formed composed of three students each. The groups had the choice to work on one of three projects, shown in Figures 2.b (wind turbine), 2.c (robotic gripper), and 2.d (spider cam). To avoid a higher frequency of students working on a particular project over others, we decided to equally divide them based on a first-come, first-served basis. Groups had the choice to claim their preferences by submitting a form to the CDIO-ILB coordinator indicating their first, second, and third choices. Based on the time log of the submitted form, a project was allocated to a particular group.

Despite the technical nature of this learning activity, engaging in a CDIO-ILB project promoted vital skills needed in the toolkit of future professional engineers, such as project and time management, critical thinking, creativity, and innovation. It also incited students to take proactive measures to seek feedback and suggestions from faculty and subject matter experts to improve and polish their project output. Although such attributes are generally seen with senior students engaged in final year capstone projects, it was inspiring and refreshing to see such professional growth among our first-year junior students. The observed response of our students to the CDIO-ILB projects is perfectly aligned with our school's strategy and vision to support our learners in thriving and unleashing their full potential to succeed academically and beyond.

REFLECTION AND SCHOLARSHIP

As noted earlier, we are putting in place an evidence-informed framework for implementing an ILB for Sheridan's engineering programs. To the best of our knowledge, very few schools have experimented with an ILB and, even if they have, they generally formed a block based on two courses (Leone & Isaacs, 2001) or have potentially considered an ILB formed with non-engineering courses (Shetty, et al., 2001). At the School of MEET, our vision is to go beyond that and to truly offer a revolutionized curriculum that will, in essence, prepare our students for the workplace. In other words, as soon as they graduate, we want them to hit the ground running in their respective professional contexts. We want our learners to be competent in technical skillsets, in problem-solving techniques, and in having the agility to connect diverse intellectual elements to solve a real-world engineering challenge. We also want our students to be professional engineers adept in soft skills which include: technical writing, technical presentations, group harmonization, conflict resolution techniques, and engineering design (Abdulla & Shayan, 2013). If we are successful in this vision, we truly believe that our students will not only be able to find competitive work opportunities, but they will also be prepared to spin off some of their engineering design ideas that incubated at Sheridan.

Since we are in uncharted territory, we anticipate that there will be challenges with the implementation of this curriculum in the next couple of years, both for the learners and the committee. However, with these challenges, we will have the opportunity to experiment and innovate with various pedagogical alternatives. To this end, to extend our research in curriculum design work, we are particularly interested to further investigate the following topics:

- In an eight-semester program, how often should a CDIO-ILB project be applied? Is having three ILBs in the program map sufficient or excessive (see Figure 1)? Namely, how do we ensure that we achieve the learning outcomes of knowledge acquisition through an ILB in an adequate and balanced manner?

- How do we ascertain that real-world engineering projects proposed by industry are appropriate for PBL and CDIO (Edström & Kolmos, 2014)? In other words, are the proposed projects compatible with the learning content and outcomes of ILB courses? Will our students have the necessary skills and know-how to embark on these hands-on technical projects?

- Generally, a combination of backward (Wiggins & McTighe, 2005) and forward curriculum design (Abdulla, Motamedi, & Majeed, 2019) is applied to a specific course. Can the same methodology be applied to a block of engineering courses in an ILB setup?

CONCLUSION

Our prime goal in exploring the CDIO-ILB approach is to ensure that we offer modern and relevant curricula that prepare our students to solve the major complexities of the future. Undoubtedly, the capacity to recognize and connect diverse technical elements to tackle a specific challenge is a vital skill for engineers. This scholarly examination allowed us to look more systematically at the intended student learning experience coupled with CDIO competencies based on instructional scaffolding. Following an elaboration on the means to manage, coordinate and assess the worthiness of CDIO-ILB projects, we highlighted early results in implementing this framework for the first time in this academic year. As we explore, engage and gain experience and feedback from faculty and students involved in ILB, we aim to continue sharing our methodology, framework and data sets with the wider community of engineering educators.

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Mouhamed Abdulla, Ph.D., is currently a Professor of Electrical Engineering at Sheridan. Since 2015, he was a Marie Skłodowska-Curie Individual Fellow supported by the European Commission at the Chalmers University of Technology in Gothenburg, Sweden. In 2017, he was a Visiting Fellow with the Dept. of Electronic Engineering of Tsinghua University in Beijing and at Nanyang Technological University in Singapore. Until 2015, he was an NSERC Postdoctoral Fellow with the Dept. of Electrical Engineering of the University of Québec. For nearly 7 years, he was with IBM Canada Ltd. as a Senior Technical Specialist. He received, respectively in 2003, 2006, and 2012, a B.Eng. (with Distinction) in Electrical Engineering, an M.Eng. in Aerospace Engineering, and a PhD in Electrical Engineering, all at Concordia University. His pedagogical research focuses on Engineering Design, Course Development and CDIO.

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EXPLORATION OF BIG DATA TALENTS UNDER THE CONCEPT OF CDIO

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ABSTRACT

As an educational idea guiding the reform of engineering education personnel training mode, CDIO education mode focuses on the cultivation of students' system engineering technical ability, especially the ability of project conception, design, development and implementation, which is widely used in the training of engineering professionals. In this paper, Outcomes-Based Education (OBE)-CDIO engineering education mode for engineering certification is introduced, and blending education is led into all aspects of engineering personnel training. Taking the talent training of big data engineering as an example, guided by the talent ability training, under the blending education and CDIO Engineering Education Concept, the paper explores the guidance and practice scheme of the goal of talent training, graduation requirements, the integrated curriculum system of blending learning, the project system of integration of industry and education, the integrated extracurricular practice system of the centralized guidance of tutors, the quality education system combining counsellors and professional teachers. In the process of implementation and exploration of mixed education, the paper takes the project of ‘data acquisition and preprocessing practice’ as an example to analyze the design of courses, the construction and use of resources. Through exploration and practice, the paper expounds the innovative research and practice of engineering personnel training, which is the combination of blending education and OBE-CDIO education mode.

KEYWORDS

OBE-CDIO, Blending Education, Big Data Engineering Talents, Training Mode, TOPCARES-CDIO, Integration of Industry and Education

INTRODUCTION

With a new round of technological revolution and the industrial revolution, as well as the boom in the new economy worldwide, higher requirements have been raised for engineering talents cultivation in the new era (Kang, Lu, & Xiong, 2008). To meet the needs of the times and society, it has become an important method for the cultivation of professional talents in China's universities to reform the education mode and create online and offline learning environment for engineering students in the internet. Among them, CDIO represents the concept, design, implementation and operation (Bankel et al., 2003), which gradually attracts the attention of the education field, and constructs the ability to smoothly link theory and practice under the guidance of this concept.

In the process of talent cultivation, we should follow the human-oriented consciousness, take CDIO Engineering Education Concept as the guidance, and combine the ideas of Outcomes-based Education (OBE) (Fu, Huay, & He, 2017). OBE is an educational concept proposed by American scholars, which is significantly different from the traditional content-based teaching concept (Zhou, Liu, & Yao, 2016). OBE based teaching uses outcomes-based teaching concept. The purpose of teaching is to make graduates meet certain ability requirements. The teaching plan should reflect the support for the graduation requirements. The teaching link is to effectively complete the corresponding "support" tasks and assess whether the graduation requirements are achieved item by item. OBE-CDIO is an innovative model of training engineering talents.

With the advent of mobile Internet, the traditional teaching model of higher education has also been greatly impacted (Bai, Xie, & Li, 2017). In traditional classroom teaching, students learn in a single, passive and uninteresting way. Also, there is a lack of interaction between teachers and students, and students' learning is always in a passive state (Zhou, Zhu, & Liu, 2018). The popular blending education mode can effectively integrate MOOC (mass open online courses) (Breslow et al., 2013), SPOC (small private online courses) and physical classroom, give full play to their advantages and realize complementarity. It advocates the cultivation of students' initiative, enthusiasm and creative learning concept, which has an important guiding significance for the cultivation of innovative talents under the background of engineering education.

However, the impact of the business value of different professionals on the social economy is quite different. Therefore, in addition to the great changes in the concept and mode of talent training, the changes in educational methodology are also related to the development of the major, the needs of talents and the requirements of ability. Nowadays, massive data resources are generated based on production and life. The digital level of the whole economy and society will follow the evolution route of "data information digital intelligent". The training of big data talents is a prerequisite for the development of the digital economy. Big data talents is engaged in the core technology-related work of big data, mainly including the core talents of research, development and analysis, and the compound talents with both industry background and big data skills.

According to relevant research statistics, by the end of the year 2018, the number of core talents of big data in China was 2 million, with a gap of 600 thousand. To deal with the shortage of big data talents, it is necessary to speed up the establishment of data science and big data technology and other related majors, and cultivate a group of compound talents with professional knowledge and big data technology, which is also the development trend of big data talents training in the future.

Based on this, we should promote the training of data science and big data technology talents with the aid of the education mode of international engineering education professional certification standard. At the same time, in combination with the development status and industrial demand of regional and big data-related industries, based on the integration and collaborative development of industry and education, the implementation of industry, school and enterprise linkage, professional teachers and enterprise personnel mutual employment, mutual assistance and joint mechanism, we explore the integrated curriculum system of training objectives, graduation requirements and blending teaching under the concept of OBE-CDIO, build the integrated extracurricular practice system guided by tutors, and the quality education system combined by the instructor and professional teachers, form the teaching mode with student-centred and learning achievement-oriented, to achieve the ability improvement of big data students.

Exploration of Big Data Talents Training under OBE-CDIO Engineering Education Mode

The Construction of the Overall Plan of Big Data Talent Training

The major of data science and big data technology, as a multi-disciplinary integration major serving the new economy and formats, not only face the future but also integrates the existing information discipline resources. This major has the characteristics of strong interdisciplinary, high knowledge requirements in the fields of mathematics and information. According to OBE's teaching concept, the society's demand for big data professionals and the orientation of major education is based on the results-oriented guiding principle. However, with the rapid development of big data technology, the demand for talents is also changing. To adapt to this change, the training objectives and contents of big data speciality should be adjusted at any time. When the needs of the current society are understood clearly, scientific and reasonable personnel training mechanism can be formulated, and personnel meeting the needs of the society can be trained.

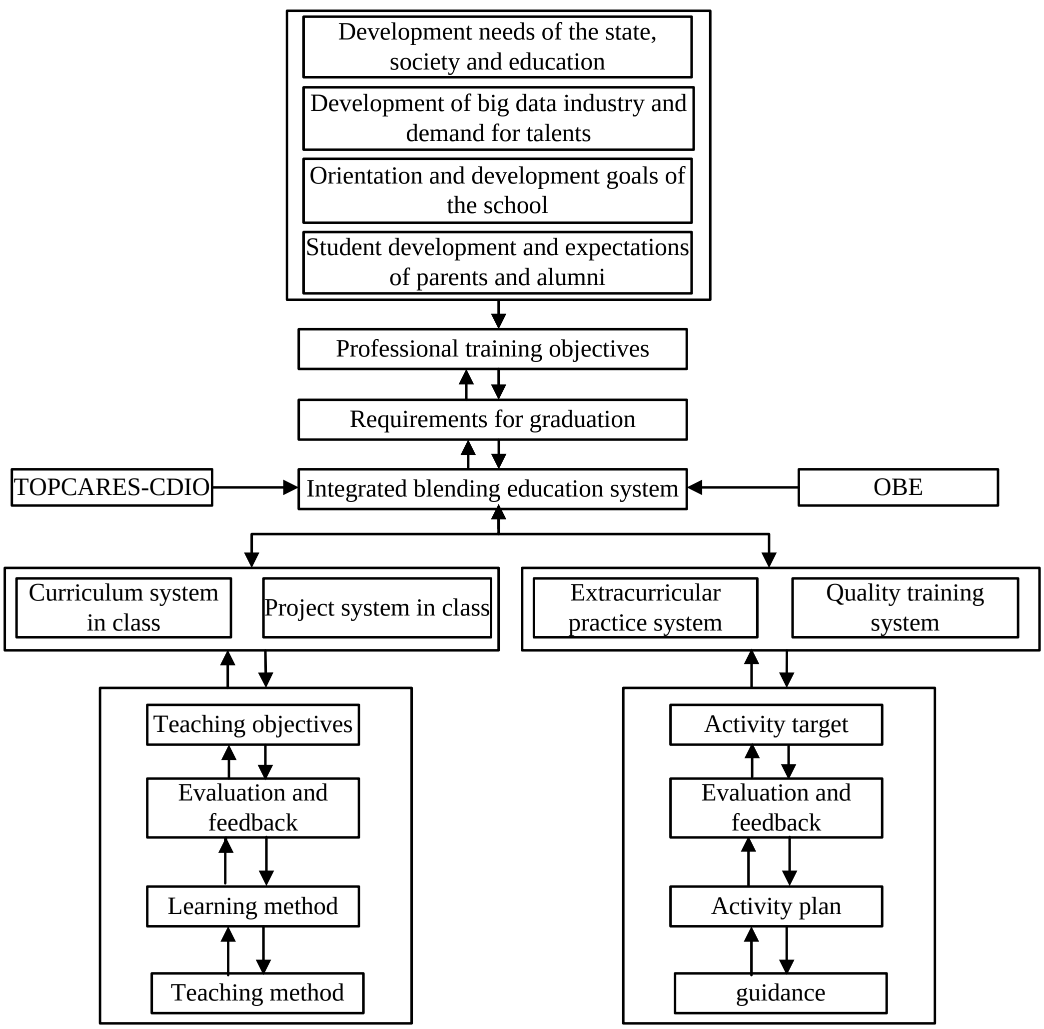

Figure 1. The Overall Design for Big Data Talent Training

Figure 1 shows the overall design scheme of big data talent training, which is student-centred. Based on meeting the needs of the society and combining with the characteristics of the school, the training objectives of the major are designed, and the abilities and levels that students should reach when they graduate are also defined. Through the integrated blending education, combined with the characteristics of the school's TOPCARES-CDIO and OBE teaching concepts, the overall program of big data talent training has been constructed.

In the blending education system, teaching in class is mainly based on theoretical courses and practical projects. Through the design of teaching objectives, evaluation and feedback mechanism, learning methods and teaching methods, the reverse ability objective matrix is constructed, and the teaching objectives are realized through reverse design and forward implementation. The training system includes extracurricular practice system and quality training system. Through the reverse design of activity goal, evaluation and feedback, activity plan and guidance, the activity goal is realized and the ability of students is cultivated.

Establishment of Talent Training Objectives

At present, the research and development of big data technology mainly embodies in four aspects: basic theory, key technology, the practice of application and data security. The connotation of this major determines the knowledge and ability that students need to learn and master, which is one of the bases for the establishment of talent training objectives.

Therefore, the orientation of this major is to cultivate the all-round development of morality, intelligence, physique, beauty and labour, have good professional ethics and humanistic quality, can design and maintain the big data platform architecture, data modelling and analysis, and solve industrial application problems, and have the lifelong learning ability in the information age.

At the same time, facing the big data-related fields such as health care, e-commerce, education, transportation, etc., students can undertake the tasks of big data platform architecture design, data collection, storage and management, data analysis and visualization, and can be engaged in big data analysis, processing, service, development and utilization in various industries in corresponding fields, to cultivate high-quality and applied senior professionals with social responsibility, innovation spirit, international vision and strong practical ability.

Establish Graduation Requirements

The training objectives of the major are used to describe and set the general requirements of the quality and specifications that can be achieved or met by the students of the major several years after graduation (LI, ZHENG, & ZHANG, 2018). The training objectives should have some characteristics such as forward-looking, stability and backtesting, and should be combined with the school's positioning, industry development and school discipline characteristics to develop a distinctive training program.

Graduation requirement is a specific description of the knowledge, ability and quality that students should master after graduating. It is one of the core links of the training scheme design. Graduation requirement plays an important supporting role in the achievement of training objectives and an important guiding role in the design of the curriculum system. Most of the sub-goals of the training objectives correspond to the graduation requirements. These graduation requirements must be achieved after the end of the undergraduate education stage, and the achievement of some of the training sub-goals is also related to the later personal efforts of graduates. Based on CDIO's education and teaching concept, with knowledge, ability and quality training as the core (He, & Wang, 2018), the graduation requirements in engineering knowledge, problem analysis, design and development plan, research, team, communication, project management, lifelong learning, use of tools, engineering, sustainable development, professional specifications, etc. are determined.

Building an Integrated Blending Education System in Class

The indicator points required for graduation are mapped to multiple groups of three-level ability indicators in the TOPCARES-CDIO training mode. The training of the three-level ability index is completed by the courses, projects and activities in the talent training program. Each course in the course system has a supporting role for the target point required for graduation (the three-level ability of TOPCARES-CDIO). The mapping relationship between the training objectives and the three-level capabilities of TOPCARES-CDIO is shown in Figure 2.

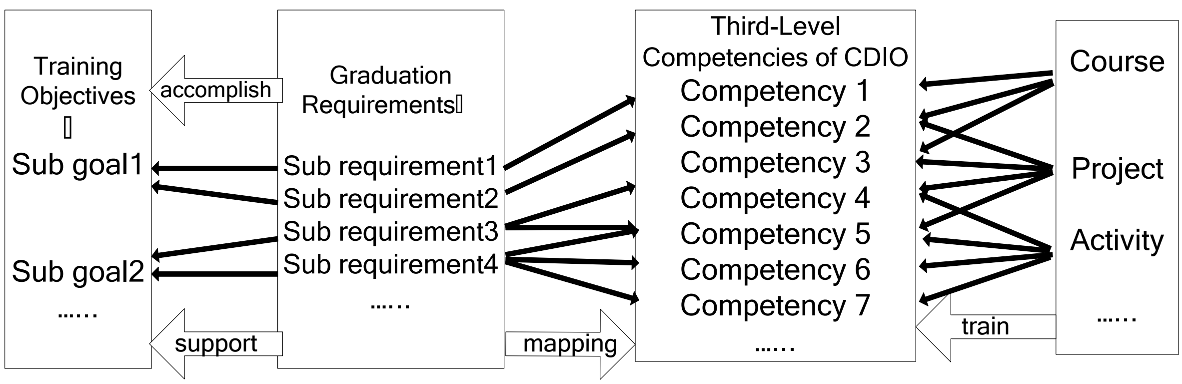

Figure 2. The Mapping of Training Objectives to TOPCARES-CDIO Three-Level Competencies

The curriculum system is not only an important support to achieve the training objectives, but also the core to improve the quality of big data talents. Under the TOPCARES-CDIO methodology, the University and enterprise jointly designed big data technology system based on five new technologies. Taking the technology of big data talents as the breakthrough point, this paper discusses the technical requirements of data analysis engineer, data algorithm engineer and data development engineer talents, and designs the technical system based on data acquisition, data processing and storage, data visualization, etc.

At the same time, through the post technology system, facing the health, education and other industries, the construction of the curriculum system and project system of big data are achieved by using the integration of industry and education. Based on the basic courses, professional basic courses, professional compulsory courses and professional elective courses as the basic modules, combined with practical projects and training projects, and strengthened the cooperation between schools and enterprises, the application-oriented talents in the field of big data are cultivated by the blending education mode.

Also, guided by students' output, schools and enterprises jointly build online and offline teaching resources. These resources involve integrated classroom teaching, practical projects, practical training projects and graduation projects. The teaching implementation process of each link pre-class, in-class and after class, and run the blending education throughout the four-year learning process of the undergraduate course are designed, as is shown in Figure 3.

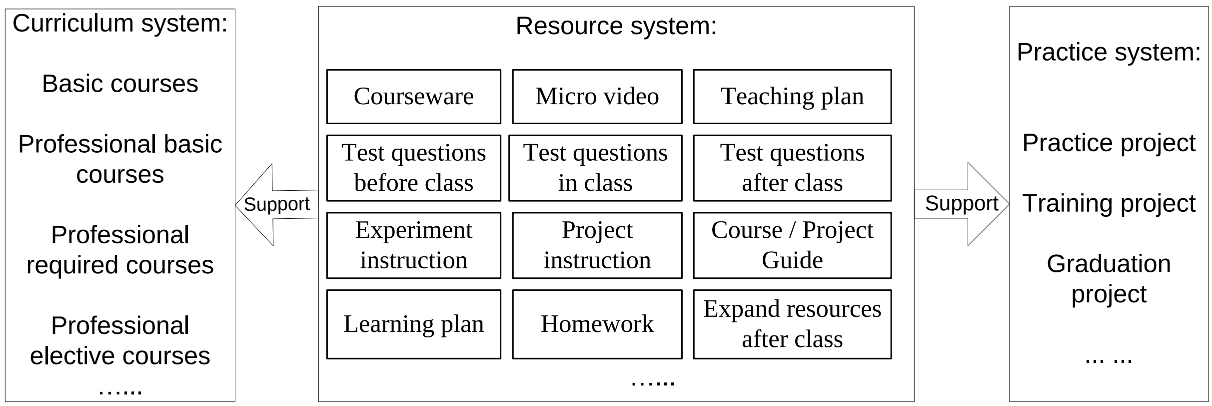

Figure 3. Blending Curriculum Resource System

Building a Blending Extracurricular Education System Under the Tutor System

Relying on Teachers' scientific research projects, students are provided with rich extracurricular learning resources. Under the guidance of tutors, the guidance and learning are carried out online and offline, and the extracurricular blending education practice system is constructed.

The system is based on interest groups and communities, with laboratories, engineering practice education centers, innovation and entrepreneurship centers, and internship bases inside and outside the school as places, with scientific research projects, innovation and entrepreneurship training projects, professional competitions, and internship projects as ways.

With the enterprise tutor and class tutor as the double teachers, assistant counsellor and assistant teacher as the double assistance, the quality training of students is organically combined with the ability to master knowledge, develop ability and solve engineering projects. A series of special lectures, short extracurricular courses, scientific research salons, special training and discipline competitions are held every year. Also, we will carry out targeted quality-oriented education projects, school league work, Party construction work and ideological education, focus on cultivating students' comprehensive quality ability, and build a blending education quality training system, which is shown in Figure 4.

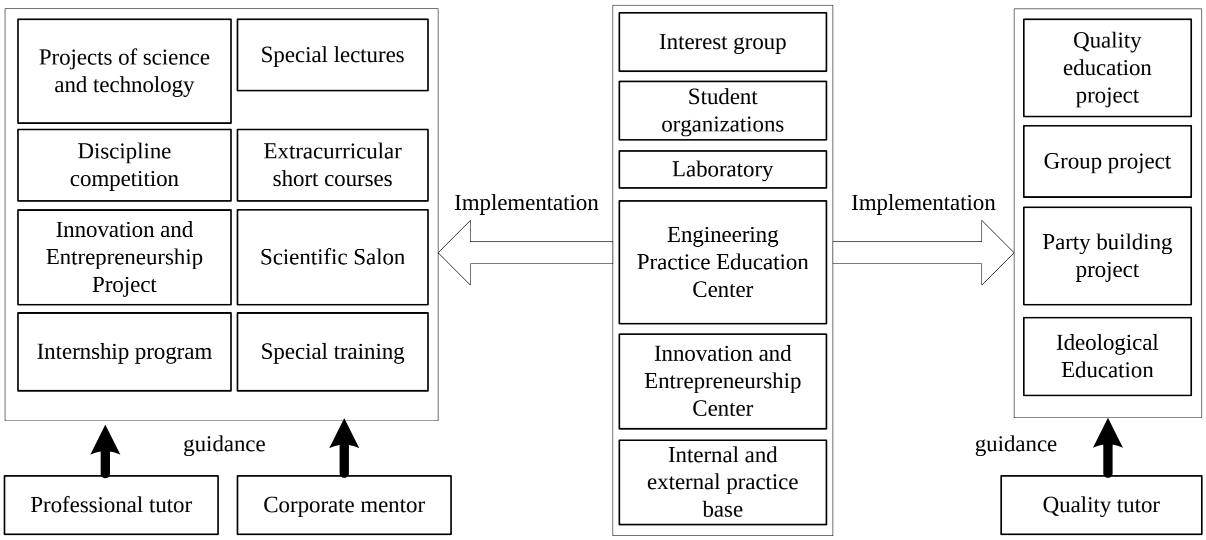

Figure 4. Extracurricular Blending Education System

THE DESIGN OF PRACTICE PROJECT IN BLENDING EDUCATION

The paper takes the project "data acquisition and preprocessing practice" as an example course to carry out research. The technology involved in this project is one of the necessary skills for the current popular data acquisition positions and data preprocessing positions. Through the method mentioned above, the graduation ability is mapped to the ability index of this course, and the training ability of this course is obtained as follows: learning attitude and habit, lifelong learning, professional knowledge and software realization processability. Based on the concept of OBE, the graduation requirements of the major are mapped to the three-level CDIO ability indicators that need to be cultivated. The curriculum system, project system and activity system of cultivating ability index are derived and determined in reverse. Through the way of reverse matrix, we can deduce each link of ability training in reverse, to further deduce project objectives, assessment methods, students' learning methods and teachers' teaching methods.

The course teaching design is jointly developed by the training program staff, the course leaders and the course team (Li, 2018). The general objectives of the course are defined according to the professional CDIO three-level competence indicators. Following decomposition, the specific course objectives are obtained and jointly demonstrated by the corporate mentors on whether or not they can be evaluated, thus determining the feedback and evaluation of the course, forming the evaluation method of the course. This step also needs to be reviewed by relevant personnel. It needs to define how students can achieve evaluation criteria based on evaluation plans, from which how teachers teach and which teaching resources are needed can be derived. At the same time, the rationality of the design needs to be reviewed again. The basic process of course design is shown in Figure 5.

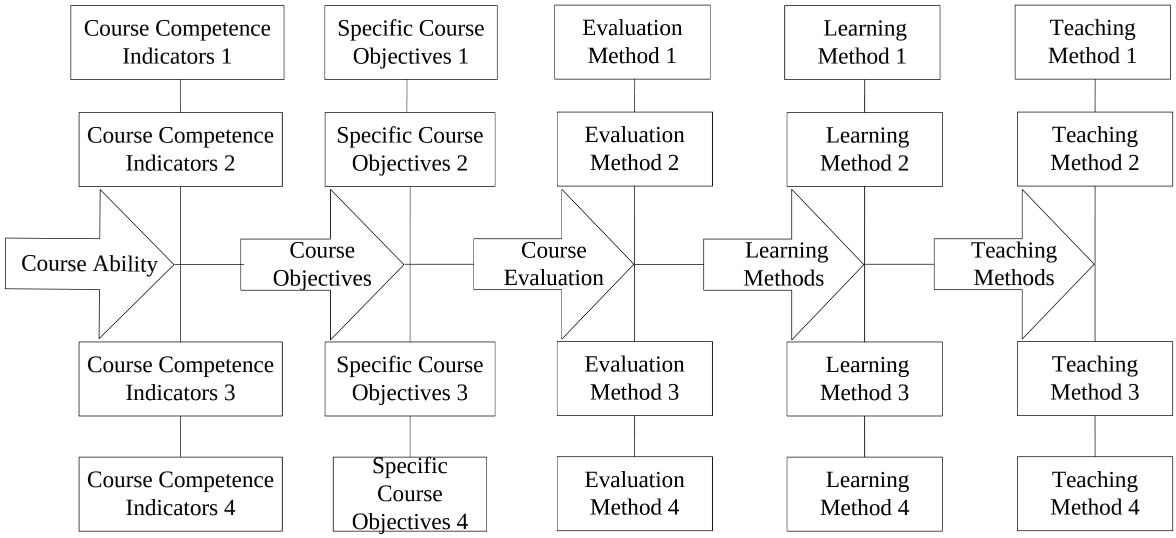

Figure 5. The Basic Process of Course Design

The project design scheme is completed six months before the class starts, and also the project review is organized and completed. In the course of curriculum implementation, it is necessary to continuously monitor and improve the implementation, and complete the mid-term and comprehensive review of project implementation to guide project improvement.

In the process of design and implementation of the project, research, evaluation and other links are combined with the cooperative enterprise, and enterprise experts are invited to participate. The project from content design to implementation process should meet the needs of the enterprise. The cases and related projects in class are based on cooperative enterprises, or come from the decomposition content of enterprise projects, or include the background of enterprises.

The teaching model of the project is mainly project-driven, case teaching, group discussion and other methods. At the same time, face-to-face teaching and online teaching support each other to guide students to make full use of online resources to achieve learning, consolidation and improvement.

Teaching Resources Construction of the Project

Starting from the needs of big data talent training and social needs, breaking through the traditional project construction ideas, based on the enterprise's advanced technology, popular framework and scientific research, combined with the professional construction talent training ideas and practical curriculum system, a three-dimensional teaching resource structure suitable for professional projects has been formed.

With the deepening of teaching and the investigation of students' cognitive level, the dimension and complexity of project resources gradually increase. The design idea of project resources is shown in Figure 6.

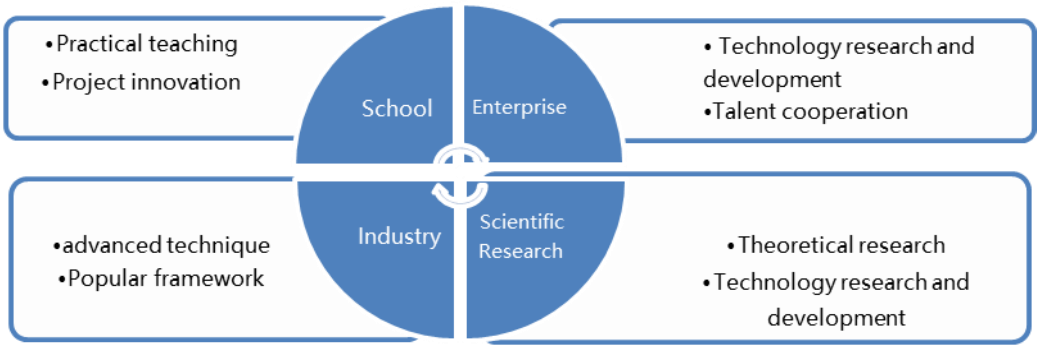

Figure 6. Design Ideas of Project Resources

Based on the design idea of professional integration, project resources involve the whole life cycle of data engineering, such as big data collection, data storage and processing, data analysis and visualization. For each stage of the project, it involves project standards, teaching calendar, courseware, micro-video, project guidance, teaching plans, cases, assessment, learning guidance and other basic resources.

Based on covering the above-mentioned resources, the resource construction of each stage presents the characteristics of hierarchy, focus and professional plate, which are embodied in the differentiation of resource focus.

Design of Teaching Implementation Plan for the Project

With the popularity of the internet and the application of intelligent terminals in education, the blending education model of MOOC+ SPOC+ Micro Class + flipped classroom has become feasible and realistic (Li, & Han, 2017). In this paper, the entire teaching process includes three stages: pre-class, in-class and after class. Learners are at the centre of the blending education and they don't limit to single course teaching method. Instead, they endeavour to exert their subjective initiative and take the initiative to acquire knowledge actively. What they need is a new learning model, so they can take full advantage of new technologies and methods.

Before class, students need to complete the tasks assigned by teachers in advance, complete the pre-class tests, and record the difficulties encountered in self-study, so that students can ask questions to teachers in class. In the class, combined with the actual needs of scientific research projects, teachers make full use of information technology, stimulate students to think actively, and guide students to analyze and process massive data in various forms through case teaching and other ways. Part of the teaching content can be set up as the flipping mode. Teachers can use various forms to interact with students, such as shooting curtain, answering questions, random questions, etc. At the end of the course, the achievement degree of the learning ability is evaluated.

After class, students complete their homework and are evaluated by the relevant test. Through the big data analysis function of the platform, teachers can know the learning state and ability achievement of students in real-time. The blending teaching process of this project is shown in Figure 7.

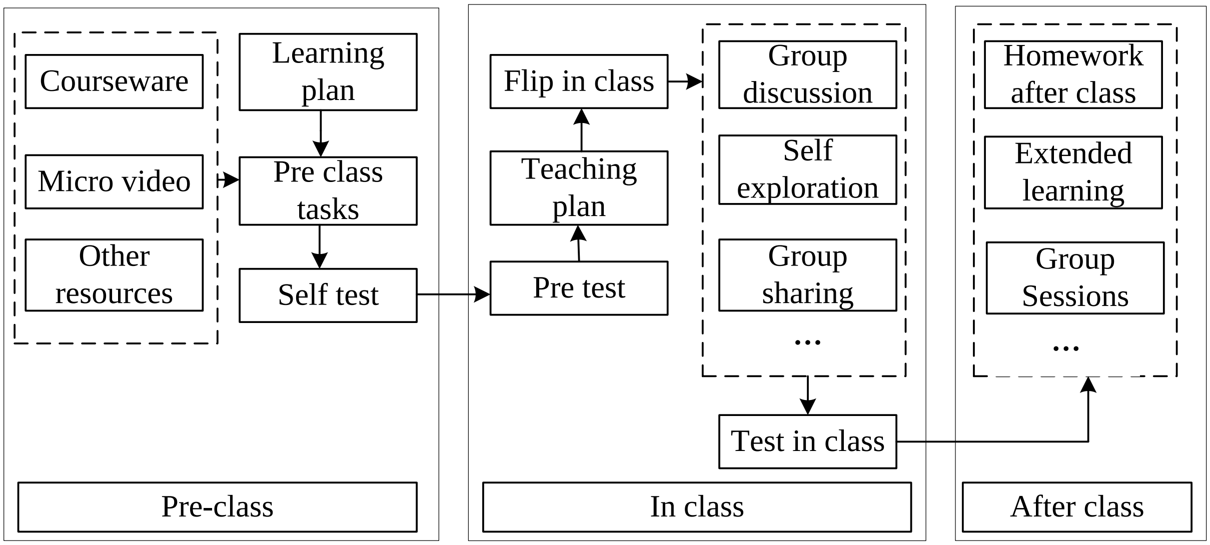

Figure 7. The Designed Blending Teaching Process

In the project design, the blending education mode is organized according to the three links of pre-class, in-class and after class, which conforms to the memory rule of human in brain science.

The preview before class is a process of memory collection. At this time, the primary knowledge model can be built. The discussion in the class is a process of memory processing. At this time, the brain sorts out the primary knowledge model and form a knowledge framework. The review after class is a process of memory solidification and knowledge application.

The formative assessment of the project includes interaction in class, tasks before class and activities after class. This kind of assessment method fully considers the different dimensions of the learning process and realizes the comprehensive training of students' knowledge, ability and quality. The final assessment is used to comprehensively investigate the learning effect of students on this project.

To ensure the effect of curriculum implementation, the systems of class tutor and enterprise tutor are introduced. Through the communication with the teacher and the tutor in time, establish the communication channels for students of different grades and levels, to facilitate the organization of students' after-school learning. The enterprise tutor brings the advanced and popular technology into the class, and helps the students master the technology framework synchronized with the enterprise in real-time through irregular online communication and school lectures.

Also, combined with this project, the competition of data acquisition and preprocessing is designed for the first time to promote the teaching implementation of a big data project. Students can relate their knowledge with the application environment of the actual production environment, and finally apply it to the practice.

16 excellent student works are included in the competition. The total amount of data obtained is 3 million, the amount of data cleaning is 2.5 million, and the number of visualization charts is more than 300. Through this competition, students' ability to use professional knowledge, learning ability and problem-solving ability can be effectively improved.

CONCLUSION

Data science is a new subject in the era of big data. It requires students to collect, store, clean, analyze and develop massive data from the perspective of industry. In this paper, the OBE education mode for engineering certification is introduced. Under the TOPCARES-CDIO methodology, combined with the blending education mode, the training objectives and graduation requirements of big data professionals are confirmed.

At the same time, the school and the enterprise have constructed the integrated blending education system, including the curriculum system and the project practice system of the integration of production and education in class, the integrated practice system and the quality education system of the extracurricular tutor system, as well as the implementation and adjustment of the evaluation and feedback mechanism are synchronized, to realize the closed-loop of talent training.

In the implementation and exploration of blending education, taking the project "data acquisition and preprocessing practice" as an example, this paper expounds the mapping process from training objectives to CDIO three-level ability indicators. Through the reverse matrix, the course objectives, assessment methods, teaching methods and learning methods are designed. Through the introduction of blending education platform, the centre of students, the teaching implementation of each link, such as pre-class, in-class and after class can be improved, to achieve the cultivation and improvement of students' professional ability, learning attitude and habits, lifelong learning ability. It is conducive to the improvement of students' software realization ability and the cultivation of big data professionals who can meet the current needs and future development.

After the practical exploration of this major, the OBE education mode and TOPCARES-CDIO methodology are combined to design the talent training mode. The practice of integrating blending education model proves that the model can achieve good results in higher education talent training of big data.

ACKNOWLEDGEMENT

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WHOLE PROCESS ENTERPRISE INTERNSHIP INVOLVING “SIX ELEMENTS” BASED ON CDIO

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ABSTRACT

Enterprise internship is not only an important method to implement CDIO engineering education, but also a complex engineering system involving multi-party interests and cooperation. Based on an in-depth study of the connotation of enterprise internship and the win-win points of all parties, using CDIO and the outcome-based education (OBE), this paper proposed an enterprise internship involving the “six elements” of orientation integrated design, target indexation, curriculum-based design, diversified implementation modes, effective evaluation and improvement, and institutional operation and management, which covers the whole process of talent cultivation from enrollment to graduation. To implement the proposed enterprise internship, a "six common" cooperation mechanism is constructed. Based on the enterprise internship involving “six elements”, a four-year coherent curriculum combining enterprise internship and on-campus courses is developed, which contributes to the talent cultivation mode with engineering abilities training as the mainline. The curriculum has been applied on the Department of Automation at Beijing Institute of Petrochemical Technology (BIPT) and the outcomes from the curriculum are reported in this paper.

KEYWORDS

Enterprise Internship, CDIO, Outcome-Based Education, Curriculum Design, Cultivation Objectives, Continuous Improvement of Education

INTRODUCTION

Enterprise internship is an important method to implement CDIO Engineering Education. But there are some problems in the implementation process, such as illegibility of personal positioning and orientation, simple form, empty content, poor implementation effect, etc. The disconnection between internships and on-campus curriculum weakens the effects. Therefore, the key point and difficulty in the implementation of CDIO is how to break through traditional intern mode and innovate internship curriculum and teaching methods, and thus to build a practical internship curriculum which aims at developing students’ practical engineering ability.

At home and abroad, a great deal of research and practice have been carried out on the construction of practical teaching system of engineering education. Wang, et al. (2017) analysed two paradigms of modern engineering education system in China. The Ministry of Education of China has put forward the requirement of " taking the construction of new engineering disciplines as a powerful hand to lead the reform of higher education" (Gu, 2017). In August 2017, MIT has launched a new round of engineering education reform, the "New Engineering Education Transformation" (NEET) program. Aiming to plan engineering education to return to the essence of engineering practice (Xiao & Qin, 2018).

German engineering higher education has effectively implemented the dual system for a long time, which organically integrate classroom theory and enterprise practice, aiming to organically integrate the dual identities of students and apprentices, and promote the collaboration of dual entities between universities and enterprises. Corporate internship is the most important part of the practical teaching system of the German University of Applied Sciences. It includes pre-entry internships and two internship semesters (arranged in the third and sixth semesters, respectively). The purpose and content of each internship are different, but the three of them constitute an organic whole. Enterprise internship and theoretical teaching are carried out parallel and gradually deepened, becoming an important measure to cultivate students' practical ability and the ability to solve engineering practical problems (Xu, 2017; Chen, 2015).

The main characteristics of French engineer education are multi-level practical training and a large number of practical courses (Wang & Jiang, 2014). Many courses are taught by experts or engineers from companies, and the teaching mode is divided into lecture and manual operation. During the study period, students must perform internships of varying duration in the enterprise. These internships are important parts of the teaching process. The internship mode is "three-stage internship", and it is strictly supervised in three parts: pre-internship related course preparation, internship approval and internship report defence. Enterprise Cognitive Internship: In the first academic year, the student worked as a worker will go to the enterprise for one month to gain basic knowledge of enterprise management and professional technology; Engineer Internship: In the fourth academic year, the students worked as a technician in the enterprise for half a year to contact and solve technical problems in actual industrial production; In-depth internship and engineer graduation internship: In the fifth academic year, the student went to the enterprise for half a year as an engineer, independently thinking about engineering problems and solving industrial production and engineering problems of a certain degree of difficulty, and writing graduation internship report around the technical problems in actual industrial projects that were solved.

Wan, et al. (2019) proposed a new paradigm of talent cultivation that runs through the entire process of training objectives, training modes, curriculum systems, teaching modes, teaching content, and training quality standards. Cultivate engineering practice ability through the school-enterprise collaborative education practice platform, and build a second classroom education system. Dong, et al. (2019) takes CDIO as the educational concept, divides the teaching content of production practice according to a certain level, and proposes a production practice mode in which universities and enterprises cooperate, and actual operation and simulation practice support each other. Sun, et al. (2013) built a multi-level internship teaching system for chemical engineering and technology speciality practice teaching per the CDIO mode, including chemical knowledge practice, chemical practice training, chemical production practice, and chemical graduation practice. Based on the CDIO engineering education concept, Jiang, et al. (2018) explored a new practical teaching mode centred on the construction of corporate practical teaching bases, reforms in the evaluation of practical teaching results, and feedback on the quality of practical teaching.

Enterprise internship is a complex engineering system involving multi-party interests and cooperation. This paper investigates the connotation of enterprise internship and the win-win points of all parties. Based on CDIO and the outcome-based education (OBE), this paper proposes the "six elements" of orientation, goal, design, implementation, evaluation, operation for a whole project life circle and then combines all these "six elements" with the whole process talent cultivation mode of Department of Automation at Beijing Institute of Petrochemical Technology (BIPT). Finally, a whole process enterprise internship involving the "six elements" is constructed and a four-year coherent curriculum combining internship and on-campus courses is developed.

CONSTRUCTION OF A WHOLE PROCESS OUTCOME BASED ENTERPRISE INTERNSHIP INVOLVING THE "SIX ELEMENTS" OF ORIENTATION, GOAL, DESIGN, IMPLEMENTATION, EVALUATION AND OPERATION

We positioned the enterprise internship as the enterprise stage learning of school-enterprise cooperative education, which includes: enterprise visit, cognition practice, school-enterprise cooperative engineering practical courses, production practice, post-practice, graduation practise, etc., covering the whole process of talent cultivation from entrance education to graduation design and employment. The methods of practice include: centralization at the base, scattered in enterprises, tourism-class-hands-on mixture, mentoring, in-post, engineering case design, site visit, enterprise engineer lecturing, enterprise team leader lecturing, etc. All these practices have clear goals. Taking these practices as teaching stages, each stage has its objectives which can be given clear indicators, so the effect of practice can be evaluated. A two-level matrix (Dai, et al. 2017) is used to reverse design the enterprise practical course system and a complete outline of is made for each of the practical courses. Thus, a systematic solution to the problem of difficult enterprise practice is implemented.

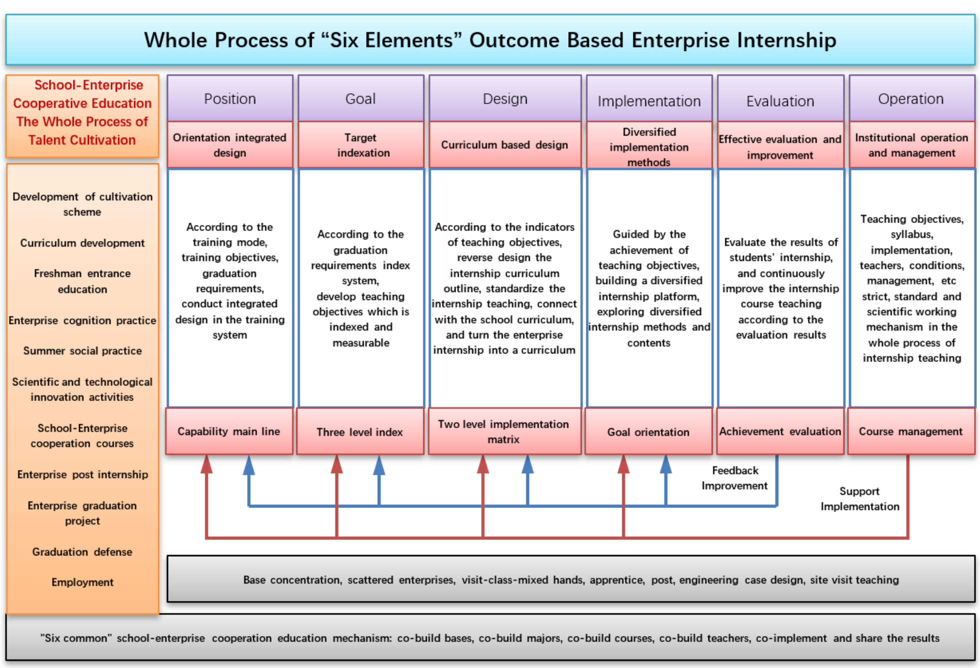

Figure 1. Whole process outcome-based enterprise internship involving the "six elements"

Whole Process: As the enterprise-stage learning of school-enterprise cooperative education, varying from cognition practice to graduation internship, enterprise internship covers the whole process of talent cultivation from entrance education to graduation project and employment, and is taken as one stage of collaborative education.

Orientation Integrated Design: Aiming at the cultivation of the ability to solve complex engineering problems, the internship and on-campus courses are integrated into the curriculum design to achieve the graduation requirements.

Target Indexation: To formulate clear, indexed and measurable enterprise internship objectives, a three-level index system of graduation requirements, index points and teaching objectives are established, which further determines the internship objectives.

Curriculum-based Design: According to the internship objectives indicators, the two-level realization matrix is used to reversely design the internship curriculum, including standardizing the internship teaching, and making the internship consistent with on-campus courses.

Diversified Implementation Modes: Oriented at the achievement of enterprise internship, diversified internship platforms, methods and contents are constructed.

Effective Evaluation and Improvement: Evaluation of internship effects is carried out according to the internship objectives. The orientation, goal, design and implementation of the internship course are continuously improved according to the evaluation results. Thus, the internship effect is eventually guaranteed.

Institutional Operation and Management: Enterprise internship is included in real curriculum management. The whole process of internship is strictly regulated, including objectives, syllabus, implementation, teaching group, environments, operation management, etc.

Outcome-Based: Reversely design the internship course system based on the teaching objectives and then improve the internship based on the evaluation of the achievement of the goal, that is, the internship effect.

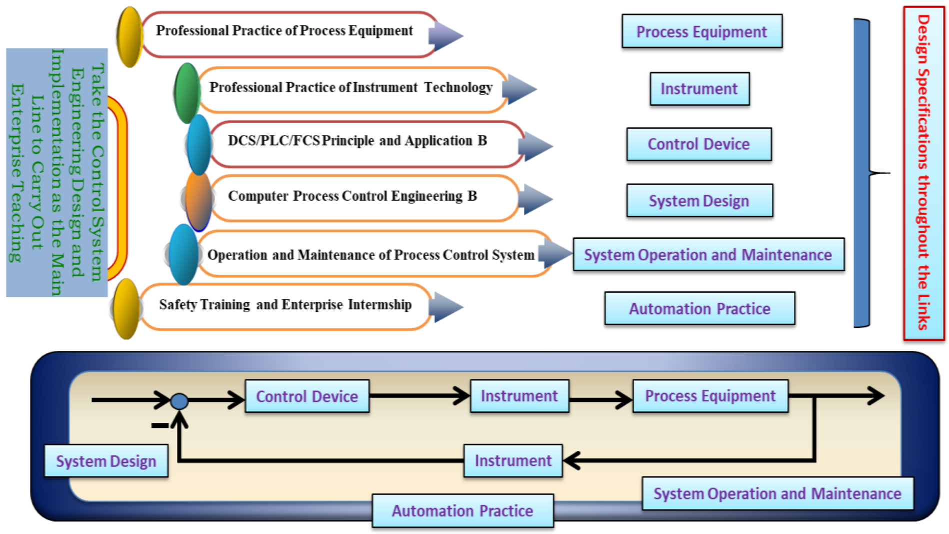

Figure 2. Designing the enterprise internship in the Department of Automation with control system design and implementation as the mainline

Taking Department of Automation in BIPT as an example, we decompose the graduation requirements based on the CDIO syllabus into three-level index system: graduation standard, index point and course teaching goal. The implementation of control system engineering design is the goal of enterprise internship teaching. The four-year coherent curriculum combining internship and on-campus courses is developed, which comprehensively promotes the establishment of professional training objectives, the formulation of graduation requirements index system, the integration of curriculum system, the reform of learning and teaching, and the construction of teaching staff. The talent cultivation mode with engineering abilities including design, practice and innovation as the mainline is constructed and implemented.

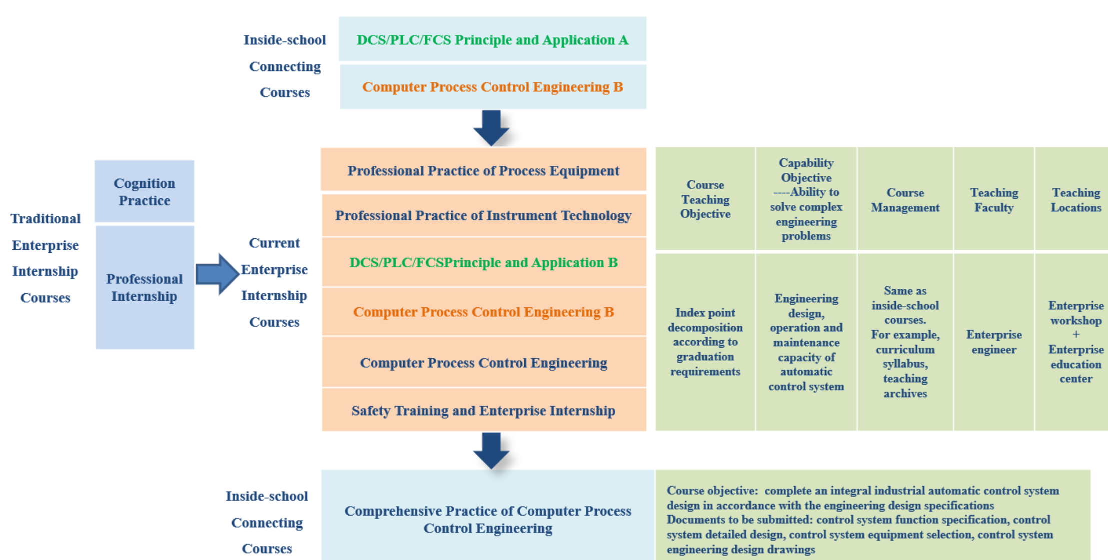

Figure 3. Inside- and outside- school integrated school-enterprise cooperation engineering practical courses for Department of Automation

CONSTRUCTION OF THE "SIX COMMON" COOPERATION MECHANISM

It requires an in-depth cooperation between college and enterprise to implement the whole process enterprise internship involving "six elements". But due to the unclear orientation, vague objective, void content and poor implementation effect, there seems to be no win-win point for enterprise internship. Therefore, insufficient internship funds are invested by our college and the enterprises also take little interest in the cooperation. To solve the difficulty in enterprise internship arrangement, a thorough investigation was made by industry representatives, teachers and leaders of our college. It is found that what college needs are the engineering environment, engineering cases and teachers with engineering background. The investment of college is education funds, an open and organized education market, teachers with research backgrounds and their research achievements. On the other hand, what the enterprises have offered are engineering environment for talent training, engineering cases and teachers with engineering background. The demand of the enterprises is human resources, talent resources, education market, capital and benefits of scientific and technological achievements. Moreover, it is found that the school demand and the enterprise match well, but the school investment and the enterprise demand match badly. Thus the win-win points which we are looking for are the talents, capital gains and scientific research achievements that can meet the demand of enterprises. Therefore, more funds are invested, the talent demand of enterprises are tracked, and cooperation mechanism that can improve the matching degree are innovated. Thus the "six common" school-enterprise win-win cooperation mechanism which includes co-construction of base, department, curriculum, teachers, joint implementation and shared outcomes is proposed. After years of implementation, the "College-Enterprise", "College-Industrial Park", "College-Research institutes", "College-Industry Association", " College-Government" and other diversified internship platforms, modes and mechanism have been established as shown in Figure 4. The construction of a national engineering education centre and several practical teaching bases has effectively guaranteed the implementation of outcome-based enterprise internships.

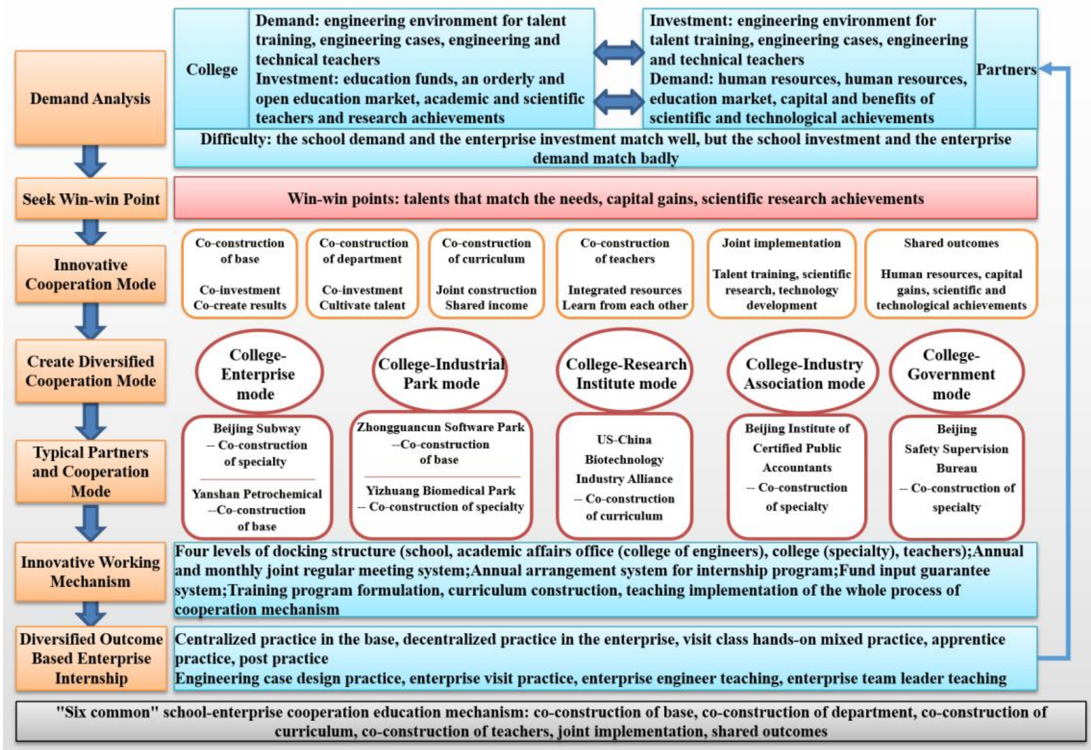

Figure 4. The "six common" school-enterprise win-win cooperation mechanism

School-Industrial Park Co-Construction Base: The cooperation between Department of Pharmaceutical Engineering and Beijing Yizhuang Biomedical Park has been implemented since 2012. In September 2013, College of Chemical Engineering and Beijing Yizhuang Biomedical Park decided to establish a "biomedical park class" after negotiation. Both parties agree that (1) The professional curriculum setting, syllabus, assessment method, and teaching implementation of the class are determined and led by the medical park. The teaching and practical teaching of the course is all undertaken by the selected teachers in the medical park. The teachers in the school only assist Manage curriculum standardization; (2) after the completion of the medical class, the students of the class shall be selected by the park enterprise for one year of enterprise training in the park enterprise; (3) when they graduate, they will make two-way selections according to both the needs of the enterprise and the individual wishes. At present, three students of the medical garden class have graduated, and one student of the medical garden class is about to graduate. Thanks to the joint efforts of both parties for several years, Yizhuang Biomedical Park became the “Beijing Municipal Off-School Talent Cultivation Base” in 2015.

School-Enterprise Co-Construction Department: BIPT has established a long-term cooperative relationship with Beijing Metro Operation Co., Ltd. Their branch office of communication signal and Department of Communication Engineering jointly build the professional field of Subway Communication and Signal. Their branch office of power supply and Department of Automation jointly build the professional field of Subway Power Supply. Every year, professional trainings are provided for students in four professional fields: subway line communication, signal, automatic ticket sales (AFC), and power supply. After taking the late-stage customized subway courses, some students go directly to the subway company to accomplish their graduation project and get employed.

School-Industrial Park Co-construction Courses: In 2012, BIPT and Zhongguancun Software Park successfully co-established the “National Engineering Practical Education Centre” and “Beijing-level Off-campus Talent Cultivation Base”. The “group-to-group” cooperation mode adopted has changed the conventional school-enterprise cooperation education mode of “point-to-point” or “point-to-face” implemented in the past, which has brought the superiorities of our College of Information Engineering into full play. Moreover, this co-construction has a good reference for BIPT to concentrate their efforts to build a high-level engineering application discipline group and improve efficiency in teaching management. Now, Zhongguancun Software Park not only provides engineering practice education for majors of Information Engineering and Mathematics in our college, but also provides open student training services for other universities.

CONSTRUCTION OF THE TALENT CULTIVATION MODE WITH TRAINING OF ENGINEERING ABILITIES INCLUDING ENGINEERING PRACTICE, DESIGN, AND INNOVATION AS THE MAINLINE

An in-depth cooperation is both the most important mode for high-level cultivation of applied engineering talents and the most difficult and weakest step. The whole process enterprise internship involving "six elements" solves this problem. The "six common school-enterprise win-win cooperation mechanism ensures the implementation. Thus the school curriculum and enterprise practice, theory teaching and practice teaching, general education and professional education, basic courses and specialized courses are integrated. Moreover, with the orientation of training target and graduation requirements, engineering ability training as the mainline, a two-level realization matrix is adopted to implement the integrated curriculum system design, which further pushes forward a systematic and comprehensive implementation of talent cultivation mode focusing on the training of engineering innovation ability (Dai, 2017). The new model has not only promoted the formulation of training objectives and graduation requirements index system, promoted the integration of curriculum system and curriculum outline revision, but also strengthened the connection between school courses and enterprise practical courses. Moreover, it promoted the construction of the teaching staff. Focusing on the cultivation of engineering practice ability and innovation and entrepreneurship education, the training mode with engineering practice, engineering design and engineering innovation ability as the mainline has been respectively constructed and implemented in different departments. This has led to the education and teaching reform of the whole school through experimental departments of excellence.

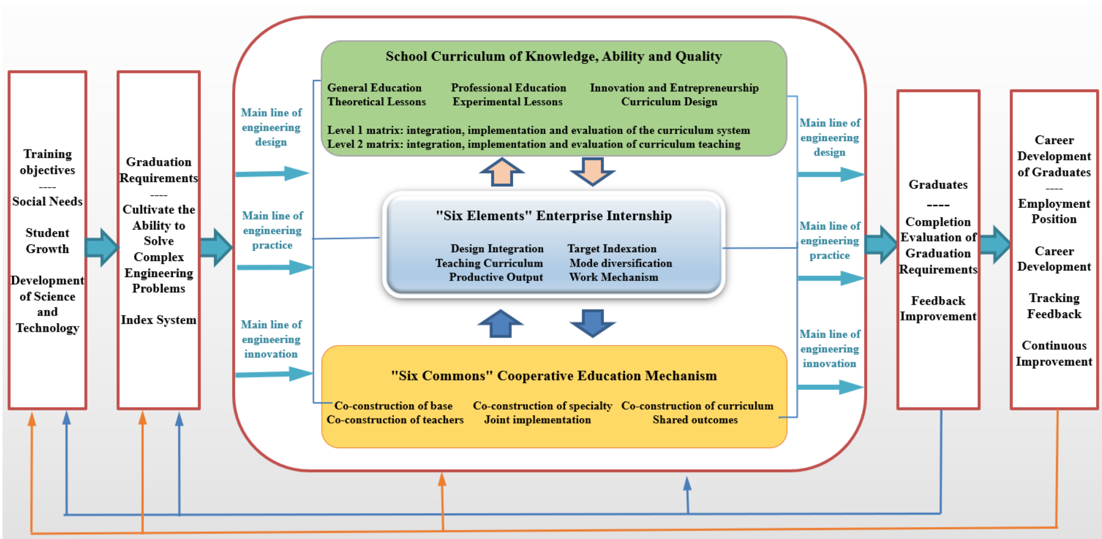

Figure 5. The talent cultivation mode with abilities training as the mainline

Construction and Implementation of a Talent Cultivation Mode Focusing on Engineering Training of Practice Ability

The automation major has implemented an application-based automation system of "one competence mainline, two-level realization matrix, and three-stage cooperative education" to prepare engineers for talent cultivation. With the goal of competence development, it has comprehensively integrated and restructured the curriculum system, formulated curriculum outlines and teaching implementation plan, students are trained around the system design, product integration, engineering installation, system commissioning, device commissioning and maintenance of an actual production device or actual engineering project to complete the process of training for the entire life cycle of an engineering product.

The major of mechanical engineering, to strengthen the cultivation of engineering application ability, combine knowledge learning, ability training and engineering practice to form a "one mainline + two pillars + three modules + four cornerstones" of the entire process of engineering application ability training as the mainline of talent cultivation mode, construct a learning system that combines the "engineering quality, engineering foundation, engineering technology" knowledge transfer system with the "engineering quality training, engineering technology training, and enterprise engineering practice" ability training system.

Construction and Implementation of Talent Cultivation Mode Focusing on the Training of Engineering Design Ability

Chemical engineering and technology major, the four-year practical teaching and theoretical teaching of the university with engineering design ability training as the mainline to build a talent training program, in the four "designs" of basic design, professional design, factory design, product and process design and research, three internships including preliminary internship, vocational internship, and professional internship are interspersed.

Construction and Implementation of Talent Cultivation Mode Focusing on Training of Engineering Innovation Ability

Taking students to participate in discipline competitions, scientific research practices, and innovation activities as carriers, relying on internal and external practice bases to build platforms for innovation and entrepreneurship projects, optimize talent cultivation modes, and integrate innovation and entrepreneurship education throughout the entire process of talent training, and build a perfect innovation and entrepreneurship education system, and formed a new mechanism of collaborative education involving schools, local governments, enterprises and institutions. Students' innovation and entrepreneurship ability has been greatly improved, and innovation and entrepreneurship achievements are gratifying.

Since 2013, a total of more than 3,200 students from 817 project groups have received support from various types of "University Innovation and Entrepreneurship Training Programs" at various levels. Each year, more than 130 students participate in the program, about 4000 students take part in it, with a large number of students participating in it and benefiting from it, forming a good echelon structure. Organized the school selection and training activities of chemical engineering design competitions, mechanical innovation competitions, electronic design competitions, mathematical modelling competitions and other discipline competitions, to achieve the full coverage of relevant professional students. Since 2011, our university has won a total of 1,015 science and technology competition awards at or above the provincial level, including 416 national awards and 599 provincial awards. In 2016, our school students won the first prize in Beijing second and the 4 prize in the three prizes of the first prize in the "Internet +" College Student innovation and entrepreneurship competition in China. The project "pipeline inspection robot" was the only one of the Beijing municipal colleges and universities to enter the national competition and win the bronze medal of the national finals. In 2014 and 2015, the practice base of comprehensive innovation education for college students and the practice base of comprehensive innovation education for mechanical engineering were successively awarded the "Beijing University demonstration innovation practice base in school". In 2017, the employment and entrepreneurship guidance centre of our university was awarded the "Beijing demonstration entrepreneurship centre", and our University has become the "Beijing demonstration University of deepening innovation and entrepreneurship education reform".

CONCLUSION

Mode innovation: Take enterprise internship as a breakthrough, and systematically implement a talent training mode focusing on engineering ability training

Difficulties in implementing the "Excellence Plan" were solved. The constructions of graduation requirement index system, curriculum system and teaching groups were promoted. Each department has established corresponding cultivation mode with engineering abilities of practice, design and innovation as the mainline.

Program innovation: The "six elements" outcome-based enterprise internship program was proposed and implemented systematically

Based on the investigation of the connotation and elements of outcome-based enterprise internship, we broke through the traditional internship model, designed a novel internship curriculum system, and constructs an outcome-based enterprise internship of "orientation integrated design, target indexation, curriculum-based design, diversified implementation modes, effective evaluation and improvement, and institutional operation and management ". Thus, system solutions have been proposed and implemented for the difficulties of internship.

Mechanism innovation: Explore and practice the "six commons" school-enterprise cooperation and win-win cooperation mechanism

Based on multi-party collaboration, increasing investment, and in-depth cooperation, several win-win modes have been found. In terms of the whole internship process and all elements of teaching, bases, departments, courses, teaching groups have been co-constructed and all the achievements are shared between our college and the enterprise. The "College-Enterprise", " College-Industrial Park", "College-Research institutes", "College-Industry Association", " College-Government" and other diversified internship platforms, modes and mechanism have been studied.

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REVIEWING AND IMPROVING IT ENGINEERING CURRICULUM IN TRA VINH UNIVERSITY

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ABSTRACT

The information technology engineering curriculum at Tra Vinh University has been designed in the CDIO approach 6 years before. Up to now, we have two cohorts of graduates from this program. Therefore, it is time to review to improve the curriculum. The program evaluation is based on standard 12 of CDIO. The paper focuses on reassessing the importance of intended learning outcomes and levels of competencies. To carry out this task, we have conducted a stakeholder survey including companies, alumni, lecturers, and students. Based on the surveyed results, the current program will be reviewed and improved.

KEYWORDS

Information Technology engineering curriculum, Importance of intended learning outcomes, achieved level of proficiency, expected level of proficiency, Standards 12

INTRODUCTION

This is the first time we review the Information Technology (IT) engineering curriculum, which has been designed according to the CDIO framework (CDIO, The CDIO Syllabus 2.0 An Updated Statement of Goals for Engineering Education, 2011), (Crawley, E. F., Malmqvist, J., Östlund, S., Brodeur, D. R., & Edström, K., 2014). Since the program has been implemented 6 years before, there have been 2 cohorts of graduates from this program. And this is the time we need to review the curriculum to aim at carrying out the censorship of the curriculum.

At the time of designing the curriculum, we selected the appropriate learning outcomes along with the expectations of the most viable student competency levels for the future indicated in the curriculum framework. However, it is necessary to initiate an experimental process to verify the developed curriculum, including every procedure from the curriculum to the specific teaching implementation. Besides, in the teaching process, both learners and lecturers must constantly update new technology and professional expertise to adapt to the global trend. To carry out the program evaluation, stakeholders evaluate the program implementation results after the actual implementation time. Based on that result, we review the achievements according to the original plan as well as the achieved results.

REVIEWING IT ENGINEERING CURRICULUM

Process of Survey

To collect data for the program evaluation, we conducted a stakeholder survey on 4 groups of stakeholders:

Group A - IT lecturers of our school and some lecturers of other universities having IT programs designed with the CDIO approach;
Group B - IT employers, IT workers and IT alumni of Tra Vinh University (TVU);
Group C - Final-year IT students of the school;
Group D - Third-year IT students of the school.

The content of the learning outcomes survey consists of three focuses: the importance of intended learning outcomes, achieved levels of proficiency, and expected levels of proficiency. The importance of the intended learning outcomes is assessed according to 4 levels: No important, Less important, Important, and Very important on a 4-point scale. Levels of proficiency are assessed according to 7 levels: Having no knowledge, Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation on a 7-point scale. Level-2 learning outcomes are surveyed as shown in Table 1. The interval scale is used to classify the surveyed value and Bloom's scale (Bloom, 1984) is used to assess the achieved and expected level of proficiency.

Table 1. Level-2 Learning Outcomes

Learning Outcomes	Level-2 Learning Outcomes
1.1	Knowledge of underlying sciences
1.2	Core engineering fundamental knowledge
1.3	Advanced engineering fundamental knowledge
1.4	Other support knowledge
2.1	Analytic reasoning and problem solving
2.2	Experimentation and knowledge discovery
2.3	System thinking
2.4	Personal skills and attitudes
2.5	Professional skills and attitudes
3.1	Teamwork
3.2	Communications
3.3	Communications in foreign languages
4.1	External, societal and environmental context
4.2	Enterprise and business context
4.3	Conceiving and engineering systems
4.4	Designing
4.5	Implementing
4.6	Operating

Results of a Survey About the Importance of Intended Learning Outcomes

With the review of the importance of the level-2 learning outcomes presented in Figure 1, it can be seen that all of the intended learning outcomes have a greater average score than 2.5 - an Important point frame. In particular, the learning outcomes 3.3 was rated by both surveyed teams A and B to have a greater average score than 3.50, the highest compared to the other learning outcomes belonging to a Very Important group. Meanwhile, the learning outcomes 1.4 is rated by both groups A and B, which has the lowest average score compared to the average of the remaining learning outcomes but they are still in an Important group. Besides, the remaining learning outcomes evaluated by both groups A and B have slight deviations compared to each learning outcome.

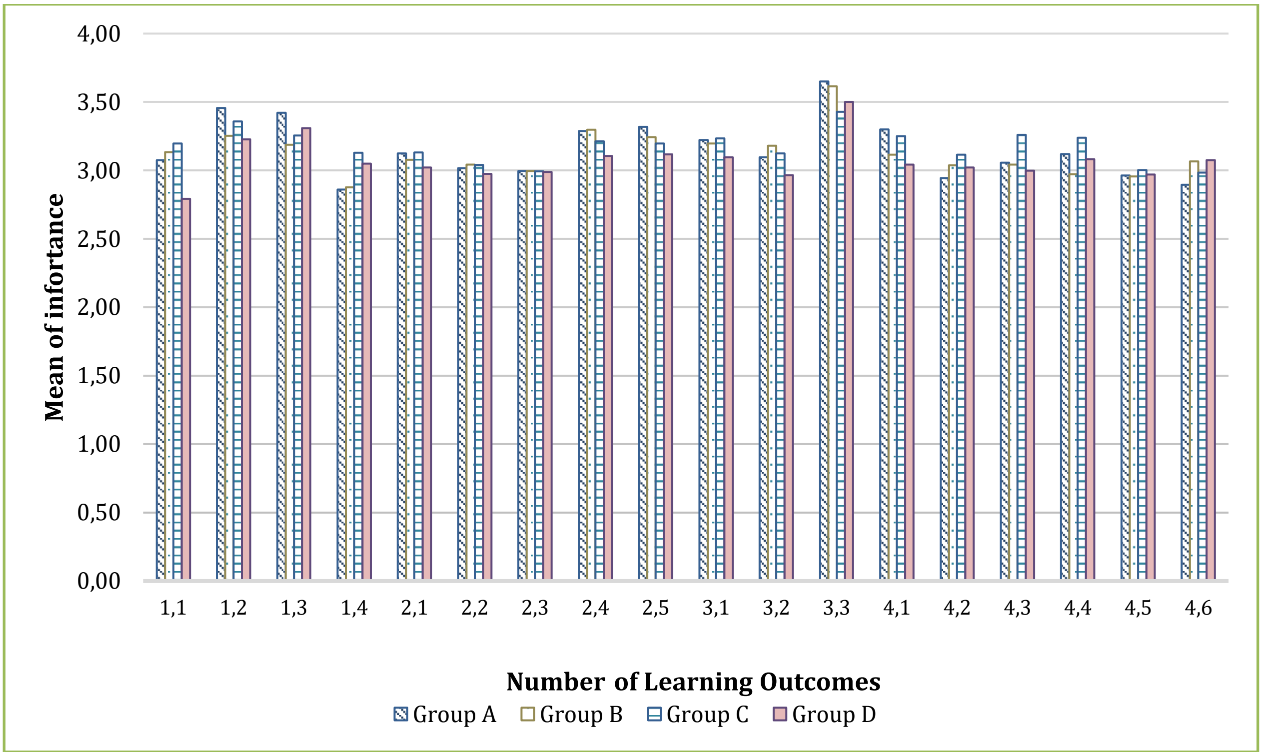

Figure 1. Diagram of the results of the survey of the importance

Students in both groups C and D have similar assessments regarding the importance of similar assessing standards of groups A and B. However, self-evaluation of group C has a higher average score than that of the others for learning outcomes 4.2, 4.3, and 4.4.

Results of Levels of Proficiency

Achieved Levels of Proficiency

According to the surveyed results presented in Table 2, generally, the average of the evaluation score of all 4 surveyed groups for the learning outcomes reached level Application on the Bloom's scale, except for the learning outcomes 2.2, 2.3, 4.5, and 4.6, which only reached level comprehension on the Bloom's scale. Therefore, compared to the initial goals of the expected level of proficiency, the program implementation process has initially achieved the set goals.

Table 2. Achieved levels of proficiency at level-2 learning outcomes

Learning Outcomes	Group A		Group B		Group C		Group D		Total Survey	
	Mean	SD	Mean	SD	Mea n	SD	Mea n	SD	Mea n	SD
1.1	3.64	0.35	3.50	0.48	3.55	0.27	3.65	0.4	3.58	0.37
1.2	3.96	0.10	3.69	0.17	3.97	0.29	3.97	0.29	3.90	0.20
1.3	3.91	0.30	3.63	0.26	3.97	014	4.19	015	3.93	0.14
1.4	3.76	0.17	3.31	0.28	3.99	0.23	4.27	0.15	3.83	0.17
2.1	3.26	0.08	3.35	0.18	4.02	0.19	4.09	0.33	3.67	0.11
2.2	3.20	0.18	3.27	0.15	3.92	0.15	4.04	0.15	3.57	0.14
2.3	3.34	0.09	3.10	0.18	4.01	0.19	4.07	0.13	3.52	0.09
2.4	3.36	0.11	3.43	0.22	3.93	0.15	4.17	0.21	3.72	0.08
2.5	3.43	0.10	3.44	0.21	4.02	0.13	4.09	0.22	3.75	0.07
3.1	3.40	0.11	3.40	0.18	4.18	0.16	4.21	0.17	3.80	0.10
3.2	3.22	0.18	3.45	0.16	3.90	0.19	4.05	0.14	3.66	0.08
3.3	3.10	0.00	3.31	0.00	4.43	0.00	4.08	0.00	3.73	0.00
4.1	3.40	0.07	3.46	0.11	4.14	0.10	4.13	0.06	3.78	0.00
4.2	2.96	0.07	3.25	0.13	4.13	0.26	4.01	0.12	3.59	0.08
4.3	3.25	0.10	3.36	0.15	4.13	0.22	4.12	0.19	3.71	0.07
4.4	3.40	0.12	3.35	0.09	4.05	0.23	4.07	0.16	3.72	0.05
4.5	3.06	0.22	3.27	0.10	3.85	0.21	3.99	0.16	3.54	0.08
4.6	3.09	0.12	3.18	0.17	3.85	0.15	4.15	0.19	3.57	0.10

However, when considering each specific output group learning outcomes 1.1, 1.2, and 1.3 evaluated by the whole group illustrate level Application on the Bloom's scale. Additionally, learning outcome 1.4 was evaluated level Comprehension on the Bloom's scale by group B level. Compared to the goal of the expected levels of proficiency in the curriculum, the requirements have been reached. This is a positive result of the efforts to achieve the goals of the curriculum.

Besides, both groups A and B strictly evaluated levels of proficiency regarding learning outcomes from 2.1 to 4.6. Therefore, these learning outcomes only reach level Comprehension on the Bloom's scale. However, there is an average score which has proximity to level Application on the Bloom's scale. In contrast, two groups C and D self-evaluated to achieve level Application on the Bloom's scale.

Expected Levels of Proficiency

The surveyed data of the expected levels of proficiency that need to be achieved in the future are shown in Figure 2. Figure 2 presents that all 4 groups showed their higher expectation on expected levels of proficiency than on achieved levels. All surveyed groups expected level Analysis on the Bloom's scale. Although the achieved average score in each group is different in each learning outcome, it is still in level Analysis on the Bloom's scale. Figure 2 illustrates that group A wanted to achieve significantly higher results than group B in learning outcomes like 1.2, 1.3, 1.4, and 4.1. However, regarding other learning outcomes, group B wanted to achieve higher than its counterparts – group A. For groups C and D, the expected levels of proficiency are not different between them and their expectations are higher than those of groups A and B.

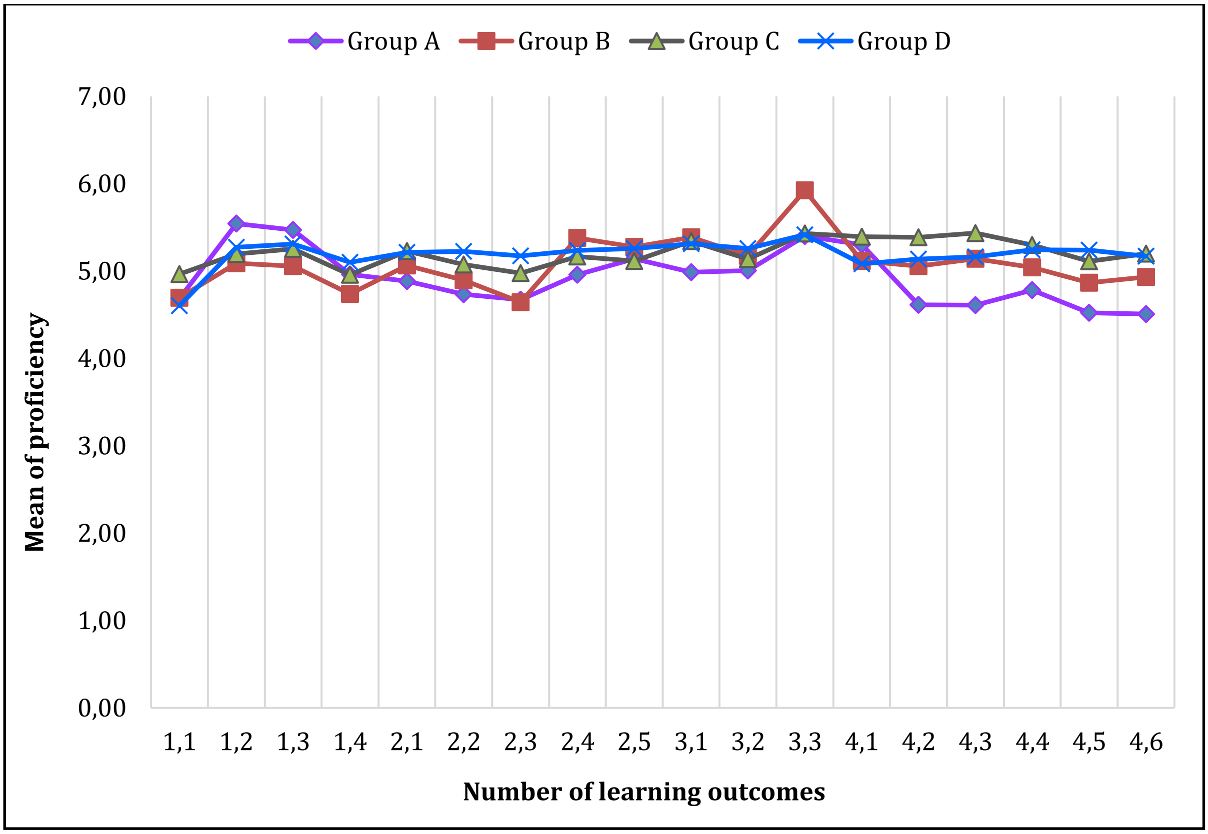

Figure 2. The levels of proficiency required from the 4 groups

To have more detailed data in the program evaluation and improvement, especially the data on group B's higher expectation on the intended learning outcomes comparing with group A's, the study continues to evaluate the results of the level-3 learning outcomes, which are presented in Table 3 (see Appendix).

According to the data, the average score of all learning outcomes expected by each surveyed groups reached level Analysis on the Bloom's scale. This result is the pieces of evidence that help us conduct a review and improvement to the curriculum.

CONCLUSIONS AND FUTURE WORK

Generally, the survey results indicated that the process of implementing the IT engineering curriculum at Tra Vinh University has reached the program objectives closely. Learning outcomes Technical knowledge and reasoning (1.1, 1.2 and 1.3) are evaluated by the whole group achieved the program objectives, meanwhile, learning outcomes from 2.1 to 4.6 are evaluated well by groups C and D. However, these output standards are lower than the expected program objectives in terms of the other groups. Therefore, we need to improve proficiency with all learning outcomes so that the evaluation of the stakeholders is going to be higher than the current proficiency.

We suggest that program improvements should include to following actions:

1. Continuing to survey students on teaching activities and the level of students' ability to meet the learning outcomes of each subject;
2. Not only enhancing experiential learning activities on each subject but also combining business partners for students to do design projects and graduation projects according to Standard 5 of CDIO (CDIO, CDIO Standards 2.0, 2010);
3. Improving the technical learning space to support students enhance the experience of designing and implementing experience according to Standard 6 of CDIO;
4. Assessing lecturers' competency in terms of professional skills and teaching competencies to plan training for lecturers following Standards 9 and 10 of CDIO;
5. Improving the process of assessing learning outcomes, performing learning assessment, using a variety of appropriate methods to learning outcomes that measure student's disciplinary knowledge, personal and interpersonal skills, as well as product, process, and system building skills according to Standard 11 of CDIO;
6. Continuously improving, the development of a course curriculum map. This requires developing an assessment plan, rubrics and other assessment tools, upgrading the Introduction to Engineering course, and enhancing lecturers' capabilities for CDIO and teaching skills;
7. Supplementing learning outcomes to improve personal, professional and quality skills, teamwork, communication, and CDIO skills, used in the inspection of the Accreditation Board of Engineering and Technology (ABET, 2019);
8. Identifying the levels of skills evaluation in the syllabus from Introduce –Teach - Use (ITU) to Teach – Use - Assess (TUA); and improving the level of competencies regarding expected learning outcomes.

With the solutions above, we are expecting to raise at least one Bloom's scale for all learning outcomes such as the survey results for the expected level of proficiency because of the following reasons:

We continue to survey students on teaching activities and the level of students' abilities on courses of the curriculum so that leaders can plan teaching and learning improvement skills for lecturers and students as they don't find competent skills. For example, lecturers will be supported to join activity experiences inside and outside the school to store up experiences for themselves. Furthermore, the technical learning space will be improved to support the hands-on experience of design, implementation, operation products, processes, and systems for students.

Established plans improve both process and form for assessment to support the evaluation of learning outcomes. The learning outcomes evaluation will be used with various forms and assessment tools that are suitable for different output standards. Moreover, by using a variety of assessment methods which adapt to a variety of learning styles, not only the reliability of the outcome results will be enhanced but also the evaluated data towards similarity in desired outcomes of the parties. Finally, improving both process and form for assessment also meets the continuous improvement process of the CDIO standard 12 as well as inspects of the Accreditation Board of Engineering and Technology next year.

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BIOGRAPHICAL INFORMATION

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Appendix

Table 3. Expected levels student's proficiency at level-3 learning outcomes

Level-3 Learning outcomes	Group A		Group B		Group C		Group D		Total Survey	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2.1.1 Technical Problem Identification	4.88	0.06	4.64	0.12	5.24	0.11	5.14	0.05	4.98	0.05
2.1.2 Modeling	4.68	0.11	4.77	0.33	4.79	0.00	5.08	0.12	4.83	0.08
2.1.3 Estimation and Qualitative Analysis	4.73	0.03	4.49	0.04	4.74	0.25	5.33	0.08	4.82	0.06
2.1.4 Analysis With Uncertainty	4.88	0.08	4.77	0.08	4.88	0.04	5.28	0.10	4.95	0.05
2.2.1 Hypothesis Formulation	4.89	0.06	4.86	0.12	4.95	0.08	5.16	0.17	4.97	0.03
2.2.2 Survey of Print and Electronic documents	5.20	0.17	4.86	0.20	4.96	0.04	5.33	0.18	5.09	0.13
2.2.3 Hypothesis Test, and Defense	4.78	0.08	4.92	0.15	4.88	0.22	5.08	0.14	4.92	0.10
2.3.1 Thinking Holistically	4.70	0.13	4.79	0.04	5.02	0.16	5.06	0.05	4.89	0.09
2.3.2 Emergence and Interactions in Systems	4.63	0.08	4.59	0.16	4.90	0.15	5.28	0.13	4.85	0.12
2.3.3 Prioritization and Focus	4.68	0.08	4.69	0.13	4.98	0.04	5.03	0.10	4.84	0.04
2.3.4 Trade-offs, Judgement and Balance in Resolution	4.68	0.04	4.50	0.05	5.00	0.20	5.33	0.12	4.88	0.08
2.4.1 Initiative and Willingness to Take Risks	4.75	0.18	5.36	0.16	4.95	0.16	5.25	0.08	5.08	0.05
2.4.2 Perseverance and Flexibility	5.10	0.06	5.53	0.10	5.19	0.06	5.31	0.10	5.28	0.05
2.4.3 Creative Thinking	5.02	0.03	5.23	0.08	5.21	0.19	5.03	0.13	5.12	0.09
2.4.4 Critical Thinking	4.93	0.12	5.11	0.09	5.33	0.12	5.22	0.13	5.15	0.04
2.4.5 Curiosity and Lifelong Learning	4.98	0.18	5.65	0.05	5.11	0.05	5.33	0.24	5.27	0.08
2.4.6 Time and Resource Management	4.98	0.04	5.38	0.00	5.21	0.00	5.29	0.06	5.22	0.01
2.5.1 Professional Ethics, Integrity, Responsibility	5.27	0.13	5.26	0.12	5.14	0.12	5.31	0.13	5.24	0.07
2.5.2 Professional Behavior	5.10	0.07	5.23	0.11	5.11	0.15	5.08	0.12	5.13	0.02
2.5.3 Proactively Planning for One’s Career	5.12	0.19	5.49	0.04	5.12	0.08	5.28	0.10	5.25	0.03
2.5.4 Staying Current on World of Engineer	5.08	0.20	5.13	0.24	5.10	0.11	5.36	0.05	5.17	0.08
3.1.1 Forming Effective Teams	5.08	0.08	5.37	0.17	5.21	0.13	5.32	0.11	5.25	0.05
3.1.2 Team Operation	5.08	0.10	5.37	0.19	5.44	0.10	5.27	0.16	5.29	0.08
3.1.3 Team Growth	4.90	0.07	5.12	0.16	5.43	0.10	5.21	0.06	5.16	0.10
3.1.4 Team Leadership	4.95	0.00	5.54	0.20	5.38	0.11	5.31	0.05	5.29	0.09
3.1.5 Technical Teaming	4.93	0.04	5.54	0.22	5.25	0.15	5.46	0.06	5.29	0.09
3.2.1 Communications Strategy	5.08	0.04	5.27	0.05	5.25	0.05	5.29	0.06	5.22	0.00
3.2.2 Graphical Communication	4.93	0.13	5.08	0.13	5.02	0.08	5.22	0.10	5.06	0.06
4.1.1 Roles and Responsibility of Engineers	5.30	0.14	5.12	0.05	5.39	0.15	5.08	0.00	5.22	0.06
4.2.1 Enterprise Strategy, Goals, and Planning	4.58	0.03	5.19	0.04	5.38	0.06	5.10	0.10	5.06	0.03

Level-3 Learning outcomes	Group A		Group B		Group C		Group D		Total Survey	
	Mean	SD	Mean	SD	Mean	Mean	SD	Mean	SD	Mean
4.2.2 Technical Entrepreneurship	4.65	0.07	4.92	0.11	5.39	0.15	5.17	0.12	5.03	0.00
4.3.1 Setting System Goals and Requirements	4.69	0.11	5.13	0.04	5.48	0.11	5.18	0.13	5.12	0.05
4.3.2 Defining Function, Concept and Architecture	4.43	0.04	5.12	0.05	5.46	0.25	5.21	0.18	5.05	0.02
4.3.3 Modeling of System and Ensuring Goals Can Be Met	4.73	0.06	5.10	0.18	5.36	0.19	5.22	0.05	5.10	0.06
4.3.4 Development Project Management	4.59	0.04	5.22	0.10	5.44	0.06	5.03	0.15	5.07	0.05
4.4.1 The Design Process	4.68	0.10	5.12	0.15	5.16	0.08	5.20	0.10	5.04	0.04
4.4.2 The Design Process Phasing and Approaches	4.55	0.09	5.00	0.08	5.36	0.19	5.36	0.10	5.07	0.05
4.4.3 Utilization of Knowledge in Design	4.88	0.04	5.19	0.05	5.43	0.20	5.25	0.00	5.19	0.06
4.4.4 Disciplinary Design	5.03	0.04	4.85	0.00	5.25	0.15	5.17	0.00	5.07	0.05
4.5.1 Planning manufacturing process	4.79	0.10	4.98	0.13	5.00	0.12	5.42	0.15	5.05	0.08
4.5.2 Manufacturing and assembly process	4.40	0.05	4.87	0.22	5.07	0.07	5.19	0.21	4.88	0.10
4.5.3 Implementation Management	4.38	0.03	4.74	0.16	5.26	0.04	5.11	0.05	4.87	0.06
4.6.1 Designing and Optimizing Operations	4.30	0.00	4.92	0.00	5.29	0.00	5.25	0.00	4.94	0.00
4.6.2 Training and Operations	4.54	0.13	4.83	0.11	5.24	0.06	5.15	0.11	4.94	0.05
4.6.3 System Improvement and Evolution	4.42	0.03	4.97	0.04	5.19	0.04	5.00	0.08	4.90	0.03
4.6.4 Operations Management	4.78	0.16	5.00	0.06	5.09	0.14	5.27	0.14	5.03	0.10

SUSTAINABLE INTERNATIONAL EXPERIENCE:
A COLLABORATIVE TEACHING PROJECT

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ABSTRACT

Within engineering education, there is an increasing need for providing our students with international experiences. This is most often done by exchange studies abroad. However, a majority of the students on engineering programs do not engage in any international exchange. This paper presents insights from a collaborative cross-disciplinary international project to give students international experience without having to travel. From both a sustainability perspective and a situation where e.g. a global virus outbreak stop students from travelling, solutions that give engineering students experience of working in an international setting are becoming increasingly important. Initial challenges, for the teachers involved in the project, that were addressed before the project started, included the assessment of students, the use of online collaborative tools, assessment of students and the dependence between the two courses. The learnings from the first and second iteration of the collaborative project were mainly focused around transparency, introduction of students to each other, communication, real-time issues and deadlines. By gradually remove these peripheral challenges for the students, resulting in making the students focus on the actual challenges surrounding the actual collaborative project. Even though this project is ongoing, the initial results clearly show that by integrating courses between different countries and disciplines, it is possible to create an environment that strengthens the students' ability in teamwork, communication and addresses the cultural and professional aspects of working as an engineer in an international context.

KEYWORDS

Internationalization, interdisciplinary, collaboration, Standards 1, 3, 7, 8

INTRODUCTION AND FRAMEWORK

The CDIO model (Crawley, Malmqvist, Östlund & Brodeur, 2007) with its standards and syllabus is an important tool when designing both study programs and courses within engineering. One thing that is addressed frequently within the philosophy of CDIO is collaboration, this is most notably addressed in the third section on the CDIO Syllabus 2.0 – Interpersonal skills: Teamwork and communication (Crawley, Malmqvist, Lucas & Brodeur, 2011). This is, of course, an important part of engineering education with most of the future professions of our students being focused on some kind of collaboration. However, most of the training is focused on the students working in teams with their classmates and communicating with teachers or with external collaborators within the industry (cf. Mejtoft, 2015; Mejtoft & Vesterberg, 2017). This is a great way to increase intrinsic motivation and also generate many of those generic skills that are sought after among our engineers.

From another perspective, internationalization is increasing in importance within engineering education around the globe (Guillotin, 2018). It is important not only for the students but also for Universities to increase the internationalization in our engineering programs. Universities that focus on collaboration (Srikanthan & Dalrymple, 2002) and internationalization, solving real-life problems (Damnjanovic & Novcic, 2011) are positively influencing perceived quality from a student perspective. This could influence not just future enrollment of students but also perceptions of a university's quality among other stakeholders, such as the industry and also helps universities to acquire a better position in the current international educational landscape.

Even though many of the engineering students at Swedish universities spend a semester abroad during their education, the majority of students do not. Hence, even though a large portion of our students acquire this important international perspective on their education, this is something that should be better integrated into the education programs to provide international experience for all, or most, of our future engineers. There are many motivations to why it is, and will become even more, important to give the students international experience without having to travel abroad. One being from an environmental sustainability perspective - the students' willingness to travel might decrease in the future. Therefore, students must be given the possibility to gain international experience without having to engage in international exchange studies. The situation with the Covid-19 global pandemic during spring 2020 makes this issue even more compelling when the global lockdown for several months is rendering it impossible for students to engage in exchange studies. Hence, it has become even more important to be able to create local (or even off-campus) training that includes international experiences during a student's time at the university.

This paper presents learnings and insights from an ongoing collaborative project to investigate the possibility of giving students high qualitative collaborative cross-disciplinary international experience without having to travel abroad. The collaborative project was set up between students and teachers that combined an engineering course at Umeå University, Sweden, and a marketing course at Edith Cowan University, Perth, Australia. This collaborative project has been running from 2017 and has, so far, been through two iterations, one in 2017 and another in 2019. This paper primarily addresses the parts of the CDIO Syllabus 2.0 (Crawley, Malmqvist, Lucas & Brodeur, 2011) that regards *Teamwork* (3.1), *Communication* (3.2), *Communication in Foreign language* (3.3) and *External, societal and environmental context* (4.1). The results are based on student evaluations, discussions with students and discussions among the teachers involved.

SETUP OF COLLABORATION

The goal of this project was to improve students' skills in both an international, inter-disciplinary and a professional context. The set up was, therefore, based on the students participating in an international online collaboration through digital platforms to provide students with a globally relevant and transformative social learning experience (Cela, Sicilia, & Sánchez, 2015). The locations of the universities within the collaboration was mainly chosen for two reasons – different time zones and the remote location of Umeå in the north of Sweden and Perth in Western Australia. For both of these locations, online collaborative technology is important to keep up with contacts at other locations both nationally and internationally. Furthermore, the established contact between the teachers at these two universities made it suitable for running tests.

The negative effect of working at more remote locations has during the last 15-20 years become less significant. This is mostly due to the introduction of online collaborative tools and social media platforms based on the ideas of web 2.0 (Boyd & Ellison, 2007; O'Reilly & Battelle, 2009). These types of tools and social media are today widely used by professionals to interact with colleagues, crowdsource ideas and engage with current and potential customers and users (Cripps, Singh, Mejtoft & Salo, in-press; de-Marcos et al., 2016). Nevertheless, not only the tools have become more intuitive and powerful, the users have become more used to online communication. Almost all students that were part of this collaborative project are digital natives (Prensky, 2001) and are used to working with general tools for online communication.

During both iterations of the collaborative project that has been carried out so far, the collaboration has been between engineering students on the five-year integrated Master of Science in engineering program in interaction technology and design at Umeå University in Sweden and marketing students at Edith Cowan University in Perth, Australia. During the first iteration in 2017, the fourth-year engineering course *Prototyping for Mobile Applications* and the third-year undergraduate marketing course *Current Issues in Marketing* were the basis for the collaboration. During the second iteration in 2019, the fourth-year engineering course *Technology for Social Media* was the counterpart to the postgraduate version of *Current Issues in Marketing* course at ECU. The reason for being able to use another engineering course was that it made it possible to collaborate during another semester and the two engineering courses are very similar in structure. The idea was that the engineering students created some kind of application or system and the marketing students provided the engineering students with a background investigation regarding the business potential for applications within the area when they started their work and, later on, created campaigns and marketing material for these.

INITIAL CHALLENGES ADDRESSED

Before the first iteration of the project was set up, several potential challenges were discussed among the teachers on the two courses. The major challenge that needed to be addressed involved the main problem for the teachers – the assessment and examination of the students. This is one of the most important issues to secure the grades to individual students and the continuation of the education for those studying on the respective programs. The main challenge in the design of the collaborative curriculum was because the teachers wanted all students to be able to finish and get a grade from their course even in case of collaborative problems arising. Hence, there could not be a total dependence between the different assessments on the two courses. The solution that was decided on beforehand was to use ad hoc flexibility throughout the collaboration. It was furthermore decided not to give the students all information about the project at the start of the courses but to rather give them the information on a need-to-know basis to gradually create a better understanding of the students' situation and made them aware of the fact that they were not depended on each other.

The second challenge that needed to be addressed before initiating the collaboration was regarding the use of online collaborative tools. The universities involved used different digital educational platforms - Edith Cowan University using Blackboard and Umeå University using Moodle and Sakai. Unfortunately, the bureaucratic systems around access to digital resources did not allow for students from another university to easily be added to the other university's educational platform. Instead of getting stuck in this situation, it was decided to flip this challenge into an advantage. Consequently, to create a more realistic situation, it was decided to ditch the ordinary educational platforms and move all students onto Slack, an online collaborative platform used in industry. Slack was then used to exchange information and ideas and submit results during the project. The reason for choosing Slack was its basic design with easy to use functions for collaboration between all students on the two courses (using public channels) and between specific groups discussing projects (using private channels).

The third challenged was since the semesters between the two universities differed. The courses started approximately one month apart with the Marketing course staring earlier than the engineering students. It was decided for the marketing students to do individual assignments that could be used by the engineering students later on during this time. The two courses ended at approximately the same time though.

RESULTS FROM FIRST COLLABORATION ITERATION

The first iteration of the collaborative project between Umeå University and Edith Cowan University was carried out in several steps with different degree of collaboration between the students (Figure 1).

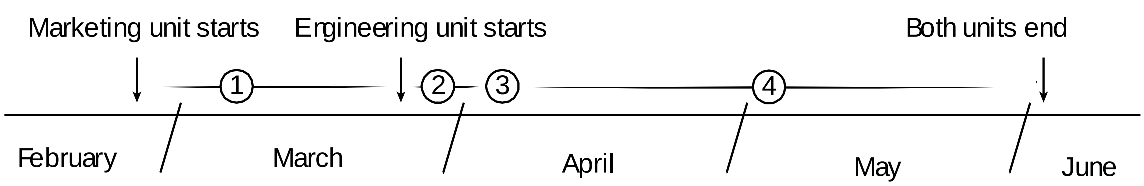

Figure 1. Timeline for the first iteration of the collaborative project.

1. The marketing students formed teams at the beginning of their course and created online public blogs containing information on the topic chosen for the project. The information was drawn from both academic and industry literature relating areas of marketing innovation such as smart home technology, connected devices, online media, gamification and environmental sustainability. The blog post formed both part the marketing students' assessment for the course and the basis for the initial investigation for the engineering students.
2. Later on, the groups formed by the engineering students reviewed the blog posts posted by the marketing students as input for their preliminary research to gather information for deciding on an idea and the need for their mobile application. Linking the assignments between the two courses, but not integrating them made it possible to partly solve the first challenged addressed regarding the dependence between the students. Hence, a situation where students could be assessed on the different tasks independently was

created. This was a good solution that lowered the fear of being dependent on someone that the student does not know and, hence, created a more secure feeling for the students.
3. After the initial research done within the area, the engineering students created a short document (approx. 1 page) and a short video (Figure 2) describing their proposed idea and app in English and posted it on Slack for the marketing students to evaluate. The video was a complement to the text and was created to more vividly be able to describe the core of their idea in a way that was easy to understand.
4. During the length of the course, there was ongoing collaboration regarding the development of the mobile applications.

Figure 2. A short video was created by the engineering students to describe the idea and concept of their application for the marketing students.

Analyzing the evaluations by the students on the two courses revealed that they liked the general concept with the collaboration around the project. However, they felt that the setup of the collaboration lacked structure and students on both courses from time to time struggled with the unknowns, as they felt somewhat dependent on students on the opposite side of the planet. However, analyzing the conversations and use of the online communication platform (Slack), it could be noted that the students exhibited skills in finding solutions and workarounds to complete their assessments when they experienced obstacles. The results of the collaboration and discussions among the teachers on the two courses concluded in several lessons learned, from a teacher's perspective, from the first collaboration:

- The unknowns need to be minimized, even if it means overwhelming information at the beginning of the courses. Hence, there is a need to explicitly explain how all parts of the collaboration and the project are going to work and how the students execute their role in each specific part.
- There were an uneven introduction and knowledge about each other since the marketing students got the videos from the engineering students and then "got to know them" through the videos. Hence, there is a need for a supervised real-time online introduction of the students, so all students have a feeling of having similar knowledge about each other.
- The time difference is a major problem for real-time collaboration, but this was part of the challenge. Hence, there is a need to provide the students with more natural real-time opportunities by setting Swedish lectures in the morning and Australia lectures in the afternoon.

- The dependence on material from the other course meant that when deadlines are not met on time, many students are sitting waiting. Hence, there is a need to set strict joint deadlines between the two courses and, foremost, make clear the consequences for the students and the collaboration of failing to meet these deadlines.

The collaboration, and consequently the communication, with students from another discipline, was valuable for the students. During an education program, most collaborations are either within the same group of students with students within a bordering discipline. In this case, the engineering students had to collaborate with marketing students and vice versa. These are students with different background and point of view but with the same goal for the project. Even though this created difficulties in communication, it also generated a more real situation as respect to their future profession. Hence, from a professional point of view, this became an important learning for the students and also something that made the students want to further tighten the collaboration to get a better understanding of the other group of students.

Due to limitation in both time for making the setup for the collaboration and the fact that this was the first iteration, the number of mandatory touchpoints between the students on the different courses were limited. One of the problems that occurred was that since both courses ended at the same time and it was needed to have the final presentations at the very end of the course (to give the students enough time to complete their tasks), it was hard to find time for final feedback between the two student groups. According to the students, they felt that “the collaboration ended in the middle of the course”, since no contact at the end of the project was mandatory. The feedback was instead given by the teachers.

Challenges that arose during this first collaborative project included: (1) stilted exchanges on issues due to time differences, (2) different understandings of cultural and professional priorities and (3) problem in aligning the timing of assessment of the two courses’ requirements. However, benefits to the students included, (1) experience to give and receive feedback to other student groups, (2) experiencing a new and international business culture, (3) experience of actual and real online collaborative work and use of digital collaborative technologies, (4) development of semi-professional online media skills and (5) solving the problems stated above. Furthermore, the engineering students were communicating and collaborating in a foreign language, which further increased the benefits from the collaboration.

RESULTS FROM SECOND COLLABORATION ITERATION

The main objective of the second iteration of the collaborative project was to address the problems that occurred during the first iteration. This was achieved by creating a tighter and more integrated collaboration and by forming stronger bonds between the students at the two universities. The problem with the understanding of the other students was addressed by setting up a formal real-time full class introduction using an online meeting application introducing the collaboration at the same time for both courses. According to the student evaluations, this created a better understanding of “who are the ones on the other side of Slack”. To further encourage the collaboration and to make the deadline stricter, another real-time full class online meeting was held in the middle of the course for discussions and feedback by the marketing students on the engineering students’ applications. Furthermore, real-time discussions between the groups in Sweden and Australia were encouraged during the collaboration but did, unfortunately, not occur to the extent desired. Another issue that was addressed was the problem with the collaboration ending too soon. As described above, real-time interaction was encouraged but was not the preferred way of interacting among the students. However, more online discussions were noticed on Slack during the latter part of the course then during the first iteration. To further stretch the “visible” part of the collaboration, a final feedback round was held at the end of the courses, which made the collaboration seem more integrated between the courses. This was, however, not done in real-time due to lack of time at the end of the courses.

From the student evaluations and discussions with students during the length of the courses, it was clear that when the initial problems from the first iteration were addressed, the students had comments regarding how the actual collaboration should be set up. The more integrated take on the collaboration increased the motivation among the students to deliver results. Nevertheless, when the collaboration became more integrated, they became aware of their lack of knowledge regarding Slack and the other online collaborative tools used.

When the initial teething problems were addressed it also became clear that the students were prepared to have even more integrated projects between the two courses. While the teachers view has been to keep the courses a little apart to shelter the students from problems that could arise from the collaboration, the engineering students requested even more integrated courses and projects. The challenge will be to create a full integration of the courses and still keep to the regulations of the respective universities regarding assessments and examinations. Learnings from the second iteration include:

- A more thorough introduction to Slack and the other online collaborative tools used should be offered to speed up the collaboration at the beginning of the units.
- Even more introduction to the other group of students and what they can expect from each other should be set up. This could be done by adding an introduction with each student group (i.e. each group of engineering students working with a group of marketing students). By supervising individual introductions, it should be possible for every individual student to be more in focus than during the class introduction.
- Better solution to how to set up projects when the semesters differ between the participating universities’ need to be discussed. This is mainly to make the most of the students’ time during the length of each student’s course.

ONGOING DEVELOPMENT

Even though evaluating and analyzing the project among the teachers involved in the collaboration revealed several challenges with the collaboration and, consequently, made the two individual courses more complicated to run, all teachers involved believed this type of international collaborative curriculum benefit the students to a great extent (cf. Chang & Lee, 2013). It is also believed that this gives the students that do not engage in exchange studies an international perspective of both their education and their future profession while still on their home turf. While new challenges have constantly emerged, there have been solutions to the initial challenges, which have made it possible for the students to focus on the actual collaboration and not on solving unrelated problems.

This collaborative project is ongoing, and the collaboration is further developed during spring 2020 with a third iteration of the collaborative project during March-June 2020. The challenges that are currently being addressed mostly focus on aligning the work among the two student groups to maximize the use of the students’ time. In the next iteration, the marketing students will not only provide background information but also provide timely feedback on the engineering students’ ideas. This third iteration became a real-time test of the idea since the

Covid-19 global pandemic not only made it impossible to travel abroad, but also made all students to work completely online for both courses. During this iteration, both the students at Umeå University and ECU was not allowed to take part in campus education and both courses were quickly transformed into online courses. This iteration is yet to be completed during early summer 2020, but many of the issues discussed in this paper have been addressed. The collaboration will be further developed during fall 2020 and during the fourth iteration in 2021, the idea is to make the marketing students to also come up with ideas during the four weeks they work before the engineering students start their course. In this way, the marketing students will become a client and the engineering students will work as a developer team. Additionally, the need to increase the spontaneous interaction between students and the number of different mandatory touchpoints between the engineering and marketing students will be addressed. Furthermore, the long-term goal is to develop more common assessments and common evaluation criteria based on both universities' regulations.

CONCLUDING DISCUSSION

The experience from the global lockdown during spring 2020 made it clear that it might not be possible to take international travel and, hence, the possibility for students to engage in exchange studies, for granted. It will be important that the issue with how to give students international experience without having to travel abroad is further raised at universities around the world. This paper presents insights and experiences from an international collaborative project to give students high qualitative collaborative cross-disciplinary international experience without having to leave their home turf.

Even though this project will be further developed, the initial results clearly show that by integrating courses between different countries and disciplines, it is possible to create a study environment that strengthens the students' ability to work both together as a team and towards other teams with other assignments but the same general mission (CDIO Syllabus 3.1). Having created a situation utilizing online collaborative tools with different degree of interaction (e.g. video meeting, voice call, chat, bulletin board, etc.) strengthen the students' ability to communicate (CDIO Syllabus 3.2). Working together with students in another country will, most certainly, also create a situation of communication in a foreign language for one part of the dyad (CDIO Syllabus 3.3). Setting all this up in an international perspective with an interdisciplinary counterpart addresses issues as cultural differences, the roles of the engineer in a larger context and also touches upon the impact of engineering on other parts of the economic and societal system (CDIO Syllabus 4.1).

It is to be believed that the importance of an international and global perspective on engineering education will continue to become increasingly important. However, it will also become important to incorporate this perspective in many of the courses that we offer to our students. This said, from a sustainability perspective, both in terms of the environmental impact, but also in terms of being able to create a system that can be continuously used in education is just as important. The objective of this paper is to describe one turn on creating a sustainable way of giving our engineering students an international perspective of their education and their future profession.

Furthermore, it is clear that having experience from working with international online collaboration and the knowledge about the tools necessary are competitive advantages in times when both professional collaboration and education are quickly moved online, such as spring 2020 and the Covid-19 global pandemic. Having the necessary technical and didactical knowledge among the teachers involved made the transition smooth.

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BIOGRAPHICAL INFORMATION

Thomas Mejtoft is an Associate Professor of Media Technology and appointed Excellent Teacher at Umeå University. He holds a PhD from the Royal Institute of Technology (KTH) in Stockholm and since 2011 acting as the director of the five-year Master of Science study program in Interaction Technology and Design at Umeå University. His research and teaching interests include not only media technology, interaction technology, interaction design, business development and students' learning, but also value creation, marketing issues and technological changes connected to the media and the media industry. He has been published in e.g. Journal of Strategic Marketing, Journal of Media Business Studies and Industrial Marketing Management and has presented at numerous international conferences within different areas including CHI, Anzmac and WMEMC.

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STRATEGIES FOR THE MATHEMATICS LEARNING IN ENGINEERING CDIO CURRICULA

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ABSTRACT

A marker of success for students in a curriculum of engineering is their performance in the first-year transition. Associated with the CDIO reform in the Faculty of Engineering at the Pontificia Universidad Javeriana (PUJ), strategies focused on supporting students in this transition have been defined. One of these strategies aims to develop mathematical thinking and strengthen students' skills for solving problems through a workshop parallel to the first-year math course. The workshop seeks for students to establish a model of learning mathematics focused on reinforcing basic concepts (numerical, algebraic and variational), building up self-efficacy, developing metacognitive skills, and mathematical abstract thinking. Therefore, this strategy has implied challenges in training and following-up faculty. Results confirm that students recognize the importance of developing mathematical skills for their learning process in engineering. Additionally, the perception of professors supports the hypothesis that students need to reinforce previous concepts from school and develop problem-solving skills to achieve engineering design projects. The workshop has allowed a better adaptation of first-year students to their academic process at university.

KEYWORDS

Engineering, Higher Education, Math Performance, Self-regulated learning, Self-efficacy, Standards 7, 8

INTRODUCTION

In higher education, developing mathematical skills is crucial to succeed in areas as engineering or science. Therefore, self-regulated learning (SRL) and self-efficacy (SE) are essential for mathematics performance. The SRL model is described as a "constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behaviour, guided and constrained by their goals and the contextual features in the environment" (Pintrich, 2000 as cited in Roick & Ringeisen, 2018, p. 148). Bandura (1991) refers that SE influences individual behaviour and determine how students assume challenges and obstacles (as cited in Musso et al., 2019).

In the learning process, students need "a variety of cognitive and behavioural strategies" (Zimmerman, 2000 as cited in Zheng et al., 2020, p. 2). Boerner et al. (2005) and Marsh et al. (2006) mentioned the importance of cognitive strategies to link new information with previous learning and metacognitive strategies to control attitude and motivation as cited in Roick et al. (2018). For the successful application of these strategies, it is necessary to stimulate students' self-efficacy.

In this context, learning strategies might facilitate and build up students' engagement in mathematics. Therefore, it is fundamental to create extracurricular learning spaces for supporting students transition to higher education, particularly, in engineering programs where students require mathematical skills for engineering design.

The Importance of Self-Regulated Learning in Engineering Design

In the field of STEM education, “engineering design requires particular knowledge schema and design processes” (Zheng et al., 2020, p. 2). “An engineering design activity usually involves high-order skills such as observing, modelling, modifying, analyzing, and evaluating a project” (Fan & Yu, 2017 as cited in Zheng et al., 2020, p. 2). The skills above mentioned are based on the self-regulated learning model, where students manage and monitor their learning process using different strategies.

The SRL model proposed by Schmitz and Wiese (2006) consists of three phases: students establish goals for the task in the pre-action phase, recognize and execute cognitive and metacognitive strategies to achieve the previous goals in the action phase, and evaluate outcomes, behaviours and strategies in the post-action phase. In the last phase, as cited by Roick et al. (2018), the feedback influences self-efficacy and determines the plan for the subsequent pre-action phase.

Many researchers affirm that “self-regulation plays an important role in students' efficiency and performance while completing an engineering design project” (Lawanto & Johnson, 2012 as cited in Zheng et al., 2020, p. 2). Based on this, the SRL model is relevant for an engineering learning environment, where students need to gain a variety of skills and learning strategies to cope with their academic performance and educational process.

The Interplay of Motivation and Complexities in Mathematics Learning

For higher education context, mathematics is considered a fundamental subject. In engineering, mathematical skills are needed to build up logical thinking, deal with problem-solving situations and achieve a high performance in other subjects applied to the discipline. Despite its application in engineering, many students experience obstacles and anxiety in their mathematics courses. Low performance in these courses may trigger an academic risk and influence students' motivation.

To overcome those obstacles, motivation is a crucial element in the learning process to engage students and develop autonomy. Motivation has been “classified into intrinsic and extrinsic motivation, with intrinsic motivation referring to doing something because it is inherently interesting or enjoyable and extrinsic motivation referring to doing something because it leads to a reward” (León et al., 2015, p.156).

Engineering students may be motivated to finish their studies for extrinsic reasons such as having a great job or position, but they may understand that mathematics courses are important for their learning and career success (León et al., 2015).

Regarding the effect of motivation in the learning context, engineering programs should be focused on laying out and implementing strategies to enhance students' self-efficacy. Fast et al (2010) have found that students with higher levels of self-efficacy are more likely to achieve a higher math performance (as cited in Musso et al., 2019).

ACADEMIC PERFORMANCE

The academic performance in mathematics has been a concern for the Faculty of Engineering at the PUJ. Some students from advanced courses have experienced difficulties for solving engineering problems. In response, the Faculty of Engineering has focused its efforts on the design and implementation of the basic skills workshop for supporting the students' learning process in mathematics. The workshop is focused on the first-year transition to overcome the obstacles mentioned above since students entered university.

Students' math deficiencies are evident in the State Exam, the entrance test and the math courses performance as described below.

Saber 11 Test

In Colombia, the State Exam for secondary education is the Saber 11 test. This test evaluates five components: mathematics, critical reading, social and civic, science and English. The exam scores each component in different levels, the performance levels for the mathematics component are described in Table 1.

Table 1. Performance levels Saber 11 test

Level	Score	Description
Low	0 – 35	The student reads punctual information but evidences difficulty to integrate different variables and compare data sets.
Intermediate	36 - 50	The student can make comparisons between a variety of data sets in contexts with little information.
High	51 - 70	The student understands information from different types of charts in many contexts, compares data sets with variables and makes algebraic and arithmetic transformations.
Very High	71 – 100	The student solves problems applying probability, trigonometry, functions and algebraic properties concepts.

The results in the mathematics component are presented in Figure 1. According to the classification in Table 3, the 51% of students have a high performance and the remaining 49% of students are classified on average at a very high level of performance.

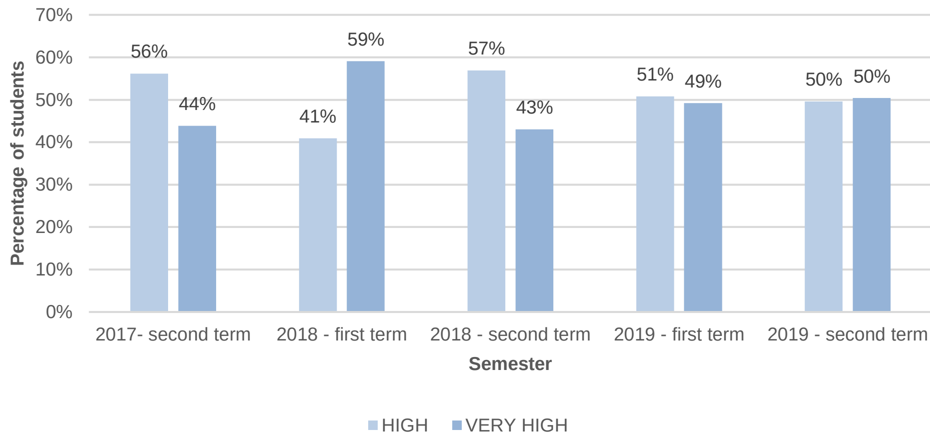

Figure 1. Historical Math Performance of Saber 11 test

Although the results seem to be satisfactory, the students present serious difficulties in addressing mathematical and numerical concepts. As shown in Figure 1, the historical performance in mathematics of first-year students has been similar.

Entrance Test

The entrance test for engineering programs at the PUJ has been applied since the second term of 2017. The test is composed of 30 questions divided into three components: numerical (7 questions), variational (9 questions) and algebraic (14 questions). The historical performance in the entrance test is presented in Figure 2.

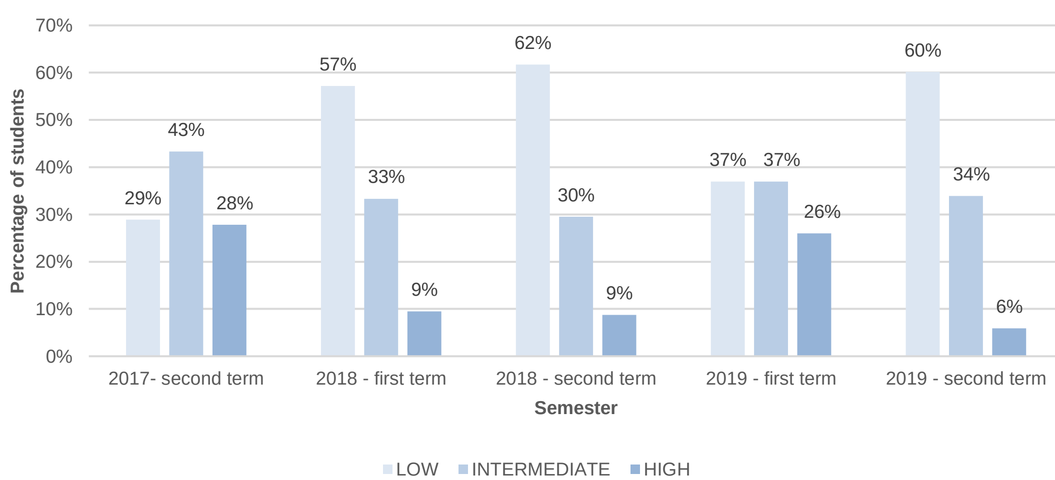

Figure 2. Historical Performance of Entrance test

Most students underperform, and only 16% of students have a high performance on average. These results evidence that students need to strengthen basic concepts and develop skills to enhance mathematical thinking.

Math Course Performance

For many engineering students, calculus is one of the most difficult courses in their academic field. This is evident in the high rate of students that fail mathematics subjects. In engineering programs, the rate for first-semester math course failures is 25% on average, and the early dropout rate (first-year transition) varies between 20% and 30% of the students.

As shown in Figure 3, the highest rates of failure were presented in 2018. For the last two terms, the rate decreased and the behaviour is similar.

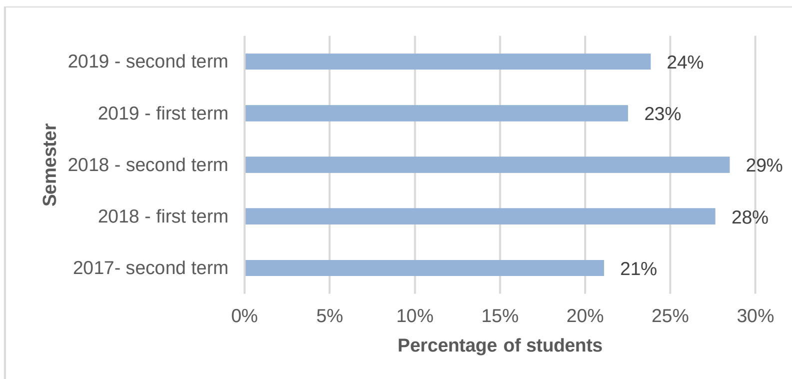

Figure 3. Historical Performance of math courses

These results evidence that students need learning spaces to develop skills and strengthen their previous knowledge from school to succeed in mathematics. Therefore, ensuring student success becomes a priority for the Faculty of Engineering.

STRATEGY FOR DEVELOPING MATHEMATICAL THINKING

The CDIO Initiative

In engineering education context, the CDIO framework provides the guidelines to improve the quality of engineering. Students may build up skills to overcome discipline challenges and program goals through the different transitions.

In response, the Faculty of Engineering has been working in the development and deployment of strategies to support the students' learning process. Furthermore, those strategies aim to reinforce students' self-efficacy and promote autonomy. To facilitate the learning process, the program should make efforts to increase intrinsic motivation in students. Students may recognize the importance of developing skills and applying cognitive and metacognitive strategies for their educational process in an engineering environment. In this context, students articulate knowledge, skills and abilities for developing engineering design projects (CDIO STANDARD 7).

For supporting the learning process in mathematics, the Faculty designed a basic skills workshop. This initiative is based on active learning, where students face problem-solving situations applied to their discipline, and working individually and team working (CDIO

STANDARD 8). Additionally, the workshop activities involve strategies for time management and autonomous learning.

Basic Skills Workshop

The workshop is an extracurricular learning space that accompanies all first semester students for developing mathematical thinking and reinforce previous math concepts learned in high school. The workshop approach is to build up self-efficacy and encourage students to assume new challenges in mathematics.

The learning environment at school is widely different at university, students have to assume new responsibilities, modify their habits, manage the time between academic and non-academic activities, prioritize tasks, build networks with peers and adapt to the exigency and complexity demanded by the university. In the adaptation process, students need tools and strategies to cope with new experiences and situations.

The strategy has been implemented since the second term of 2017 and adjustments have been made to the structure according to students' needs and teachers' perception and feedback. At the beginning, the workshop was focused on levelling out math deficiencies according to the entrance test performance. However, this methodology was not well-founded since students need to develop mathematical thinking skills for engineering design. Nowadays, the workshop is articulated with the first-semester math course, this strategy has increased students' motivation and changed their attitudes towards learning mathematics.

The workshop is divided into two modules; an intensive course and an extensive course. The intensive course aims to level students in fundamental concepts and takes 4 hours per week during the first three weeks. In the extensive course, tools are provided for strengthening the learning process in math involving aspects as management time, teamwork, study habits, autonomous learning and perception of math. The extensive module has an intensity of 2 hours per week after the third week and lasts through the end of the term.

The methodology deployed is based on the key factors of the Singapore math method: concepts, skills, processes, attitudes and metacognition. Integrating these components leads students to become active agents of their learning process, which means that they can develop skills and apply the strategies for solving abstract and real mathematical problems. The key factors are described in Table 2.

Table 2. Key factors of the Singapore math method

Component	Description
Concepts	Mathematical knowledge in different areas: numbers, geometry, algebra, statistics and probability, and data analysis.
Skills	Skills to understand procedures and apply them to problem-solving.
Processes	A variety of abilities that build up students' mathematical thinking.
Attitudes	Attitude towards mathematics learning, influenced by academic and non-academic experiences.
Metacognition	Ability to recognize thinking processes during the learning process.

Furthermore, the implementation process required teacher training and continuous feedback from students and professors to adjust the activities according to their needs.

Strategy Results and Feedback

The evaluation process was conducted by applying a perception questionnaire at the end of the workshop. This instrument evaluated different aspects: metacognition and study habits (Huertas, Vesga, & Galindo, 2014), time management (García & Pérez, 2012), team working (Ku, Tseng, & Akarasriworn, 2013), note-taking (Martínez & Pantevis, 2010), attitude toward mathematics (Aiken, 1974). The aspects above mentioned were assessed with scales proposed and validated by previous authors.

The questionnaire was applied to all the students enrolled in the workshop ($N = 340$) using an online survey tool, achieving a sample of 76 students. The main results of each scale are presented below.

Metacognition

90% of students are conscious about the weaknesses and strengths of their reasoning ability. 84% of the students consider that having prior knowledge about a topic facilitates their learning process. The 10% of students recognize deficiencies in organizing information and they do not question themselves about the different strategies for problem-solving.

Study Habits

24% of students do not use diagrams or outlines to structure information when they are studying. The majority of the students, around the 83%, ask someone when they do not understand a topic, they do not try to search for information or use their resources.

Time Management

50% of students assure that they do not well manage their time. 41% of the students do not define priorities to achieve their academic tasks and 45% of the students do not set deadlines.

Team Working

The majority of the students, more than the 60%, consider that team working is a useful practice for their learning process. Although they believe that working individually is more effective than teamwork, their performance is higher.

Note-Taking

92% of students assure that they usually take notes in class. However, 67% of the students do not often review their notes at home.

Enjoyment and Value of Mathematics

The 84% of students consider that studying mathematics is pleasant, they recognize that strengthen their skills is a priority as well as gaining knowledge in this area. Students value mathematics, they assure that is an essential subject for different disciplines. 72% of the students acknowledge that mathematics is not only memorizing concepts or formulating.

The results evidence that students need to enhance and develop skills focused on mathematics and other aspects as metacognition, time management, study habits, etc. to overcome challenges that their discipline demands.

Students recognize the usefulness of the workshop for reinforcing previous concepts, developing skills and mathematical thinking. They consider that the activities are well-designed. However, adjustments may be implemented in the methodology to enhance students' motivation and commitment.

On the other hand, teachers recognize that most of the students have difficulties to focus and develop activities when they work individually. Additionally, students prefer solving problems without using technological tools such as a scientific calculator because they ignore how to use them. Teachers value activities related to engineering problems to build up students' self-efficacy on mathematics performance.

CONCLUSIONS

The learning process is influenced by different variables in the education context. Enhancing self-regulated learning strategies foster self-efficacy beliefs that impact students' performance. In engineering, it is important to engage students in new learning spaces for developing skills needed to overcome discipline challenges.

The workshop has been a rewarding experience for teachers and students, because both of them have gained skills for a better process of teaching and learning. During this process, it has been identified the need of training continuously teachers in learning strategies and recognize its application in the academic field. Furthermore, the profile and competences of the professor must be defined to ensure the deployment of the strategy.

The strategies to improve students' mathematical learning must be design between the Faculty of Engineering and the Department of Mathematics, to consolidate efforts and enhance the workshops' implementation and following up.

For future research, the evaluation scales must be assessed at the beginning and end of the workshop to evidence improvement in students’ skills.

The CDIO framework is an essential element for continuous improvement in the engineering programs. In this context, articulating the curricula and active learning spaces is a strategic goal.

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PROPOSALS FOR VISUALIZATION AND SUPPORT OF GENERIC-SKILLS THROUGH OVERSEAS INTERNSHIP

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ABSTRACT

National Institute of Technology, Sendai College (Sendai KOSEN) has been engaged in global education for students by offering them internship programs at overseas universities since the early 2000s. Currently, several programs are being implemented, e.g. short- and long-term internship, internship at foreign companies and so on. By dispatching students to overseas internship programs (OSI), we are focusing on the development of the global mindset of the students. A continuous survey on the Generic Skills (GSs) of students using an objective method, meanwhile, started in 2014. Since five years have passed since the survey started, it has become possible to measure the growth of Generic Skills objectively before and after their overseas internship. It is reported the results revealed that their GSs trend before dispatch of students who want to participate in OSI and growth characteristics of their GSs between before and after dispatch. By utilizing this PROG continuous survey, it is thought that effective and individual pre- and post-support can be realized for students who will participate in OSI.

KEYWORDS

Visualization of Generic Skills, PROG, pre-support, post-support, Standards 11, 12

BACKGROUND

Since first signing an agreement on Academic Exchanges with INHA Technical College in Korea in 1991 and then with Helsinki Metropolia University of Applied Sciences in Finland in 2002, Sendai KOSEN has signed the agreements with 10 universities in the European region and 5 universities in the Asian region. In these agreements, exchanges of students are included. Therefore, Sendai KOSEN is committed to fostering a global mindset of our students by dispatching our students to OSI and accepting international students for our school programs.

As part of quality assurance of education, on the other hand, a continuous survey of students' GSs, abilities to comprehensively adjust to society, has been conducted from the academic year 2014. Through these continuous surveys, it is possible to know the GS characteristics of the students who want to participate in OSI and the GS growth between before and after the internship. The results of these surveys can be used to improve the contents of pre- and post-guidance and supports to make OSI more effective.

OVERSEAS INTERNSHIP PROGRAMS AT SENDAI KOSEN

Sendai College has several overseas internship programs, which are outlined below.

1) A program to dispatch 5th grade students of regular course to the universities in Finland, France or Thailand for about 5 months
2) A program to dispatch 1st grade students of advanced course to summer schools of Helsinki Metropolia University of Applied Sciences in Finland or King Mongkut's Institute of Technology Ladkrabang in Thailand for 2 to 4 weeks
3) A project-type training program that accepts international students for 6 week to 5 months
4) A program to dispatch 1st grade students of advanced course to foreign companies for several months (up to 3 months)
and so on.

In this paper, the differences of GS growth characteristics between the students who participated in a 5-month OSI (#1, longest program) and those of other students from Hirose campus are reported. Participation conditions for #1 program are TOEIC score of 400 or higher, and presentation practice in English is provided as advance guidance. After the internship, furthermore, debriefing sessions would be held for the participants themselves to reflect on their experience and also to introduce the program to the students who wish to participate in the following year. By comparing the GSs of the student who participated in OSI with those of other students, some tendencies are observed in the differences in the abilities of students before participating in the internship and the differences in growth characteristics with and without the participation of OSI. By analyzing these trends in detail, it is possible to achieve more effective overseas internships. For that purpose, we will introduce the results of the differences in GS growth with and without overseas internship participation of our students.

EVALUATION METHOD OF GENERIC SKILLS

In order to quantify GSs, there are two representative methods, that is, direct evaluation using rubrics, and indirect evaluation using external assessments. Progress Report on Generic Skills (PROG), one of Japan's standard tests (Kawaijuku Group, 2019), was adopted in this survey because the test has advantages of eliminating evaluators' subjectivity and of being able to use for comparing our students' results with those of university students. Since Ito (2014) reported the assessment of PROG as an useful assessment tool, the results of PROG have been used in the evaluation of educational effects and proposals for new educational methods, for example, the proposal of A^3 Learning system of Takahashi et al. (2016) and the combination with other educational tools of Takahashi et al. (2020).

The PROG consists of two parts: Literacy part, which evaluates the examinee's ability to apply knowledge to solve new or inexperienced problems, and Competency part, which evaluates the examinee's coping abilities with their surroundings, including decision making or action principle characteristics.

Literacy part consists of questions such as numerical reasoning and text comprehension. I In 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 in a five-scale ratingfrom "Very friendly" to "Very politely." The evaluation of each component in this 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.

Table 1. Evaluation elements of PROG

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			
Competency	main (3) categories	medium (9) contents	small (33) components
	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 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 were made at the 15th International CDIO Conference, and the development of Generic Skills is now one of important topics.

RESULTS OF THE SURVEYS

Information of the Surveys

The target students in these surveys are those who were dispatched to 5-month OSI program in their 5th grade (#1) and took the PROG in the academic years before and after the dispatch. Specifically, it targets 5th grade students in the academic years of 2015, 2016 and 2017. In 2015, eight students were dispatched to OSI, and all six of them took the PROG in their 4th grade and in the 1st grade of advanced course, respectively. Similarly, eight students were dispatched in 2016, and six and three of them took the test at 4th grade and at 1st grade of advanced course. For 2017, 10 students were dispatched, and eight and four of them took the test in the 4th grade and in the 1st grade of advanced course. (As for the PROG examination, only those who want to take the examination, so the dispatched students and the students who took the examination do not match. In addition, since some students did not go to the advanced course, the number of students who took the test in the 1st grade of the course is further reduced.)

The students in the survey did not differ significantly in the curriculum compared to other students, except that they participated overseas internship in their fifth grade. Despite the differences in elective courses at regular and advanced course, all students study in curriculum of electronics and information. Therefore, it is considered that the difference between the students who participated in the internship and other students is due to the difference whether they participated in overseas internship.

Generic Skills characteristics before Dispatch: Comparison between Students were Dispatched to OSI and Others

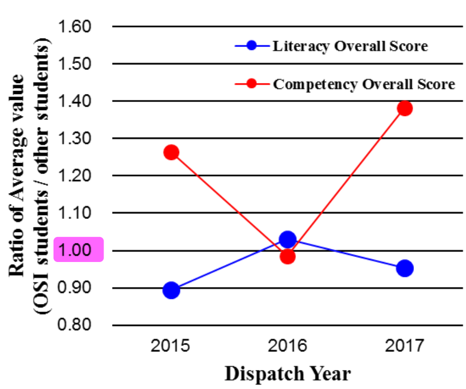


Figure 1. Comparison of Overall scores between OSI students and other students. (“OSI students” means the students who participated in the Overseas Internship.)

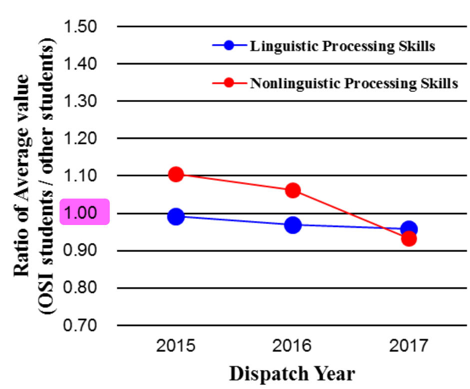


Figure 2. Comparison of Linguistic processing skills between OSI students and other students.

Fig. 1 shows a ratio between the average value of the students who were dispatched to OSI and the value of other students (a value of average score of the students participated in OSI divided by the scores of other students) for the Literacy and Competency overall scores in PROG which they took at 4th grade. If this value exceeds 1.00, it means that the students who were dispatched in the OSI have higher abilities at the time of the 4^{th} grade before dispatch. As shown in Fig. 1, the value of "Literacy overall score" was between 0.89 and 1.03, and no significant difference was observed in any year. On the other hand, with regard to “Competency overall score”, the scattered results were observed. In 2015 and 2017, the scores of student were dispatched OSI were much higher. Especially in 2017, the ratio was a very high value of 1.382, which represents a significant 1.25 point difference in the PROG score. Fig. 1 shows that the students who participated in OSI tend to have higher Competency skills one year before the dispatch than other students, while there is no significant difference in Literacy.

Next, a comparison of “language processing skills” in Literacy part was shown in Fig. 2, since it is considered that students who wish to participate in overseas internship have higher language skills than others. The ratio of "language processing skills" showed a value of 0.96 to 0.99, which indicates that the students who want to participate OSI do not have high language processing ability in particular. Therefore, it became clear that the level of language processing skills did not match the desire to participate in OSI.

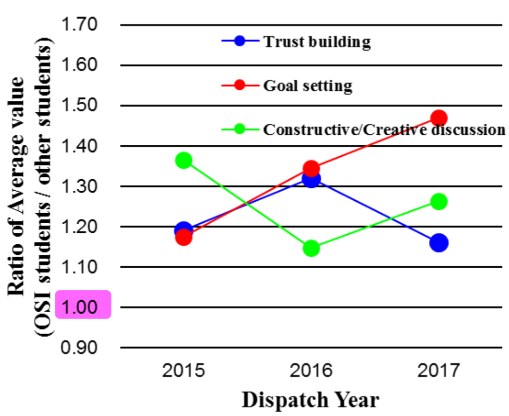


Figure 3. Comparison of elements which were measured higher for OSI students.

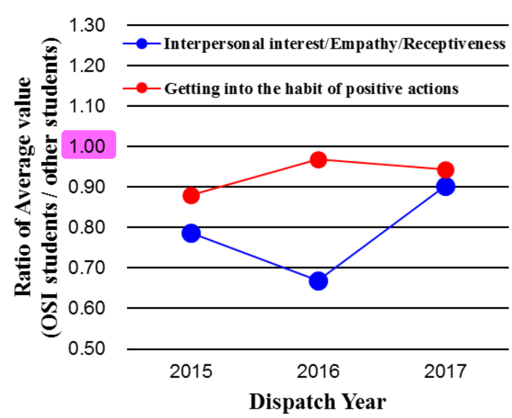
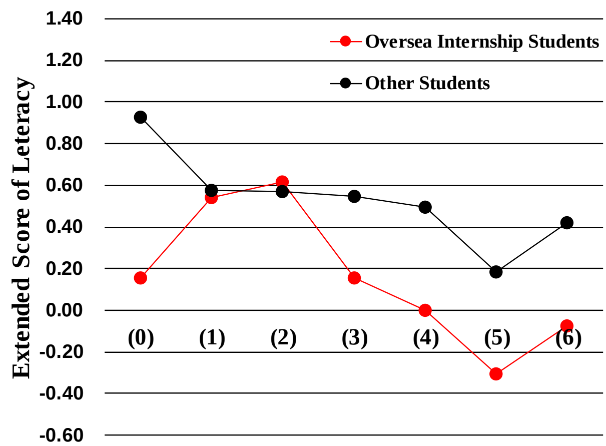


Figure 4. Comparison of elements which were measured lower for OSI students.

Finally, we will examine at the Literacy and Competency elements that make a clear difference between the student who wants to participate in OSI and other students. Fig. 3 shows the results of a comparison of “Trust building,” “Goal setting,” and “Constructive/Creative discussion,” which were measured higher for the students want to participate in OSI in all dispatch years. Regarding the “Building up a network of connections”, “Talk to each other”, “Express opinions” and “Practical action”, in addition, the students who were dispatched to OSI showed higher values each year. Conversely, Fig. 4 shows a comparison of “Interpersonal interest/Empathy/Receptiveness” and “Getting into the habit of positive actions”, whose scores of students sent to OSI were measured lower. For other elements, only “Linguistic processing skills” was lower. Fig. 3 and 4 shows that the students who want to participate in OSI have stronger tendencies to be confident in themselves, less swayed by others, and push towards goals.

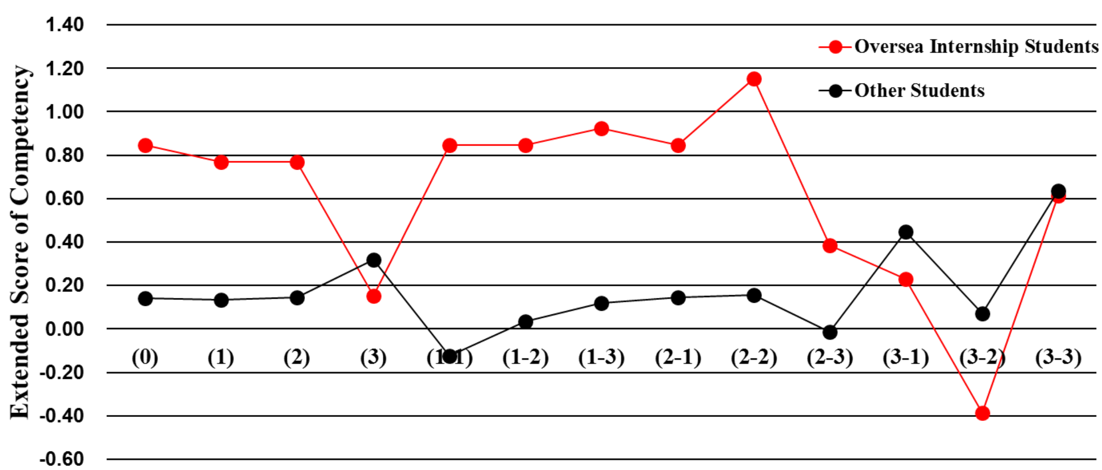
GS Growth Characteristics Before and After OSI (Comparison between Students were Dispatched to OSI and others)

Fig. 5 shows GS score improvement (the value obtained by subtracting the score at 4th grade before dispatch from the score at 1st grade of advanced course after dispatch) before and after OSI in the evaluation elements of Literacy part. From this point on, the growth of GS was treated as the average of all dispatched years, due to the small number of students taking



(0) Literacy Overall
(1) Collecting information
(2) Analyzing information
(3) Identifying problems
(4) Forming strategies
(5) Linguistic Processing Skills
(6) Nonlinguistic Processing Skills

Figure 5. Score improvement in Literacy.



(0) Competency Overall
(1) Teamwork skills
(1-1) Relating with others (1-2) Cooperating with others (1-3) Team management
(2) Personal skills
(2-1) Self control (2-2) Self confidence (2-3) Behavior control
(3) Problem solving skills
(3-1) Problem identification (3-2) Planning solutions (3-3) Implementing solutions

Figure 6. Score improvement in Competency.

PROG at 1st grade of advanced course. It was found from Fig. 5 that score improvement of those who participate in OSI is lower than those of other students. Therefore, regarding improvement of Literacy part skills, it is clear that studying at Sendai KOSEN is better than participating in OSI.

Next, GS score improvement in each evaluation element of Competency part before and after OSI were shown in Fig. 6. In contrast to Literacy, students dispatched to OSI have higher scores for most elements of Competency than others. In the main (3) category, "Teamwork Skills" and "Personal Skills", students dispatched to OSI scored about 0.75 points higher than before dispatch, while the score of students who did not participate in OSI is in the range of -0.2 to 0.2, that is, students dispatched to OSI grew more on the factor than others. On the other hand, it was found that the students who did not participate in OSI had higher score improvement for each element belonging to the "Problem solving skills". Therefore, it became clear that OSI program can efficiently enhance Competency abilities, which are considered to be difficult to improve by just attending lectures. In particular, every element of "Teamwork Skills" and "Personal Skills" grew efficiently.

CONCLUSION

Sendai KOSEN has been engaged in global education for students by offering internship programs at overseas universities since the early 2000s. In this paper, the GSs of Hirose campus students who participated in the 5-month OSI program are surveyed before and after OSI by an objective method.

From the survey before OSI, it was found that the students who want to participate in OSI tend to be more self-confident, be less swayed by others, and push towards goals more strongly than others. On the other hand, it became clear that the level of language processing skills did not match the desire to participate in OSI.

Furthermore, from the comparison of results between before and after OSI, it became clear that OSI program can efficiently enhance Competency abilities. Since Competency abilities, especially personal and teamwork skills, are considered to be difficult to improve in just attending lectures at school, the results of our survey seems to prove the educational effects of OSI (the training experience overseas).

It is considered possible to visualize the effects of the OSI program on GSs by continuing these surveys and conducting more detailed analysis . Since feedback of the visualized effects to the students participating in the internship is expected to make more effective and fulfilling OSI programs possible, we will continue these surveys and analyze the effects of overseas internship by analyzing student OSI growth trends.

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A STUDY ON CDIO-BASED STEAM PROGRAM DESIGN AND IMPLEMENTATION

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ABSTRACT

STEAM (Science, Technology, Engineering, Art, and Mathematics) education has gained popularity in schools, colleges, universities across the United States, Europe, parts of Asia, recently raised in Vietnam. Despite its attraction and preparation for the 21st-century skills, little empirical research and good implementation exists to guide the STEAM program design process as well as effective instructional practices, and even less is known about the challenges associated with individual assessment aiming to expected learning outcomes of the modules developed in the STEAM program. This paper will present a study on the design process and implementation of a CDIO-based STEAM program. In which, the CDIO framework, standards and syllabus are embedded and aligned with the STEAM program in two aspects: in most of the stages of the continuous improvement process of program development and implementation, and in lesson syllabus structure. The research concludes with implications for educational researchers and educators to consider that it is very potential to apply CDIO principles for an integrated curriculum with a project-based method for STEAM education, especially with the CDIO-based STEAM syllabus. The initial satisfaction survey which was taken on more than a hundred students has been carried out and obtained a high score of satisfaction, revealing the suitability in both curriculum and teaching-learning activity design. The CDIO-based maker space reflects its superior advantages of supporting innovative learning environments. Therefore, good practices on CDIO implementation are recommended for further discussion by the STEAM community.

KEYWORDS

STEAM Education, STEAM Curriculum Design and Implementation, Maker Space, CDIO Standards 1, 2, 3, 5, 6, 7, 8, 9, 10, 11

INTRODUCTION

STEAM Education

According to the National Science Teaching Association, "STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy" (Tsupros, 2009). The term of "Arts" is adding to STEM to bring the art factor to the topic, in the way student design and implement and the output impact of their products. This may help to nurture student's innovative ability and empathy, creating balance and connection between STEM subjects and Art.

STEAM education, especially in the Industrial Revolution 4.0, focuses more on the application of knowledge, by that STEAM knowledge has been conveyed into active teaching and learning activities such as project, digital fabrication or additive manufacturing, etc. Instead of learning each subject separately, STEAM education trends to bring them together for an interdisciplinary, multi-skill educational approach based on practical application. Learner's competences on problem-solving and soft skills are developed through experiential and active learning activities. Therefore, in each topic of STEAM, students mostly face with a specific real challenge and need to search, discover, utilize equipment, tools, technology and apply their related knowledge in STEAM to solve the problem. These inspire students with making and innovation and by then enhance them with personal and interpersonal skills in consideration of outcome impacts such as application, environment, community, society, etc. Generally, STEAM education promote creative learning - a factor that stimulates students' passion for learning (Leshner, 2018).

CDIO-Based Relevant STEAM Approaches

While the CDIO framework is designed for post-secondary engineering programs, it has been successfully used at the high school level and even junior high level to teach topics in STEM fields. As studied in (Hladik, 2017), there are barriers including a lack of teacher knowledge and confidence in the subject, and in Canada, a lack of a nationally-defined curriculum. Computational thinking is often taught outside of the formal educational system, and in some cases, alongside engineering design concepts. The breakdown of each of the C-D-I-O steps in section 4 of the CDIO Syllabus 2.0 is analyzed and compared against programming and computational thinking frameworks and design processes. The proposed technique provides a framework for teachers to create their computational thinking activities which facilitate elementary students to move through the CDIO steps as they complete such activities.

STEM-based learning in the educational process of CDIO-based undergraduate programs has been implemented and reported in (Gafurova, 2017). Proposed gamification model is applied through the first year of Introduction to Engineering course as a stage of students' acquaintance with the problems of the engineering profession. The game utilizes the CDIO approach by recreating the mechanisms of engineering companies' functioning at high-technology market. The experience of implementation of STEM-based learning in undergraduate programs, organized through networking collaboration between Siberian Federal University and STEM-Games LLC was shared by Arnautov (2018). STEM-based learning activities are shaped into two modules representing a team-based engineering design competition with an emphasis on different aspects of engineering. The modules utilize the principles of CDIO bringing up a project-based approach and active learning as primary educational techniques.

Though integration of engineering into middle school science and mathematics classrooms plays an important role in developing engineering aspect to early students, successful pedagogies for teachers to use engineering talk in their classrooms has not been fully understood. A study by Johnston (2019) addresses "How a middle school life science teacher use engineering talk during an engineering design-based STEM integration unit". The CDIO principle was exploited behind the story: The teacher used to talk to integrate engineering in a variety of ways, skillfully weaving engineering throughout the unit. Engineering concepts with science and mathematics content of the unit are integrated and modelled the practices of informed designers to help students learn engineering in the context of their science classroom. In another research by Cedere (2019), teaching/learning approaches for the Millennium generation are studied to find out the meaningful ways to this generation. This issue is especially important in STEM education. The obtained results showed that students-millennials as regards the learning of STEM subjects can be described as real-life oriented, digitally educated who want to participate actively in the teaching/learning process and who want to receive the feedback. This certainly show greatly potential application of CDIO standards 5, 7 and 8 in making STEM education effectively to the Millennium generation.

Challenges in STEAM Program Design and Implementation

As STEAM education has been approving obvious advantages and has been applying widely, many challenges have been existing in design and application of STEAM education at any levels, even at modern and developed educational systems such as the United States and other countries over the world, and so in Vietnam. Some of the key challenges of STEAM program design and implementation as named as follows:

- Lack of supporting policy and guidance on STEAM education implementation, from learning outcomes formulation, curriculum design to implementation and quality assurance, lack of standard syllabus and framework for STEAM lessons, etc;
- Which learning and teaching methods are suitable and effectively applied, how to connect and integrate into the school curriculum to not overload students with new knowledge and skills, how to evaluate learners as well as STEAM program at their outcomes, etc;
- Inadequate interest of administrators on STEAM education; not relevant competencies of the management staff and STEAM teachers;
- Lack of infrastructure of schools, making space for students to make and innovate.

Proposed CDIO-Based STEAM Program

Considering challenges in STEAM program design and implementation, we propose in this study our STEAM Program, named GoFab (Go for Fabulous Leaning), developing the power within children through innovative co-making and English learning. GoFab is operated as a public-private partnership educational model to drive innovation, between The University of Danang, Arizona State University (USA) and Fablab/Maker Innovation Space Danang. The program curriculum has been based on the needs of stakeholders (community, partners, parents, K-12 children) to set its program learning outcomes. An outcome-based STEAM program development model has been proposed by LYD Edu according to CDIO framework as demonstrated in Figure 1. The continuous improvement process of the STEAM program development and implementation follows 4 phases: Conceive - Design - Implement - Operate, in which, most stages of the process are designed aligning to CDIO standards. In lesson level, the syllabus structure for STEAM subjects is developed well-matching with the CDIO Syllabus. The knowledge is conveyed to students through a series of teaching and learning activities which, in meanwhile, also helps develop students' personal, interpersonal and creating skills.

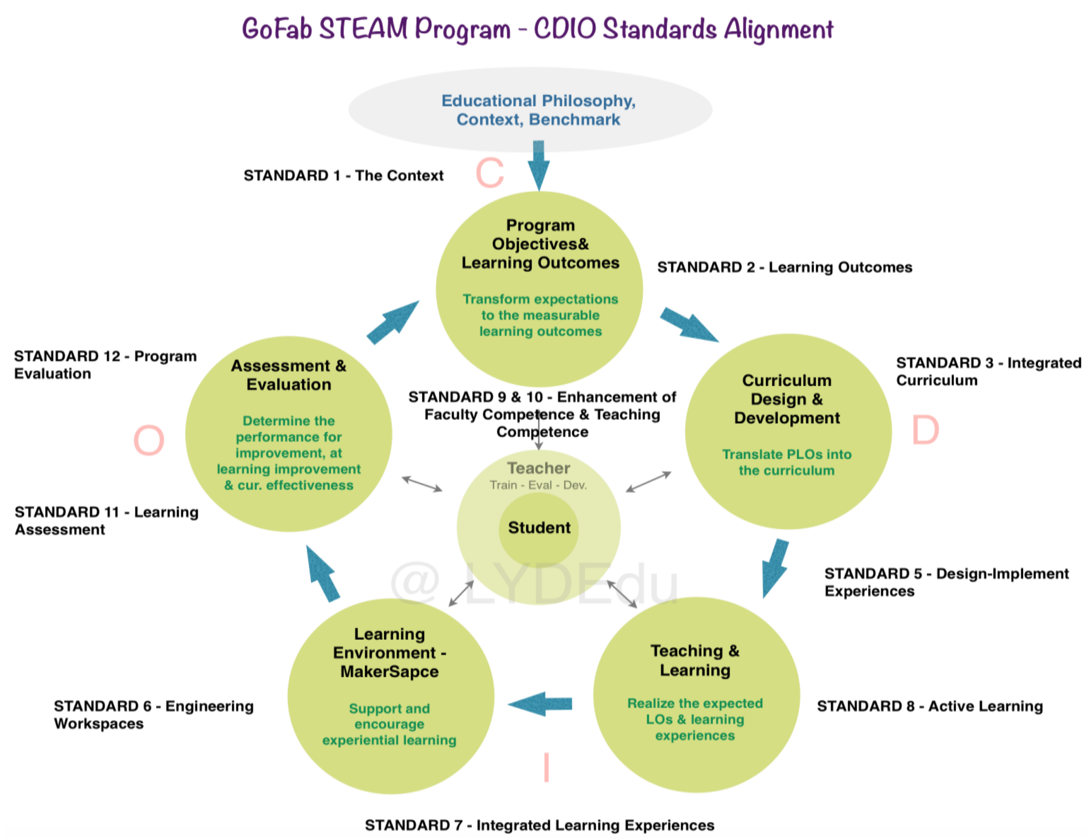

Figure 1. The outcome-based STEAM program development model *(designed by LYDEdu)*

CDIO-BASED STEAM PROGRAM DESIGN AND IMPLEMENTATION

The Context

Approaching to CDIO Standard 1 "The Context", the continuous improvement process of GoFab STEAM Program is designed in a lifecycle development and deployment according to 4 major CDIO-based phases:

- Conceive of the context: Demands from stakeholders (community, partners, parents, students) in STEAM education, STEAM standards, the available competences of students and the financial capacity/furniture of the institutions as well as benchmarking to other STEAM organizations have been considered.
- Design the program: Expected program learning outcomes (PLOs) and then the integrated STEAM curriculum have been designed to translate the program objectives and PLOs into the curriculum, including lessons, designed teaching-learning-assessment activities to make its learning outcomes attainable and realistic.
- Implement: Designed teaching, learning and assessment activities have been conducted at every STEAM class; faculties have been trained for STEAM teaching competences;

Maker Innovation Space has been developed to directly support a space and tools for hands-on activities designed in the integrated curriculum.

- Operate: Performance of students have been assessed and feedbacks from stakeholders have been collected have been assessing for the program continuous improvement.

Expected Learning Outcomes

Program expected learning outcomes have been designed focusing on developing competencies (including knowledge, personal and interpersonal skills, and attitudes) for students to be confident in communication, be able to work in a team, be able to apply their studied knowledge and skills as well as new knowledge to solve real-life problems in STEAM fields, and be able to make a prototype following design thinking process. Based on the outcomes and feedback from stakeholders on the program, the learning outcomes could be reviewed for continuous improvement.

Curriculum Design and Development, and Teaching Learning Activities

Based on the proposed learning outcomes and regarding CDIO Standards 3,5,7 and 8, GoFab STEAM integrated curriculum has been developed applying project-based learning method to provide students with active learning, design-implement experiences.

Among a variety of educational methods, project-based learning (PBL) is considered to be the key method for integrated curriculum and generally for STEAM education. PBL brings students chances to expose their active learning ability which is essential for their study in an integrated or international learning environment later on and prepare them life skills. A key factor for effective STEAM education is a teaching-learning method in which students can learn to innovate, think critically and independently and self-discovery. For example, the topic of robot design in which students have a chance to design, assemble, program and control a robot can cover both 5 subjects of science, technology, engineering, arts and maths. Moreover, these practical activities will help students remember knowledge longer and deeper. Students will work in groups, discuss and explore by themselves, apply knowledge into practical activities and then be able to transfer knowledge to others. With this way of learning, teachers are no longer the ones who impart knowledge but will be the guides for students to build their knowledge.

Project-based lesson plans for specific STEAM topics have then developed following 5E's model and design thinking process, and well-aligned with CDIO syllabus as demonstrated in Table 1.

Table 1. Mapping GoFab lesson plan teaching-learning activities to CDIO model.

Period	CDIO-based activities	STEM activities	Duration
1	C	Warm-up	0-5 mins
	C	Engage-Explore-Explain	15-45 mins
	C	Elaborate	0-20 mins
2	D	Image-Design-Plan	0-20 mins
	I	Create-Test	30-45 mins

	I	Competition/Game at the end of the lesson	0-20 mins
	O	Homework: Evaluate-Improve	Carried out at home

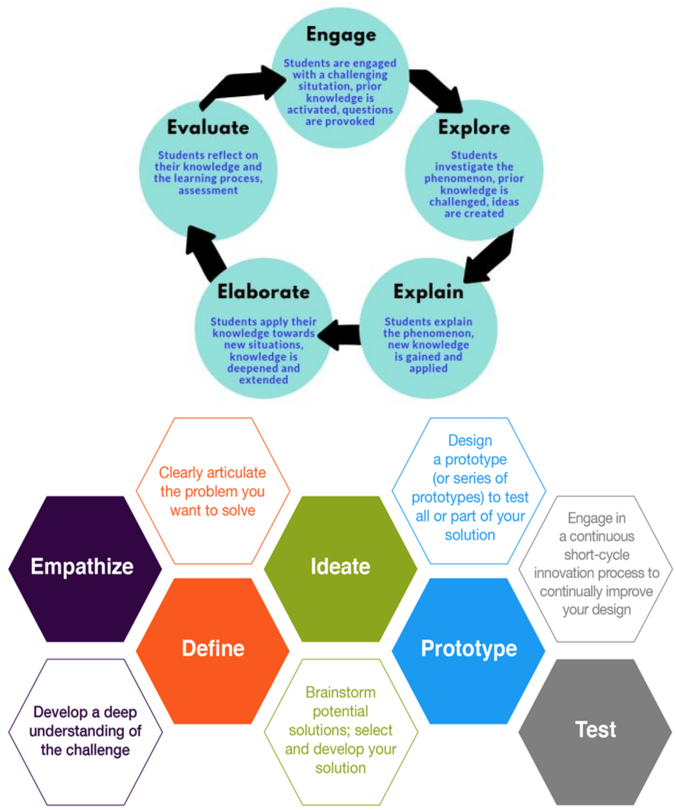

Figure 2. The 5E's learning cycle model (Bybee, et al., 2006) and Design thinking process diagram.

The 5E's (Engage - Explore - Explain - Elaborate - Evaluate) model (Bybee, et al., 2006) and Design Thinking process (Lee C., et al., 2018) are showed in Figure 2. The 5E's model is popular in teaching science because it follows the natural way that people apply to explore and gain new knowledge in their lives. Besides, the design thinking process is also applied in solving problems and creating new products for the future. The combination of 5E's model and design thinking process could be integrated into a proper approach to conduct a STEM lesson by adding 2 extra phases called Imagine-Design-Plan and Create-Test in the following structure: 1. Engage - Explore - Explain; 2. Elaborate; 3. Imagine - Design - Plan; 4. Create - Test; 5. Evaluate.

Structure of a GoFab lesson plan for a 90-minute lesson includes these teaching and learning activities. Particularly, students firstly face with a challenge (the main problem to solve) related to a specific topic of STEAM. Students are driven to Engage to the problem through related videos or attractive situations. They will then be asked to search and Explore by themself to understand the theory or principle behind. In the next steps, they are asked to Explain to others through several questions or games, and then will Image, Plan and Design their own solution/product based on what they understand in available resources of materials in the team. These phases are necessary for a lesson with creating activity. In the phase of Create-Test, they will have a good opportunity to work with the tool, to make mistakes and to deal with the real problems. After finishing their product or finding their solution, students will present their solution to others, and then improve if needed based on comments from their peers and instructors, with or without using English. This step could be repeated until they are satisfied with the final solution/ product/ prototype. Figure 3 demonstrates learning activities using the integrated 5E's model and design thinking process at a GoFab STEAM lesson.

Such GoFab lesson plan follows project-based approach and Conceive-Design-Implement-Operate model allows students to place themselves as an innovator, recall and reinforce their knowledge, explore and discover different possible solutions, develop critical thinking, build-up their skills of problem-solving, communication, teamwork, practice, English language, and follow the design process. Each lesson activities and outcomes will contribute to the achievement of designed program learning outcomes.

Figure 3. Learning teaching activities at a GoFab STEAM lesson at Fablab/Maker Innovation Space Danang.

Learning Space for Innovation and STEAM Practice

Along with teaching and learning methods, workspace - mentioned in CDIO standard 6 - equipped with tools and equipment that supports students in making and innovation is one of the important factors of STEAM education. Different models of fablab or maker space has been applied over the world to help students and the community for self-fabricate activities. Such making space would be very helpful for STEAM learning and teaching activities.

Fablab/Maker Innovation Space Danang was founded for the purpose at the University of Danang, is a fabrication innovation network model developed worldwide, born at Massachusetts Institute of Technology (MIT), to provide tools and mentorship for collaborated innovation, to serve children, students, faculties and startups. It provides equipment, software, space for co-making (and mentorship at needed) to help students design and fabricate prototypes. Fablab/ Maker Space model, at the higher level, is also helpful for designers, artists, businessmen and others; assisting makers in innovative experiments in a collaboration way, serving those working in STEAM and extended to business and social studies, etc. Figure 4 shows the model of Fablab/Maker Innovation Space to support students in learning, making and innovating.

Figure 4. STEAM education at Fablab/Maker Innovation Space Dananang.

Faculty Competences Training

Faculty competence improvement as required in CDIO Standards 9 and 10 is the most key factor for the success of a STEAM program. Even though at new educational methods as project-based, problem-based, or experiential learning, the faculty does not anymore take the role of a teacher but plays more on the role of a facilitator who drive the activities in STEAM class. However, to inspire students with a passion for innovation, there is a need of passionate STEAM teachers who has enough ability to help students to reinforce their knowledge and develop their personal and interpersonal skills through projects, problem-solving, in teamwork activities or at maker spaces, etc. Many organizations have put their effort to train STEM teachers. In November 2009, the US government's "Educate to Innovate" program invested US$ 700 million with the desire to train 100,000 STEM teachers. Beside STEAM curriculum development, Fablab/Maker Innovation Space Danang has developed the Train-The-Trainer program to help enhance faculty competence covering knowledge, skills and attitude through training modules and experiential learning activities such as:

- introduction to steam, teaching strategies, lesson planning and assessment
- steam roadmaps and project-based units of inquiry
- design process, maker spaces, and game-based learning in steam
- reflecting and improving, maximizing student engagement and blended resources.

Student Assessment

Student assessment has been conducted in GoFab STEAM program through different forms of formative and summative assessments, such as Q&A, prototype accomplishment for knowledge learning outcomes assessment; student performance in group discussion and working, idea presentation for skill learning outcome assessment by teachers or their peers; and observation by teachers or peer ratings for attitude learning outcomes assessment.

As GoFab STEAM program focuses on project-based learning where students need to apply their knowledge and both personal and interpersonal skills (such as teamwork, leadership, communication, information searching, making, time handling, even economic consideration,..) to be able to solve the problems or complete the project, assessment on final results/products of the individuals or groups has been used as one of the most effective and suitable methods of student assessment.

OUTPUTS AND REFLECTION FROM STAKEHOLDERS

Over the last 4 years, we have initiated, designed, implemented, and operated, kept revising to introduce this pilot STEAM education program to students and society in Vietnam. The GoFab program has been delivered to 4,000 kids and more than 7 schools and received positive feedback from learners who have experienced this program on a variety of topics in STEAM and satisfy their passion in innovation and making things and producing prototyped solutions, of which about 400 are often like studying foreign languages.

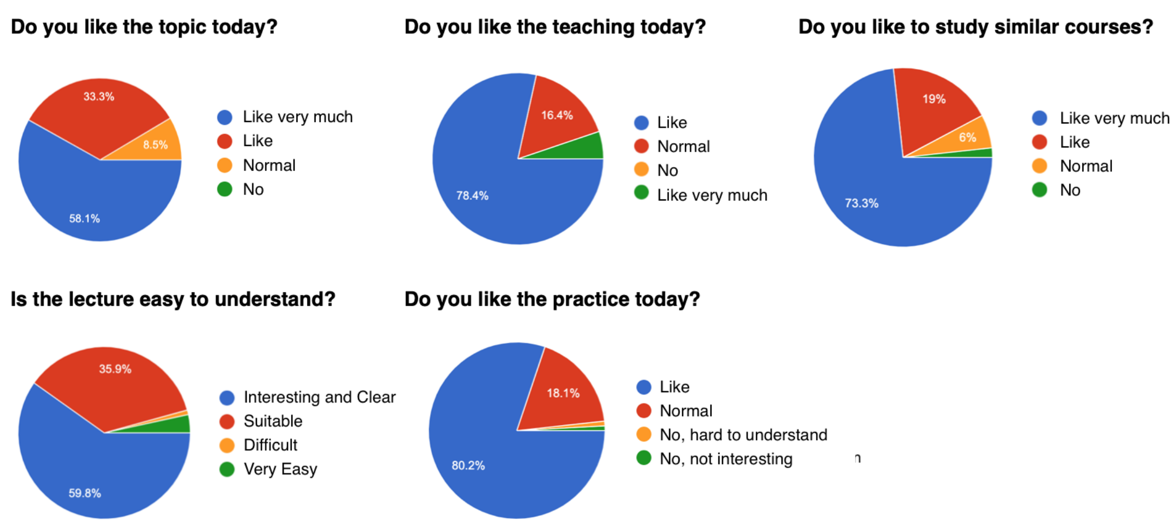

Figure 5. Survey results of 117 students turns joining GoFab STEAM program, taken in 2018.

A survey on satisfaction of 117 primary students, from Skyline International School - Danang, Vietnam joining 10 different STEAM topics and being taught by 7 different STEAM teachers on GoFab STEAM program on 2018 were taken and indicated in the Figure 5. The topics were about: Make a Flipbook, Create a Snow Flake using 3D printing, Build a Study Table with Newspaper, Design a Stamper, Build Your Nametag, Make a fabric pencil case,...which were designed to be appropriate to the age.

More than 90% of 117 responses showed their very positive feedback on the *Curriculum Topics, Lesson Content and Structure* ("Do you like the topic today? Is the lecture easy to understand?) and 92% like to continue the program (Do you like to study similar courses?"). This means the topic and the lessons were suitably designed for the learners. On the other hands, more than 80% of feedbacks showed their interests in the *Teaching and Learning methods and activities* ("Do you like the teaching today? Do you like the practice today?"), which were carefully designed for the integrated curriculum. In that, each lesson was project-based design with initial guidance on theory and following hands-on activities for creating things. With this teaching-learning method, students were provided opportunities to reinforce their knowledge and develop their personal and interpersonal skills. The students had to complete their project at the end of each lesson and through that, student's performance were assessed. Therefore, this positive result also reveals an initial success in developing learner skills since the students were mostly satisfied with their learning process and the results they achieved. The assessment on students and program has been in progress but such initial result approved the effectiveness of CDIO principles applied on the program.

SUMMARY OF EXPERIENCES AND CHALLENGES

Recommendations and Sharing

STEAM education is an integrated teaching method with an interdisciplinary approach and through practice and practical applications. STEAM education reduces the gap between academia and reality, creating a workforce with "instant" work capacity in a highly creative working environment of the 21st century, whose main skill set includes critical thinking and problem-solving skills, communication and collaboration skills, creativity and innovation skills, leadership and social influence skills, technology, information and media literacy skills, etc. It is believed that STEAM education will bring fundamental benefits in preparing a new workforce for the 21st century. This is consistent with the trend of new integrated education.

The CDIO standards 1, 2, 3, 5, 6, 7, 8, 9, 10, 11 have been well reflected in the whole GoFab program and showed a significant impact on its success. The program outcomes, curriculum, syllabus, teaching and learning activities, facility support through maker space, train-the-trainer have been implemented and revised for continuous improvement following CDIO framework based on feedback from stakeholders.

CDIO-based STEAM program will bring to the educators many benefits and a systematic administration, from curriculum design, teaching-learning methods, faculty training, maker space development and maintenance. Despite all these benefits, efforts and all the potential for development, change is slow and far from certain. Changing institutions and their associated cultures is not an easy task as there are many interconnected units in the institution. For smaller-scale change, we only need to consider a subset of these issues. However, for large-scale institutional, it is so important to change everything relevantly; every piece must be addressed, and all the above elements of the STEAM program model needs to fit together.

Since different types of customers have different demands on the program, listening to the needs will make the program development more realistic and successful. Integrated curriculum design, guided with CDIO syllabus, is the best choice for new education, especially STEAM education, where students are the centre and able to develop their competence including knowledge, skills and attitude.

We are now with well-meaning faculties that are largely unaware of the dramatic advances that have been made in the past few decades in understanding the learning of STEM and best practices for teaching. It is necessary to build design-implement lessons embedding active-learning methods and creating additional opportunities for integrated-learning experiences within the STEAM program.

Although the benefits of maker spaces for STEAM education are obviously, the management for effective usage and maintenance should be considered. A business model for the operation of a maker space for sustainable development has still been discussed. Many models of maker space have been introduced, such as a fablab/maker space belonging to a school/university like a free lab for student, or one belonging to a school/university charging on use, or such a one operating independently to a school/university, applying membership fee for anyone using, etc. Each has its pros and cons.

CONCLUSIONS

STEAM education highly promote the formation and development of problem-solving capacity for students. This educational objective means that students should engage, explore, study the knowledge of related subjects to the problem through different sources (books, online sources, etc.) and utilize maker spaces for tools, equipment to solve the problem. The design-implement experiences, integrated learning experiences and active learning standards are recognized as perfect matching tools to reach the objective. This knowledge and skills must be integrated and complementary to each other to help students not only understand the principle but also be able to practice and create their products in life. Therefore, the CDIO syllabus and integrated curriculum standards are the key factors to the successfully integrated STEAM program.

To have any hope of spreading changes in STEAM education at all levels, from elementary school to university, we must take into account all the units within institutions that are relevant to the change being made. The renovation should start from changing multiple faculties, departments and how the institution operates, down to modifying individual courses and curriculum, upgrading infrastructures which enable innovating and co-making abilities of students, and last but not least, the faculty development needed to support such efforts. The context and working space standard, thus, must be applied for the effective Conceiving--Designing--Implementing--Operating of the STEAM program.

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BIOGRAPHICAL INFORMATION

Fablab Danang (Gofablabs) was only one of three start-ups selected to demo innovation products to President Barack Obama in 2016 in HCMC and also, selected as one of eight start-ups out of about 1,000 applicants to join the Global Entrepreneurship Summit in Silicon Valley 2016, hosted by President Obama and the United States government.

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.

Hoi Ba Nguyen got his Engineering degree at the University of Danang-University of Science and Technology; Master degree of Asian Technology Institute, Bangkok, Thailand; was a technological engineer at Microfuzzy GmbH Munich Germany; doctoral degree at CUA University, in Washington DC, USA and Washington National Hospital. Hoi co-founded and co-operated Novas from 2005 through 2015, developing a technology company to more than a hundred employees, with the most prominent technical products & services being the four-way LHD device and automatic production system, factory-wide and model teaching products. He was also a co-founder and advanced university program manager for 2005-2009, in partnership with Washington University, Seattle. Currently, Hoi is the interim Dean of School of International Education, University of Danang, in collaboration with Arizona State University to develop and operate GoFabLabs / Makerspaces for the community: Gofab initiative to serve students' creativity through digital manipulation, GoGoHab Apparel low-cost rehabilitation services for patients, and VPICS / Projection for students developing new products that serve the community.

Tram Kha Ngoc Nguyen graduated Master’s degree from the University of Danang - University of Education with Methodologies of Physics major. She is passionate about education with 5 years of work experience, teaching 7-15-year-old students and developing lesson plans. Being the Innovation Curriculum Lead of GOFAB and STEM teacher at Fablab/Maker Innovation Space Danang gives her the ability to work under pressure with dedication, responsibility and to bridge the gap between theory and practice in building STEM curriculums.

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.

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INTEGRATED CURRICULUM APPROACH IN DEVELOPING 21ST CENTURY INDUSTRY-READY GRADUATES

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ABSTRACT

The experiences in designing an integrated curriculum for the Bachelor in Civil Engineering Technology (BCT) programme is presented in this paper. The programme currently being offered in Politeknik Ungku Omar is adapting the innovative engineering education framework of Conceive-Design-Implement-Operate (CDIO) real-world systems with the objective to produce a new generation of engineering technologists. Precisely, the curriculum was designed using CDIO Standard 3 – Integrated Curriculum and CDIO Standard 7 - Integrated Learning Experiences focusing on providing integrated learning experiences for students to take an active role in their learning process. The 40-week structured on-the-job training or Work-based Learning (WBL) with partnership from the nation's key-industry players and construction companies were discussed. The industry collaboration and partnership aim to provide a real-life work environment and facilitate structured and experiential learning for Year 4 students before graduation and eventually join the workforce. The paper concludes with an evaluation of the efficacy of the integrated curriculum measured through feedback received from the industry partners on students' performance in the WBL and the graduate employment rate. Graduate employment has significantly improved and BCT graduates are well accepted by the industries. The graduate has been recognized to be more industry-ready and confident in facing challenges in the construction industry. However, the interaction with recent graduates and industry partners indicates that there are still gaps in BCT graduates' skill sets and actions to address these gaps are discussed.

KEYWORDS

Integrated curriculum, work-based learning, Standards 3, 7

INTRODUCTION

The Construction Industry Transformation Programme (CITP) 2016-2020 is a Malaysia national agenda that aims to transform the construction industry to be highly productive, environmentally sustainable with globally competitive players without neglecting on safety and quality standards. One of the strategic thrusts in CITP is 'Productivity', the primary engine of growth towards Malaysia's high-income targeted in the 11th Malaysia Plan. Among the initiatives included in CITP were to accelerate the adoption of Industrialized Building Systems (IBS) mechanization and modern practices and to roll out technology advantage across project life cycle by facilitating Building Information Modelling (BIM) adoption in construction industry via regulations. The civil engineering sub-sector is expected to remain as the driver of the construction sector in Malaysia to spearhead the 11th Malaysia Plan. This is supported by expansions in high impact infrastructure projects such as in rail links and transit lines, airports, roads and highways as well as the new planned supply in the affordable homes and industrial segments, making the demand for industry-ready workforce is set to grow in the construction sector (Ministry of Finance Report, 2019/2019).

In response to this, the Bachelor in Civil Engineering Technology (BCT) curriculum at Politeknik Ungku Omar (PUO) were revised in 2015 focusing on new technologies and modern practices namely Information Technology (IT) Construction via Building Information Modelling (BIM), risk assessments and quality management in construction sector. These technologies and practices were integrated with personal skills, interpersonal skills, teamwork and communication, product, process, and system building skills to prepare graduates for the 21st century challenges. Additionally, the innovative engineering education framework of Conceive-Design-Implement-Operate (CDIO) principles and guidelines were also adapted into the revised curriculum (Crawley, Malmqvist, Ostlund & Brodeur, 2007). The CDIO Standard 3 – Integrated Curriculum was adapted in this curriculum to better reflect the multidisciplinary nature of Civil Engineering Technology. Other than that, the CDIO Standard 7 - Integrated Learning Experiences, focusing on providing an integrated learning experience, active learning and self-discovery for future career needs were also applied.

METHODOLOGY

Integrated Curriculum Design

A need analysis was carried out to the current construction industry landscape and workforce needs in Malaysia through a survey with BCT alumni. The interviews with leading construction associations nationwide, Master Builders Association Malaysia (MBAM) and the government agency that regulates the construction industry, Construction Industrial Development Board (CIDB) were also conducted. The outcomes of the need analysis are summarized as follows:

- Feedback from MBAM indicates that the current BCT curriculum remained relevant to the construction industry for skill sets in the areas of infrastructure planning, designing and constructing. Nevertheless, skill sets that support the latest technology in IT Construction, risk assessments and quality management as well as personal and interpersonal skills are suggested to be further enhanced into the curriculum.

- Information gathered from CIDB pointed to the emerging workforce needs on skill sets to support the government push towards higher productivity using IT Construction and environmental sustainability in the construction industry.

- The BCT alumni responded that the current curriculum successfully equipped them with strong foundation knowledge and skills in infrastructure planning, designing and constructing. Nevertheless, employment in the construction sector seems to require different skill sets particularly on the latest construction technology, operation and maintenance, and quality compliance.

Integrated Curriculum

The CDIO Standard 3 – Integrated Curriculum (Figure 1) is the key strategy in designing this revised curriculum. It aims to mutually support the disciplinary courses with an explicit plan to integrate personal, interpersonal, and product, process, and system building skills (Crawley et al., 2014). Currently, there is a global trend where employers placed higher emphasis on 21st century skills than technical skills as necessary attributes from their workforce (Reeve, 2016). Therefore, the curricula of higher learning must incorporate effective platforms, such as collaborative project-based learning, for students to develop and demonstrate these attributes (Zhou, 2012).

Following the design process recommended by Malmqvist, Ostlund and Edstrom (2006), the objective of the revised curriculum is to train a cohort of Civil Engineering Technology graduates to be technically competent, professionally proficient and socially responsible in planning, designing and constructing infrastructures as well as an advantage in acquiring competencies of new technologies and modern practices namely IT Construction via BIM, risk assessment and quality management in the construction sector. This is followed by an iterative process of developing the learning outcomes, aligning the learning outcomes, designing the learning activities and applying the assessment methods of the courses offered in this curriculum in an integrated manner to meet the construction sector's needs. The sample of revised curriculum designing process is shown in the diagram below.

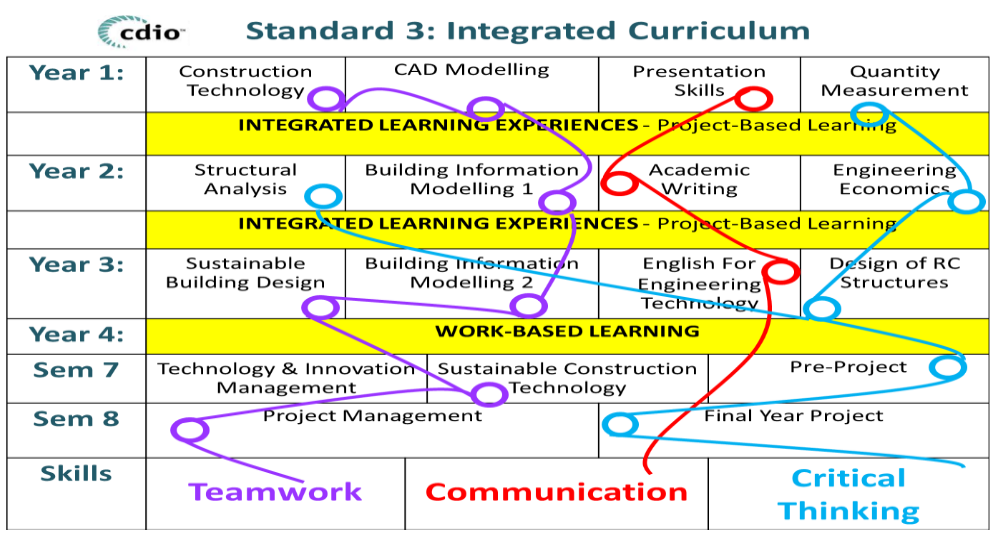

Figure 1. The Revised Integrated Curriculum Learning Track of the Bachelor in Civil Engineering Technology Programme (BCT)

Integrated Learning Experiences

The Intra-Programme Integrated Learning Experience (IP-ILE) is incorporated in BCT curriculum learning track. It is a collaborative project-oriented problem-based learning (POPBL) integrated into two or more technical courses (core-discipline) and a communication course (common core) within the same semester as shown in Table 1. The assessments are carried out on the process and the project outcomes for both individuals and group work. In general, the purpose of IP-ILE are as follows:

i. To engage, enable and empower student's skills through multidisciplinary projects.

ii. To deepen and diversify student skills, in both technical domains and project execution for 21st century skills, such as collaboration, communication, critical and creative thinking, and problem solving.
iii. To enhance students’ presentation and public speaking skills.
iv. To inspire and encourage innovation culture whilst providing a risk-free environment.
v. To give the students’ opportunity to optimize their student learning time (SLT) effectively and be more focused to produce a better project.

Table 1: An Example of Integrated Learning Experiences and Experiential Learning (CDIO Standard 7) in PUO Collaborative Project-Oriented Problem-based Learning

APPROACH		CURRICULUM TRANSFORMATION	
Intra-Programme Integrated Learning Experiences			
Project LOs	**Courses**	**Related CLOs**	**Assessments**
At the end of the project, students will be able to: **1. Collaborate in a team and use parametric modelling (BIM) to construct a model and make the quantity measurement for building according to Standard Method of Measurement, Malaysian Standards, guidelines, regulations and practices.** **2. Present the building model effectively and confidently using appropriate presentation as well as language and non-verbal communication skills.** **3. Explain the technical aspects of the model clearly in a Q & A session.**	BCT 2043: Civil Engineering Construction Technology	Synthesize technical skills on using parametric modelling in civil engineering construction technology. (C5, PLO2) Exhibit the ability to engage in independent and life-long learning to society commonly encountered in construction of civil engineering technology careers. (A5, PLO9)	POPBL Project - 20%
	BCT 3073: Contract Procedure & Quantity Measure-ment	Measure rate the building element by using Parametric Modelling in quantity measurement. (C5, PLO2) Develop good teamwork skills in quantity measurement.(A4, PLO12)	PBL Project - 10%
	BUE 1013: Presentation Skills	Deliver informative and persuasive speech for specific purposes using appropriate language and relevant presentation skills. (C6, A5)	Presentation - 30%
	BCT 1033: CAD Modelling	Apply the principle of plane geometry and isometric drawing by using CAD software. (C4, PLO2)	POPBL Project - 35%

Work-based Learning

Work-based Learning (WBL) is a learning approach in which polytechnics and industries work together to conduct teaching and learning process (Boud, Solomon & Symes, 2001). This is a well-structured on-the-job training (OJT) programme developed together with BCT's industry partners to meet the training needs of an industry and to provide a real-life work environment. It has been designed as a structured internship programme with core discipline courses incorporated in the learning track for BCT Year 4 (Figure 1). Through the experiential learning, students can further deepen their competencies for occupational skills, transferable workplace skills and personal effectiveness skills. Students were able to carry out internships in several related project management practices within the construction projects and gained valuable experience on risk assessment and quality management in the construction industry. The WBL is implemented in the final year of the programme i.e. in the 7th and 8th semester, covering 20 weeks per semester (see Figure 1). In total, students will be attached to the industry for 40 weeks or equivalent to 1600 hours of OJT. At the same time there are three core discipline courses offered in the 7th semester; BCT7264 - Pre-Project, BCT7275 - Technology and Innovation Management and BCT7288 - Sustainable Construction Technology with a total of 17 credit hours. Meanwhile, in the 8th semester, two core discipline courses are offered: BCT8297 - Project Management and BCT83010 - Final Year Project totalled 17 credit hours.

PUO BCT programme collaborates with Master Builders Association Malaysia (MBAM) and its participating companies and Universiti Malaysia Pahang Holdings (UMPH) with its subsidiaries companies in implementing WBL since 2016. The WBL learning process in BCT context requires students to sit for several courses while undergoing the internship. These courses are monitored and assessed directly by lecturers of the polytechnic. Concurrently, students will be assessed by the industry mentors appointed for projects or work assigned at the workplace. Primarily, the industry mentors will supervise all practical work while student's academic achievement will be assessed by polytechnic lecturers at the workplace. Therefore, these students will be observed by polytechnic lecturers from time to time as scheduled in their learning process (Figure 2).

In facilitating the student learning process, PUO lecturers and industry mentors use learning activities, environment and assessments that align with the learning outcomes (Biggs, 2003). To assist the industry mentors, a team-teaching approach consisting of two or more lecturers teaching the same course are paired-up with the industry mentors (Buckley, 2000). The team-teaching from both PUO and industry able to share ideas to convey knowledge to the students. This can shape the value of teamwork among lecturers and industry mentors in delivering teaching and learning (T&L). The industry mentors oversee the practical aspects of the course whilst the theoretical aspects are led by the polytechnic lecturers. The team T&L can be in a blended learning format using e-Learning approach.

E-Learning refers to the use of information and communication technology to facilitate the process of T&L (Department of Higher Education, Ministry of Higher Education, 2011). A combination of 70:30 online learning mode and face-to-face of the course content is employed in this WBL T&L. In assessing the WBL, appointed lecturers will carry out an observation at the company premise scheduled by the PUO WBL coordinator. The continuous assessments, appraisal and feedback from the industry mentors will be gathered during this observation visit. Eventually, the result will be presented to the industry at the end of the WBL period. (Figure 2). The feedback and suggestions received is used to improve the future T&L process.

Session conducted by industry trainer

Supervision by visiting lecturers at the company site

Student skills application on site supervised by industry mentor

Visiting lecturers on site

Presentation of result for practice-oriented assessment to participating companies at the end of each cohort

Figure 2. BCT-WBL Teaching and Learning by the Industry and PUO

The diagram underneath summarised a complete circle of the PUO BCT- WBL teaching and learning.

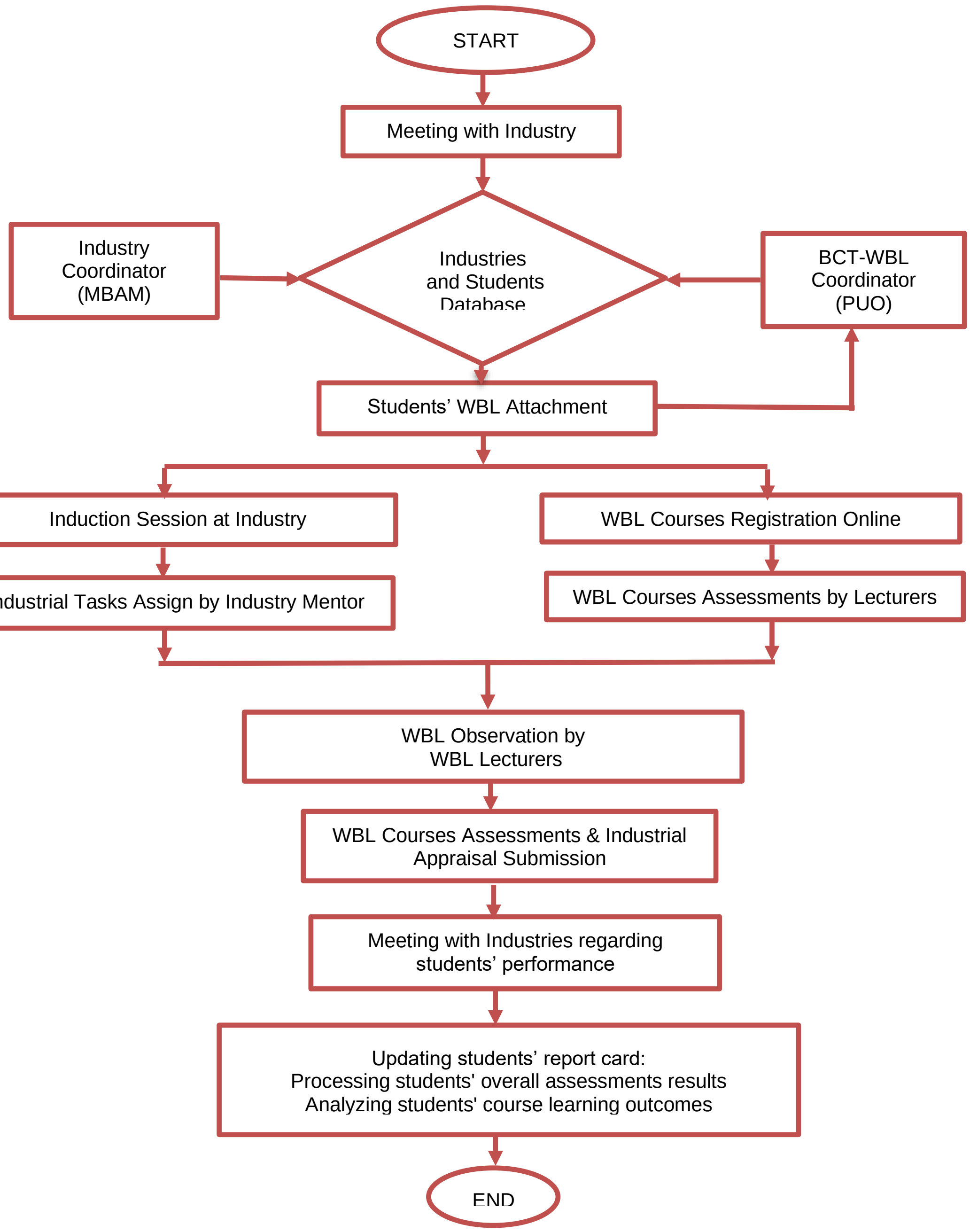

Figure 3. PUO BCT-WBL Implementation Flow Chart

RESULTS AND DISCUSSIONS

The collaboration between PUO and Malaysia leading construction industry has gained a positive impact on BCT graduates' employability. Total time spent at the workplace through WBL (40 weeks) enabled the students to be trained and exposed with real work environment.

Students become more competent in both technical and non-technical skills such as personal and inter-personal skills in communication, teamwork, leadership, critical thinking and problem solving. PUO WBL participating companies has given full commitment and they are basically satisfied with the graduates. Indeed, the first cohort of the graduates were fully employed immediately after their graduation. To date, the BCT programme has had produced 4 cohorts of graduates and all have an outstanding employment rate record. Graduates employability data collected annually by the Department of Polytechnic and Community College Education (DPCCE) during the graduation using TVET Tracer Study System - *Sistem Kajian Pengesanan Graduan-TVET* (SKPG TVET) recorded that almost all graduates has been employed either by the partners' company or other company in the same field locally and overseas, some became entrepreneurs, others pursue further studies and a few took a break for personal reasons. The BCT employability rates are summarized below:

Table 2. Graduate Employability for PUO BCT-WBL Graduates

Year / Cohort	Number of graduates	Work with Participating Companies	Work with Other Companies	Self Employed/ Entrepreneur	Further Study	%
February 2017 1st Cohort	28	11	10	5	1	96
February 2018 2nd Cohort	28	8	18	1	1	100
August 2018 3rd Cohort	25	11	11	2	1	100
August 2019 4th Cohort	30	Result still in progress				

The statistics show that the BCT graduates were immediately offered a job upon completing their WBL, with the longest waiting time of two months. For the first cohort, one of the graduates was unable to commence work immediately due to personal reasons, making up the employability rate of 96%. In the second cohort, there were three graduates who turned down the offer by participating companies and one was offered to work overseas. There are many reasons why these graduates turned down the offer by participating companies, for example the location of the project site, distance from family/hometown, salary offered by other competitors as well as pursuing further education. In addition to the tracer study conducted, a testimonial by employers were also gathered. The summary of the testimonial is depicted:

Table 3. Industry Testimonials of PUO BCT-WBL Graduates

No.	Testimonial	Organization and Position
1.	"PUO BCT-WBL programme has become a benchmark programme by universities in Malaysia. Under the wing of various mentors from the companies, the students were able to adopt the soft skills promisingly and received their training with open hearts. I am proud to say MBAM has no regrets working with PUO on this program and always welcome more activities in future. All the big public listed construction companies which participated in the program valued their employees who were PUO BCT-WBL graduates."	Tan Sri Sufri Mohd Zin, Deputy President of Master Builders Association Malaysia (MBAM) cum Group Managing Director of Trans Resources Corporation (TRC) Sdn. Bhd.

2.	"PUO BCT-WBL student do not requires another learning curve, they can immediately start work and able to catch up with site works as soon as possible. We indeed have no hesitations in hiring them immediately after their graduation"	Ir. Selvaraja Marappan, Project Manager of Sunway Construction Group Berhad.
3.	"The student is able to work with least supervision and very innovative. We have adopted the project designed by the student, "e-Borelog", an application that prepares bore log as a payment claim. The project is very helpful to us as it really saves us time and money as we move forward into a paperless society".	Ir. Shalom Morris, Senior Engineer of Bauer (Malaysia) Sdn. Bhd.

CONCLUSIONS

Since the launch of the revised curriculum for the Bachelor in Civil Engineering Technology programme in 2015, a total of 111 BCT students completed this WBL track in various job functions in the construction companies. The effectiveness of the integrated curriculum in this track was measured through the feedback received from the industry partners on students' performance in the WBL programme and the graduate employment rate. Positive comments were received from the industry partners on the students' performance. The industry mentors highlighted that BCT students demonstrated an excellent attitude in approaching the tasks assigned to them and had always given their best efforts to all tasks assigned. The students showed commendable initiatives in contributing new ideas and producing innovative solutions to problems encountered at the workplace via their Final Year Project. It was also highlighted that BCT students were competent in performing good project management practice which reflected their experience in conducting risk assessment and quality management in the construction industry.

Graduate employment survey showed an excellent result indicating industry recognition that BCT graduates are more industry-ready and confident in facing the complexity and challenges of the construction industry. However, through interaction with recent graduates and industry partners it shows that there are still gaps in BCT graduates' skill sets. They expressed that the students should be more resilient as working in the 3D (Dangerous, Dirty and Difficult) environment of the construction sector, requires them to have higher tolerance and to recover quickly from difficult work situations at the construction project site. In addressing these gaps, immediate action by PUO is by introducing an outbound camp activity for the upcoming cohorts. The activity is hoped to build students' flexibility and perseverance in the challenging situations as well as to apprehend their full potential through the tasks and challenges given during the camp's expedition.

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BIOGRAPHICAL INFORMATION

Yong Rashidah binti Mat Tuselim is a senior lecturer at the Civil Engineering Department, Politeknik Ungku Omar (PUO). She has been actively training and facilitating Malaysia Polytechnics' lecturers and students in the CDIO integrated curriculum framework and Design Thinking activities for social innovation projects and industries projects. Her current focus is on the continual improvement of Work-based Learning approach in Malaysia Polytechnics' Bachelor's Degree programs with the nation's industry players.

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Riam Chau Mai is the head of Corporate Industrial Services and Employability Centre of Politeknik Ungku Omar, Malaysia. Her expertise covers research on soft skills and skills related to student marketability of the institution beside the teaching work in accounting related subjects. Her task is to liaise the institutions with the community and industry locally and abroad. She is also a CDIO master trainer for the Department of Polytechnic and Community College Education Malaysia since 2015.

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Engineering Education Research

SKILLS BUILDING TOWARDS SELF-DIRECTED LEARNING VIA ACTION RESEARCH REFLECTIONS

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ABSTRACT

In the fast-paced, changing global economy, it becomes increasingly important to develop self-directed learning (SDL) skills in our students to stay competitive and adaptive to the ever-changing needs. In support of more SDL teaching and innovation activities, Singapore Polytechnic (SP) has developed the SDL framework. However, many practitioners are unfamiliar with it. There is also currently a lack of knowledge of the appropriate ways of simulating and introducing SDL to our students. This paper thus aims to use a feedforward process where some interventions to promote SDL for our students were tested out. In the pilot action research, two instances of SDL strategies were carried out for 96 freshmen engineering students from Oct 2018 to Feb 2019. In addition, students were asked to do a simple self-assessment on SDL to see if they can use this as a tool to assess their SDL behaviours and suggest appropriate changes. To our surprise, 4 out of the 5 classes rated themselves significantly higher compared to their lecturer's rating of themselves. A simple follow up with the students and classroom observations revealed that many of them were seem multitasking during the lessons, and not revising what they have learned as regular as we would expect them to. We see these factors as the contributing factors that could hinder students from being more self-directed. Plans to improve on student's study habits thus become the focus for the next action research. We see that the use of action research methodology help us to kick start this journey. The continued use of this approach is believed to help educators design better lessons that are suited for our engineering student's profile, thus effectively helping them to transit from being too dependent to more self-directed.

KEYWORDS

Self-directed learning, motivation, growth-mindset, problem-solving, active learning, programming, inquiry, meta-learning, debugging, Arduino, action research, learning strategies, Standards 7, 8

BACKGROUND

"Cher….. can you show me how to do this again?" How many times have we heard students asking similar questions like this? These observations were too common and familiar for teaching staff who have taught the 1st year Diploma in Computer Engineering (DCPE) students taking Introduction to Engineering 2 (IE2) module throughout the 15 weeks duration. This module is 3 hours weekly project-based module in which the students are expected to learn basic programming using the Arduino based Zumo robot and later work in pairs to battle opponents from their class and other classes in the final Zumo competition challenge. The objective of using the Zumo robot is to demonstrate that engineering is fun, rewarding, relevant, and interesting. It also helps students see the direct connection between the program as written and the visible behaviour of the physical devices, rather than as just a text printout on a screen. They will also be able to reflect on the effectiveness of their solutions and will be able to experiment to obtain alternative solutions and evaluate their effectiveness in comparison with each other.

What the teaching staff has commonly observed in the classroom is having a handful of students displaying a strong tendency to either seek their peers' assistance and/or expecting their lecturer(s) to provide direct solutions on a one-to-one basis. Some students were not even able to recall any of the preceding lessons and were always lost to begin with. Some students would ask the same questions again over time, while some would expect us to troubleshoot for them all their errors. Although we do have students who were very motivated, self-directed, and showed enthusiasm in trying out, experimenting, and having fun throughout the lessons, the number of students who displayed the mentioned learning dependency can be overwhelming for teaching staff to handle. In some cases, we observed panic and anxiety among the students, and the teaching staff has to guide them with considerable effort. All these indicated strongly that quite a number of our students were just not ready to take ownership of their learning. It thus leads to us thinking: "How can we cultivate the learning environment to support students to take more responsibility in their learning?"

THE NEED FOR SELF-DIRECTED LEARNING

Knowles (1975) described self-directed learning (SDL) as "a process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes."

Phases of SDL (Gibbons, 2002)	Student's readiness	Student's SDL Characteristics		
		Ownership	Monitoring and Management	Extension of learning
Self-directed learning	High	High ownership, identify and commit to learning goals	Skilful in managing and monitoring own progress of learning	Extend learning beyond school's curriculum
Self-planned learning				
Self-managed learning				
Teaching students to think independently				
Incidental self-directed learning	Low	Low ownership, dependent on teachers to direct learning	Unable to manage and monitor learning	Learning is limited to resources provided in classrooms

Figure 1. Gibbons' (2002) SDL Spectrum and Student's Readiness

To have a better understanding how ready our students may be for SDL, one can draw on Gibbons' (2002) work where SDL can be viewed as a spectrum that begins from the lowest level identified as "incidental self-directed learning" to the highest level termed "self-direct learning or SDL" (see Figure 1). These phases may not necessarily occur in a linear and hierarchical order. It is to indicate the progressive development of students' readiness in self-direction. Using the given definition of SDL and Gibbon's SDL spectrum, one can easily identify that our students were at different levels, with quite a handful of them falling into the incidental self-directed learning phases of SDL as they have exhibited behaviours that indicate low ownership. To prepare students for a world, we cannot even predict; our institution recently came up with the SDL framework, as shown in Figure 2.

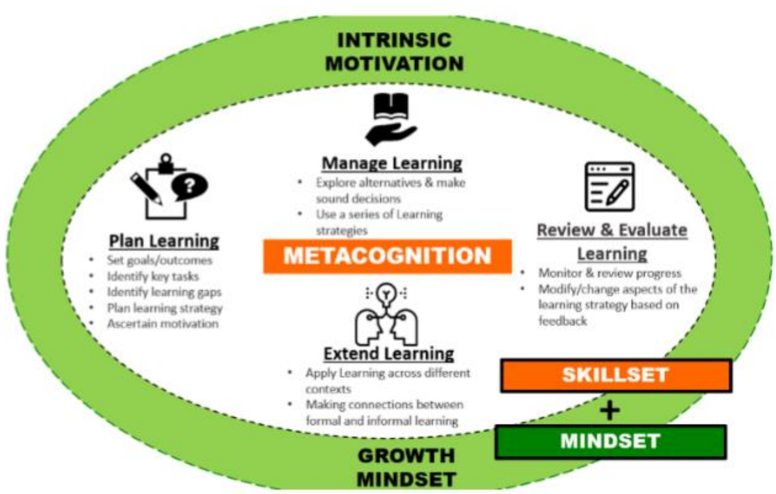


Figure 2. SP Self-Directed Learning framework

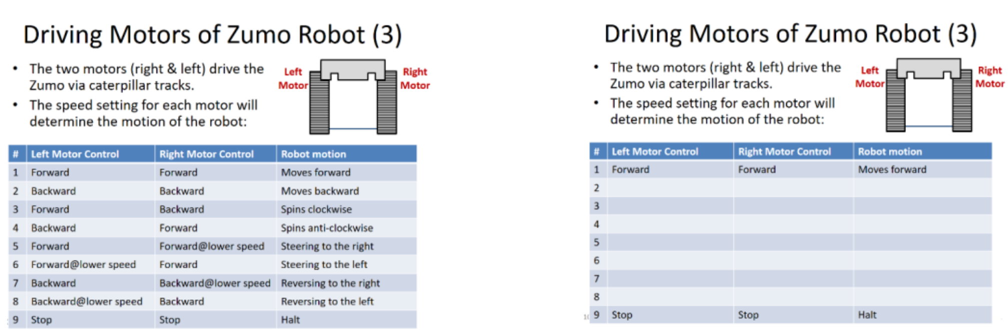
The SP's SDL model encompasses a range of cognitive and metacognitive skills. The key underpinning competence for students to become self-directed in their learning is to help the learner develop a growth mindset (Dweck, 2006) and Metacognitive Capability (Flavell, 1979) under the learning environment that can motivate learning (Ryan, 1980), which is often loosely defined as "thinking about thinking." To cultivate students to be more self-directed, the framework suggests, the learner needs to be able to plan his/her own learning goals, manage their learning by exploring a series of learning strategies and evaluate their learning where the students reflect on the effectiveness of their learning/thinking process and re-plan based on the evaluation. Lastly, the learner takes on a reflective process where he/she makes connections to other learning areas and analyse how their previously adapted strategies could be applied in another context.

The role of the teaching staff is, thus, vital to help students develop the necessary skills. However, as pointed by Csikszenthmihalyi (1997), goals should be sufficiently difficult and challenging to bring greater 254ulfilment in their accomplishment. If the goals are perceived to be overly challenging, it could lead to a high level of anxiety and unwillingness to give it a try. As one of my colleagues, after going through the SDL framework training session, told me: “It seems so complicated, I don’t think I can do it!”. Besides, the presence of so much new knowledge such as growth mindset, metacognition, and self-determination theory may leave educators confused and unsure about how to proceed, placing a heavy burden or mental barrier on already busy educators. Added to the challenge, there is currently a lack of knowledge of the appropriate ways of simulating and introducing SDL to our students.

This paper thus aims to use a feedforward process where some interventions were tested out to encourage students to be more self-directed. The action research methodology was adopted in this study to gather insights and observations in the pilot run. Insights and observations from the pilot run were then used to improve the next run. This becomes an iterative design process with the aim of us to design better lessons to help transit our students from being too dependent on a more self-directed learner.

THE PILOT ACTION RESEARCH

To address the observed non-self-directed learning behaviours in the classroom, a pilot action research to promote SDL was conducted from Oct 2018 to Feb 2019 for 96 1st year DCPE students taking the IE2 module throughout the 15 weeks long module. The SDL strategy began with the author giving the usual, and familiar teacher-directed instructions approach for the first two lessons followed by less and less teacher-directed instructions with increased questioning in the next 7 weeks. Figure 3 illustrates an example of a simple modification the first author has made in the PowerPoint slides that support less direct-instructed approach.



(a) Before (b) After

Figure 3. The simple modification of the PowerPoint slides for teaching staff to use more questioning and less direct-instruction approach.

In this particular instance, the author asked the students what all the nine possible Zumo Robot motions are; and how these can be achieved. Two examples were provided to start the thinking process, and it was observed that most of the students were excited to answer and able to fill in all the blanks with some hints provided. During this period, students were encouraged to track their understanding, identify their learning gaps, and ask as much as they could during the lessons with the end goal to win the Zumo competition. In the 2^{nd} half of the module, we decided to place more focus on stage 2 of the SP SDL framework with simple motivation strategies to promote SDL opportunities to take place. For the remaining weeks, the students would work in pairs. A worksheet was also designed to guide the students in the planning of the Zumo competition. They would receive 5 tokens, which they could use, a token at a time, to ask questions if they need any clue, rather than directly receiving the answer during their preparation of the Zumo competition. This process aims to promote students to think before asking and help them to manage their expectations and adjust their learning steps from the very beginning. With this simple modification, we hope such an SDL strategy can increase students' ownership in taking care and managing their learning and be less dependent on their lecturers to provide direct solutions.

Students' Self-Assessment of SDL, Perceived Interest and Growth Mindset

Unlike learning programming skills, students can easily obtain feedback if they have achieved the learning objectives by testing their codes using the Zumo or from the text screen with the given learning tasks. It is, however, not so straightforward for students to know if they have become more self-directed. To introduce students how they can access their SDL behaviours and make appropriate changes, students from the 5 classes (1A24, 1A21, 1A22,1B02, and 1B03) were invited to complete the self-assessment on SDL near the end of their Zumo competition preparation. Items 8 to 11 questions were added to assess students' perceived motivation and growth mindset. 94 out of 96 students completed the self-assessment with the results shown in Table 1. The students were then asked to share, "What do you think you could have done to be more self-directed in your learning?" For this question, only 74 out of the 94 students' comments were relevant and valid. Their responses were collected and grouped into identical/similar meanings, as summarized in Table 2.

Insights and Reflections

In the first half of the module, the authors find that the less-direct instruction approach worked well and was considered a success. However, it was not always plain sailing, especially when only little direct instruction provided. In one instance, the students were first taught how to write a simple loop program to access all the contents in a 1D-array variable on the whiteboard. The students were then challenged to extend their understanding to try out by writing their program codes to access the contents for a given 2D-array. This was what was observed: some students struggled and got it; some struggled and failed; some others simply copied the programs from online resources without trying or/and understanding. Presumably, a few students displayed an attitude that as long as it worked, they have no desire to understand how it worked. Besides, weaker students, who think programming was a rather difficult task and abstract to learn, shared with us that they felt anxious and unsure of follow up despite hints were provided. Thus, appropriate direct-instruct instructions were still necessary at the end when students failed to figure out.

As seen, educators can encounter a situation like this even with simple adaptation to the teaching strategies. Even with attempts to troubleshoot and intervention, there may just be no easy solutions. Thus, it is important we do not implement strategies that may be too overwhelmingly demanding for the students. In the attempt to strike a balance between students who find it just challenging and weaker students who panicked over the questions and challenges, a trial was made. When students faced similar struggles with the challenges presented to them, they were asked to recall what they have just learned. This seems to help them make connections to what they have learned, and more students were able to complete the mini-challenges. However, one must still be ready to provide more direct instructions if students were still struggling within a reasonable amount of time.

Table 1. Results of students' self-assessment of SDL, perceived interest, and growth mindset.

Q	Behaviours indication	1A24	1A21	1A22	1B02	1B03	Groups Mean
1.	I formulate questions and generate relevant inquiries.	3.4 (0.92)	4.06 (1.06)	3.63 (0.89)	4.16 (0.9)	3.9 (0.85)	3.83 (0.92)
2.	I try different ways to solve problems on my own.	4 (0.95)	4.26 (0.93)	4.06 (0.93)	4.89 (1.1)	4.35 (0.59)	4.31 (0.9)
3.	I try to understand what went wrong.	4.35 (1.09)	4.79 (1.03)	4.69 (0.95)	4.74 (0.81)	4.85 (0.88)	4.68 (0.95)
4.	I explore a range of possibilities and make sound decisions.	4 (1.17)	4 (0.94)	3.88 (0.96)	4.74 (0.81)	4.11 (0.81)	4.14 (0.94)
5.	I self-plan and self-manage my time well.	3.15 (0.88)	4.05 (0.97)	3.69 (1.14)	3.84 (0.6)	4.55 (0.83)	3.86 (0.88)
6.	I look for available resources to improve learning.	3.65 (1.09)	3.95 (0.91)	4.59 (0.80)	4.58 (0.77)	4.2 (1.20)	4.19 (0.95)
7.	I critically reflect on the effectiveness of my learning and gather feedback from my peers and lecturer(s) to achieve my learning goals.	3.75 (1.07)	4.43 (1.12)	4.00 (0.79)	4.21 (0.85)	4.2 (1.20)	4.12 (1.00)
	Overall average (SDL)	**3.76**	**4.22**	**4.07**	**4.45**	**4.31**	**4.16**
Perceived interest/Enjoyment (item: Q8)							
8.	The IE2 labs were interesting.	**4.15** (1.35)	**4.21** (1.36)	**4.41** (1.33)	**5.21** (0.85)	**4.2** (1.20)	**4.44** (1.22)
Perceived growth mindset (items: Q9, Q10, Q11)							
9.	I see making mistakes as learning opportunities.	4.63 (1.16)	4.42 (1.12)	4.81 (1.05)	5.05 (0.78)	4.9 (0.79)	4.76 (0.98)
10.	I see many opportunities for me to take charge of my learning.	4.4 (1.19)	4.32 (1.20)	4.41 (1.00)	5 (0.82)	4.4 (0.94)	4.51 (1.03)
11.	I believe I can manage/take charge of my learning. (G)	4.05 (1.57)	4 (1.25)	4.41 (1.06)	5.11 (0.94)	4.6 (0.94)	4.43 (1.15)
	Overall average (growth mindset)	**4.36**	**4.25**	**4.54**	**5.05**	**4.63**	**4.57**
*The assessment uses a 6-point Likert scale (1=not at all to 6 = All the time). Items Q1 to Q7 were selected and taken from Tan, Seng Chee. (1965) and modified slightly ascribed to the study							

Table 2. Students' comments on what they could have done to be more self-directed.

Response with similar/identical meaning	%	Selected actual written comments from the (N=74) students
Be more resourceful/Read up more (n=22)	27%	*"Research on the codes more at home."* *"Practice more coding to get familiar with the IDE."*
Poor time management (n=19)	26%	*"I could have managed my time better."*
To ask more questions (n=9)	12%	*"I could have to ask more questions."*
Pay more attention/not distracted in the class (n=7)	9.5%	*"not be distracted doing other things other than coding for the Arduino."*
Practice more(n=6)	8.1%	*"I could have explored more into how to code more strategy to be able to understand even better and try out new stuff."*
Understanding the codes(n=4)	5.4%	*"I should revise the chapters gone through in-class and redo the codes for better understanding."*
Late for class(n=3)	4.1%	*"Not be late and come earlier for lessons."*
Direction/goals (n=2)	2.7%	*"More concrete goals @ relative points of the project. Having a goal and ideas of what to do and complete."*
Preparation(n=2)	2.7%	*"I should have read through the day before to have more ideas at what is going on in class."*
Others (n=1)	1.4%	*"I should have been more confident in learning the language of learning how to code the Zumo and not relied on my partner."*
	1.4%	*"Allow more moments to discover and discuss with friends."*
	1.4%	*"Reflect & improve on past mistakes."*

In the 2nd half of the module, the actual practice of fostering effective SDL amongst students using 5 tokens to limit the questions the students can ask during their Zumo competition preparation period have mixed outcomes. The following are the brief observations for the 5 classes provided by the lecturer who is teaching them the module:

<u>1A24 (Lecturer 1):</u> The class enjoyed some part of the lessons but was always seem to have a short attention span. Some attempted to use the token to ask very general questions in the hope of getting as much help as possible. Some kept quiet, seem lost what to do, and only seek assistance after panic kicked in. End of the day, some were not even able to code a simple program with the Zumo responding to the sensor's inputs.

<u>1A21 (Lecturer 1):</u> They are in general playful, and some of them were only willing to try out the activities during the class when asked. Quite a handful of them did not use the tokens as they relied on their peers. However, not all seem to bother to learn when their peer was teaching them. Those who helped their peers became better.

<u>1B02 (Lecturer 1):</u> This class was seen as very motivated and loves challenges. When given a challenge, they were excited to solve it on their own. More than 80% of the students refused to use the token to ask the lecturer any questions while they were preparing for their Zumo competition. Most believed they could solve the problems on their own and did not mind spending the extra time and effort to constantly improving their strategies and test it out with other groups.

1A22(Lecturer 2): This class appeared much happier and during lessons demonstrate a fun attitude. Most students use one or two tokens while preparing for their Zumo. Though most of them did not revise/review their learning regularly, most are ready to demo their coding and test run their project.

1B03(Lecturer 2): Only 30% of students in this appear to be enjoying the module. Others show lots of worry in learning and claim difficulty due to a lack of programming skills. 50% of the class displayed difficulty in catching up and take a much longer time to respond to testing their project and coding. Most of them still expected high dependence from the lecturer.

From the findings, we also gained the following insights that are useful for the next action research:

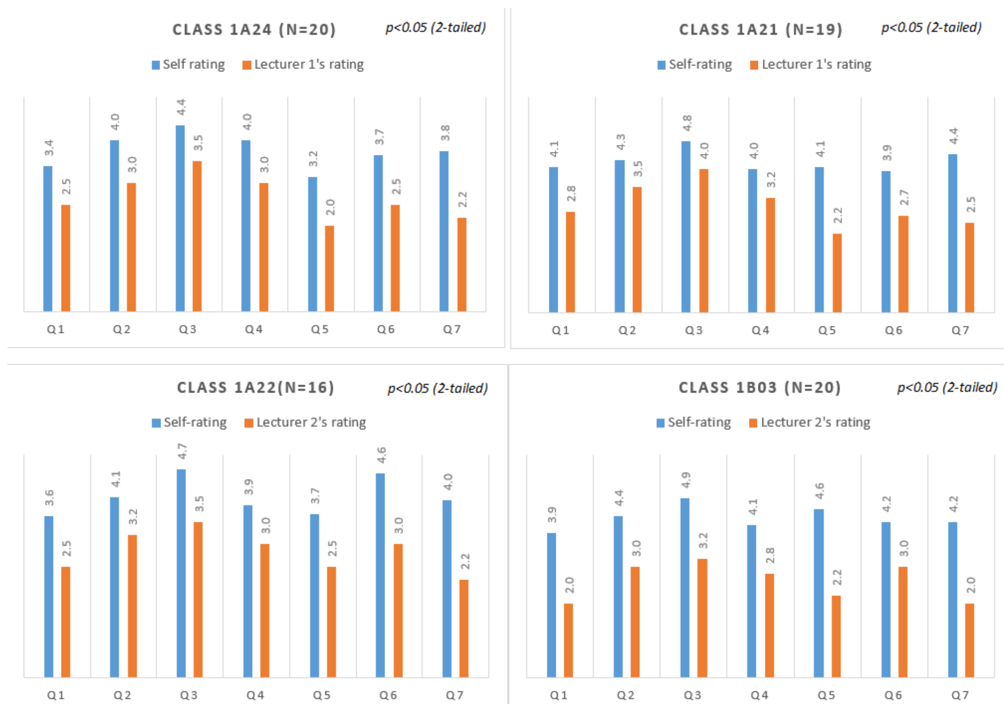


Figure 4. Students rated themselves higher on their SDL behaviour than their lecturers (statistically significant) for class 1A24, 1A21, 1A22 and 1B03

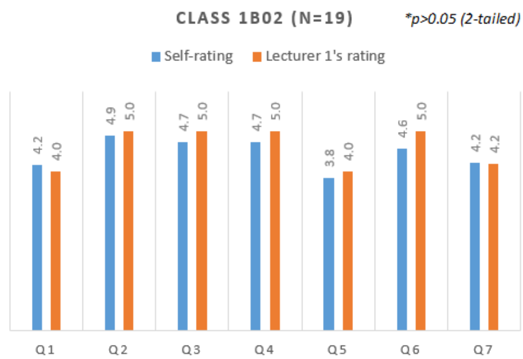


Figure 5. Students from 1B02's rated themselves slighter lower on their SDL behaviour than their lecturer (not statistically significant)

Students Who Enjoyed the Module, But Many Did Not Revise/Review Learning Regularly

In general, the majority of the students enjoyed the module, as they have indicated with a minimum score of 4 in the self-assessment form. However, it was not known if the students from 1A24,1A21,1A22 and 1B03 have a strong growth mindset as there were no obvious classroom observations to support the high score they have given to themselves. When we followed up with the students, some of the students did continue to display strong confidence that they were able to manage their learning. We thus suspected one of the contributing factors was that they were not revising and reviewing regularly.

Students who are seen SDL ready rated themselves lower compared to lecturer's rating of themselves

The student from class 1B02 displayed a strong growth mindset that they can solve their problem. They were observed to have high ownership of their learning and were ready to work more independently. However, as seen in Figure 5, these students ranked themselves lower than what their lecturer will rank them.

Students Who are Seen to Have Low Ownership of Their Learning Rated Themselves Significantly Higher Compared to Lecturer's Rating of Themselves

On the contrary, students who were observed to display having low ownership of their learning rank themselves statistically significantly higher than what their lecturer will rank them. This can be seen in Figure 4. During the 1st half of the module, they were all encouraged to ask as many questions when they are learning something new. However, comments such as "the sensor did not work," and "the Zumo codes does not work properly" were still common during the 2nd half of the module. While the authors attempted to ask questions to get the students further describe the problems, most of them were still expecting direct solutions. This could be due to panic and anxiety, as they did not review their learning regularly and had to do their coding at the very last minute.

Students Displayed Poor Time Management and Were Multitasking

There are many factors for students not taking ownership of their learning. One key factor both authors observed were the students (except for class IB02) did not manage their time well.

They have always seen multitasking during the class and always procrastinate on the given learning tasks (e.g., submitting an assignment late). This results in not having sufficient practice to construct their knowledge before they can work on the codes themselves to prepare for the Zumo competition. When it was time for the students to code on their own, a handful of them suddenly felt panic and anxious as they did not ensure that they have learned prior materials. When asked, many admitted that they did not pay sufficient attention in class and practice sufficiently even though they believe they can manage their learning if they have planned earlier. All these were consistent with students' comments, as seen in Table 2, "poor time management," "read up more," and "ask more questions during the classroom," being the top 3 frequent responses.

Revising Plans for Cycle Two

The strategy to use less direct instruction and more questioning to promote active/independent learning in the classroom was a very helpful approach and will remain in the 2nd cycle. However, through pilot action research, both the authors came to realise that many students did not spend enough time to practice their coding. One of the key factors is students simply do not typically use distributed practice as they work toward mastering course content. When we followed up with the students, we realised that many might unknowingly think they can master the content using massed practice, or they felt they have already mastered the knowledge by understanding what is being delivered to them during the class.

Let the Students Experiment that Knowledge is Constructed and not Transferred

Thus, to encourage the use of the distributed practice, it is important to first let our students understand that knowledge is constructed and not transferred, as quoted by Peter Senge (1990). For this, a simple activity can be designed where students will be asked if they think they have learned the material after what is being taught. It can then be follow-up with a learning task where students need to apply what they have just learned. It is very likely that students who are doing it for the very first time would have some struggles.

Encourage Distributed Practice and not Massed Practice

To further encourage distributed practice, the students need to understand how our brains learn and the benefits of using distributed practice compared to massed practice as Willingham, Daniel. (2002) has shared. However, in the beginning, we foresee that most students forget about what the teaching staff has mentioned. They will only begin to prepare and study only when they are reminded of the coming test or project assignments. By that time, cramming is their only option. To distribute practice over time, we plan to recap important concepts and have weekly or biweekly mini-quizzes before each lesson. On top of this, we plan to get students to come out with their learning plan so that we can help them to map out how many study sessions they will need before the Zumo competition preparation.

Introduce "Pomorodo" Technique during the Class

As students were always multitasking in the classroom, it is difficult for them to be able to focus on learning during the class. To deal with this, we plan to introduce the Pomorodo technique to all the students during the class. Barbara Oakley, who teaches a course on "learning how to learn," says one of the most effective techniques she knows of was created by an Italian named Francesco Cirillo. It's called the Pomodoro Technique. The technique is very simple. It begins with deciding what task to be done. The timer is then set to typically 25 minutes. All the students were to work on the task by putting their phones away, not browsing the web until the timer rings. After the timer rings, the students can take a short 3 to 5 minutes break to check their handphones and start their timer to work on the task/another task again. However, the authors foresee it may be difficult at the beginning since it is natural for the brain to shift its attention to something else in the first few minutes. Thus, it is very likely that some amount of collective practice over a few weeks are needed for the students to build this useful learning habit.

CONCLUDING THOUGHTS

This paper presents personal experiences with instances of how students rely on us on their learning. These experiences were similar among colleagues, as well. The SP's SDL framework that was established to address this area of concern was presented as well. However, it was perceived by many that it would be overwhelming if one expected to implement all the SDL phases accordingly to the framework. Like many teaching staff, the authors were not sure how to proceed and thus decided to test out some interventions to promote SDL. Through the pilot action research, we discovered some useful insights. One, we find that the self-assessment tool is unlikely to help students with low ownership of their learning to manage their learning process. Two, we find that students have poor time management, did not have sufficient practice before the given project assignment, and were always seen multitasking in the classroom. All these factors seem to greatly hinder the students from being more self-directed. To deal with these issues, learning strategies, including teaching the students the right mindset for the next action research, were planned.

Lastly, we find that it is very challenging to facilitate self-directed learning as it involves scaffolding of the thought processes. After all, many of us were new to teaching and assessing students' cognitive skills. Running these sessions often requires us to devote sufficient time to first understand our students' challenges and be able to recommend strategies that can help them. This means we need to constantly build our knowledge on how the brain learns and builds "how-do coach" skills to help students develop these cognitive skills. All these are enough to make fostering SDL amongst students challenging and overwhelming to many colleagues who are unfamiliar. The use of reflective action research to implement simple SDL inventions at a time is thus appropriate. Such methodology helps us to build our experiences, knowledge, skills, and confidence. We hope this piece of work can also encourage our colleagues to kick start in the way they feel they can manage and come together to share/reflect the practices.

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LEARNING FROM EDUCATION INNOVATION USING THE 4TU.CEE INNOVATION MAP

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ABSTRACT

Rapid changes in society and student demographics pose major challenges for universities, who are responding by innovating education visions, learning goals, curricula, and courses. These education innovations are often reported in the literature and at conferences on a single-project basis, resulting in a large number of differently structured publications that make it difficult to find interesting examples or learn from a wide variety of education innovation projects. To counteract this, the four technical universities in the Netherlands (in Eindhoven, Wageningen, Twente, and Delft) offer standardized information about their education innovation projects on the innovation map website (4TU.CEE, 2020) of their joint Centre For Engineering Education; 4TU.CEE. University staff around the world can use the innovation map to find interesting examples of education innovation. Our analysis of all projects contained within the innovation map shows that, over the last four years, the innovation priority of the four universities has been on solving present-day challenges in their courses. The main approach has been improving education design and optimizing blended learning. This has been particularly useful for the universities that faced a large growth in the number of students. In the future, however, the priority of the four universities must shift to their longer-term strategies, such as Future Engineering Skills, Interdisciplinary Education, Dealing with Diversity, and Education Excellence. That also means more focus is needed for changes both to the curriculum and beyond. Furthermore, evaluation and dissemination should be more explicitly included. The purpose of the innovation map is to offer input for further university education innovation projects and research.

KEYWORDS

Education innovation, education vision, learning goals, curricula, course, education design, Standards 2, 3, 4, 5, 6, 7, 8, 11, 12

INTRODUCTION

Our world becomes full of Volatility, Uncertainty, Complexity, and Ambiguity (Kamp, 2016). This has consequences for the position and task of universities, the learning goals for students, and the way students learn. Kamp (2019) describes the effects at the university level: “Science and Technology universities have to become much more socially engaged and culturally open to remain relevant and take the lead. They shall no longer produce knowledge for the world alone, but have to become more active in the world.” He also sees clear effects on learning goals: “Engineering students have to learn that people, policies, environmental aspects, politics, economics, or cultural values often override disciplinary expertise.” In addition, student populations are becoming more diverse, which has consequences for the design of courses (van Puffelen, 2017). For some universities, the growth in the number of students dictates the redesign of courses and curricula.

Universities are responding to these challenges by innovating their education visions, learning goals, curricula, and courses. These education innovations are often reported in the literature and at conferences on a single-project basis, resulting in a large number of differently structured publications that make it difficult to find interesting examples or learn from a wide variety of education innovating projects. To counteract this, the four technical universities in the Netherlands (in Eindhoven, Wageningen, Twente, and Delft) offer standardized information about their education innovation projects on the website (4TU.CEE, 2020) of their joint Centre For Engineering Education; 4TU.CEE. The website interface for this information is called the “innovation map,” which enables users to select projects that are interesting to them and obtain standardized information to compare and learn from several projects. There are filters to select projects by theme or by many innovation characteristics, in addition to free-text search capabilities. Additional information, including the contact person, downloads, and links, help to explore each project further. The innovation map is an ongoing project itself; new projects are added constantly, and the information can be updated by all staff members involved in the projects. It is the key information source on Education Innovation for the federation of the four Dutch universities of technology: 4TU (4TU, 2020).
In addition, the information on all projects can be used by university staff worldwide.

The projects reflect the combined effects of bottom-up and top-down innovation initiatives at the four Dutch technical universities over the last four years. Analyses of the project information enable those universities to better align their education innovation with their education strategies, generating results that might also be useful for universities worldwide. Tassone et al. (2020) developed a framework to analyze education innovation projects, consisting of 13 criteria. In the present study, three of those criteria are used to analyze the projects: reasons for innovation, evaluation of the projects, and dissemination. This analysis is supplemented by the distribution of the projects over the characteristics covered by the innovation map.

MATERIALS AND METHODS

The information on the education innovation projects in the innovation map website is continually updated and extended by the staff involved in all projects and the 4TU.CEE. For the present study, the information available on January 20th, 2020, was used. At that time, there were 215 education innovation projects on the website, involving a total of 285 staff members (115 from Eindhoven, 95 from Wageningen, 49 from Twente, and 26 from Delft, including staff counted twice in joint projects). For each project, the relevance of one or more of six themes is indicated on the innovation map:

Active Learning & Large Groups
Blended Learning & Virtual Labs
Education Excellence & Coaching
Future Engineering Skills
Interdisciplinary Education
Dealing with Diversity

First, the presence of each innovation theme was determined on the innovation map, for each course and curriculum innovation. This was supplemented with counts of any additional results (articles, workshops, and tools) and evidence-based innovations. In addition, all project texts were scanned to identify any detailed reasons for innovation, evaluation, and dissemination, the subset of the criteria developed by Tassone et al. (2020) explored in this study.

RESULTS AND DISCUSSION

The majority (192) of the 215 projects studied were course innovations (Table 1). Articles and workshops were relatively rare additional results, and about 25% of the projects also yielded a tool for teaching. Only 28-course innovation projects were reported to be evidence-based, indicating that personal judgment is typically used to steer the innovation. The results for the separate themes showed the same pattern.

Table 1. Distribution of results and themes for course innovations

	Course innovations	Additional results			Evidence -based
		Article	Workshop	Tool	
Project total	192	28	12	48	28
Themes (projects can have multiple)					
Active learning & large groups	105	16	10	22	16
Blended Learning & Virtual Labs	88	10	6	26	9
Education Excellence & Coaching	74	7	1	26	11
Future Engineering Skills	44	9	2	13	10
Interdisciplinary Education	39	9	3	1	11
Dealing with Diversity	36	6	4	8	6

The lower part of Table 1 shows the distribution of themes in the course innovation projects, sorted by frequency. As each project can be geared towards multiple themes, the column totals for themes are higher than the total number of projects. The most frequently observed themes were Active Learning & Large Groups, Blended Learning & Virtual Labs, and Education

Excellence & Coaching. In general, these themes are important for present-day course challenges, but they might be geared to some longer-term goals as well. Less common themes were Future Engineering Skills, Interdisciplinary Education, and Dealing with Diversity. These themes include more adaptation towards the needs of the engineer of the future. It seems that, in past years, short-term challenges had a higher priority.

Only 68 of the 215 projects were curriculum innovations (Table 2), of which 45 also contained innovations at the course level. The reported education innovations were, therefore, mainly performed at the course level. Again, articles and workshops are relatively rare additional results for curriculum innovations, and about 25% of the projects also yielded a tool to be used in teaching. Only 13 curriculum projects were reported to be evidence-based. The results for the separate themes show the same pattern.

Table 2. Distribution of results and themes for curriculum innovations

	Curriculum innovation	Additional results			Evidence -based
		Article	Workshop	Tool	
Project total	68	12	2	15	13
Themes (projects can have multiple)					
Active Learning & Large Groups	38	6	1	5	7
Blended Learning & Virtual Labs	28	3	0	8	4
Education Excellence & Coaching	24	5	1	8	5
Dealing with Diversity	19	4	2	3	5
Interdisciplinary Education	17	5	1	1	4
Future Engineering Skills	17	6	0	3	7

The lower section of Table 2 shows the distribution of themes in the curriculum innovation projects, sorted by frequency. Again, the three most common themes are more geared towards present-day challenges, while the three less frequently observed themes include more innovation towards the needs of the engineer of the future.

Projects can be defined within the six fixed themes in the innovation map. Project staff can also formulate their reasons for innovation freely within the project information text. The formulations found for all projects were grouped into six overarching reasons, as shown in Table 3.

Table 3. Reasons for innovation, as reported in the project texts.

Reasons for innovation	
Optimize education design and assessment (due to increasing students/different needs), as well as coaching	159
Improve online learning for flexibility of learning and tackling problems related to increasing student numbers and online safety	63
Improve student motivation and interaction	56
Dealing with diversity; knowledge level/cultures/work in groups	41
Improve teacher education methods	38
Future skills (planning, career choices, etc.)	17

The results for the freely formulated reasons for innovation reflect the same trend as seen in the themes in Tables 1 and 2 above; present-day challenges have been considered more important than long-term innovations geared towards the engineer of the future. The main topics are within the fields of the optimization of education design and blended learning.

Only 86 of the 215 projects reported an evaluation, with 14 of these 86 projects reporting two or three methods of evaluation. The most frequent approach was "implementation in courses/BSc program; evaluation afterwards by the project team," as shown in Table 4. That approach might include the standard course evaluation performed by the universities. This suggests that, in general, little additional effort was made to evaluate the 215 education innovation projects.

Table 4. Evaluation of the innovation projects, as reported in the project texts.

Will this innovation project be evaluated, and how?	
Implementation in courses/BSc program; evaluation afterwards by the project team	54
Student course evaluation	29
Evaluation of a pilot group	11
Teacher evaluation	5
Discussion with professor(s)	4

Most projects reported some dissemination activity; only 18 projects did not. The most frequent form of dissemination was an integration in the course(s)/BSc program involved, which was almost always the goal of the project anyway, as shown in Table 5. For 79 projects, there was a clear additional effort for the publication of an article. Other dissemination options were found to be less frequent.

Table 5. Dissemination of the innovation projects, as reported in the project texts.

In what way will this innovation project be disseminated?	
Integrating in course(s)/BSc program	86
Report/journal published	79
Video	26
Presentation	22
Poster	21
Handout/module	18
Website	5
Workshop	3

The results are similar to those reported by Tassone et al. (2020), who analyzed the characteristics of 88-course innovation project proposals at Wageningen University. Most of these projects are also included in the innovation map. For this subset, they found;

“Most intended innovations are driven by changes in student populations. To a lesser degree, they are driven by challenges in teaching, learning, and assessment, and by challenges with logistics and resources. Hardly any innovation is driven by changes in society. The most prominent reasons for innovation are the increasing number of students, and the related need for guaranteeing student learning and performance.”

“More than half of the intended innovations do not include an evaluation strategy. Only 15% of the proposals include and specify an evaluation strategy.”

“Most innovations intend to disseminate results by providing detailed knowledge about the innovation, for example, through a presentation of the innovation. Few proposals only intend to foster the further uptake of the innovations (dissemination for action).”

These findings are in line with the results of this study of the 215 projects at the four universities of technology; education innovation has focused more on present-day problems and less on long-term strategic goals. Tassone et al. (2020) reported even lower rates of evaluation and dissemination than are presented here, which could be because these researchers scanned the proposal texts, while the innovation map reports results, including the less explicit evaluation and dissemination within the courses involved.

CONCLUSIONS

The reported education projects run by the four Dutch technical universities show a focus on course-level innovations and present-day challenges. Furthermore, these projects indicate a preference for innovation by optimizing education design and balancing blended learning. These changes may have been introduced in response to the strong growth in student numbers experienced at these institutions over the past few years, particularly in the two universities with most reported projects, Wageningen and Eindhoven. Of course, strong student number growth is a very urgent challenge that must be tackled. The steps for optimizing education design were described by van Puffelen (2017), while advice for balanced blended learning was previously provided by van Puffelen, van Berkum, and Diederen (2018). Additionally, approaches for teaching large groups were proposed by Tho and den Brok (2019).

Present-day education challenges should not be the only focus of such innovation projects; however, because the four Dutch universities of technology have longer-term strategic goals. These goals have been expressed in four topics within the 4TU.CEE strategic plan (den Brok et al., 2019):

1. Educating Future Engineers
2. Interdisciplinary Engineering Education
3. Engineering Educational Ecosystems
4. Teaching Excellence in University Engineering Education

To innovate towards these goals, the focus of innovation projects will have to shift to meet them. This will also require an innovation shift from the course level to the curriculum level and beyond. It would help to monitor this, if the tradition to mainly report course innovations is changed to more include the curriculum and above curriculum level. The addition of the beyond-curriculum level to the innovation map at the end of 2019 should facilitate the monitoring of its inclusion in innovation projects.

The evaluation and dissemination of the projects have mainly occurred within the innovated courses themselves; however, it would be better to explicitly include evaluation and dissemination actions in the proposals, project activity, and reports going forward.

The innovation map serves its purpose at its present scale of four universities. For staff around the world, it offers a flexible way to learn from the results of university education innovation projects. The Netherlands Initiative for Education Research (NRO) is interested in using this approach on a national scale, and its use on an international level such as offered by the CDIO initiative (CDIO, 2020) is another option.

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Emiel van Puffelen is the leader of the 4TU.Centre for Engineering Education at Wageningen University & Research. At Wageningen University, he supervised the creation and full-scale operation of the University Teaching Qualification program. He also developed MOOC production teams, knowledge clip studios, the education innovation consultancy, the educational portal, and a team for the innovation of the IT learning environment. He is a senior consultant for the innovation of higher education and has worked for national organizations. He has a special interest in activating learning, blended learning, training teaching staff, and the novel design of curricula and courses.

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CHANGE FOR GROUP DESIGN EXERCISES IN A LIGHTING DESIGN PROGRAM

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ABSTRACT

The lighting design education was recently converted to a three-year bachelor program, from a two-year non-engineering track, in which students' group design exercises resembled a design studio process characterized by high uncertainty, self-anchored problem solving and creativity. Consequently, students who attend this program are less disciplined in engineering, which predominates other educational programs at the School of Engineering. The aim of this study was to map the Lighting design students' ability for a problem-solving approach and their ability to control group design exercises to create a strategy for sustainable change, if necessary. The study employed a mix-method approach. In the quantitative data gathering, an online survey collected 18 students' responses using convenience sampling on the locus of control. Additionally, this survey registered the student's perception of the experienced group design exercise in terms of how concrete (assignment-based) or open (problem-based) the design exercise was. The visualization of this data, together with the locus of control measurement, revealed that students in the first year (N=4), tend to be located centrally with no preference for a problem-solving approach. In the meantime, the second-year students (N=6) developed an open (problem-based) approach to problem-solving, while their overall control in life is still more external. Finally, the trend for the students in the third year (N=8) moves to a more assignment-based approach and more to an internal locus of control. The qualitative investigation involved three focus group interviews (N=13) emphasizing on the following themes: open/closed projects, control, the teacher's role, instructions, demands, realism in the projects, project size, project budget, project time, group dynamics, group size, group roles, leadership, personality, and conflicts. Results reflect a shift in confidence in the ability to exert control over one's own motivation and behavior in the group design exercise. The themes were also reflected in the content of the focus group interviews. Based on these findings and according to the adaptation and implementation of a CDIO's design-implemented experiences, the preparation for introducing small gains for students and staff members were proposed.

KEYWORDS

locus of control, lighting design, learning outcomes, active learning, Standards 5

INTRODUCTION

In recent times, an engineering education ought to be positioned so that a deep approach to learning and conceptual understanding should complement each other for increasing student motivation, interaction with (each)others, and collaboration. In the meantime, students should be prepared for a career in engineering, which necessitates enhanced (inter)personal skills to communicate, increase problem-solving skills, experimentation, critical and creative thinking in the face of uncertainty. In addition to personal improvements, engineering students should be able to reflect upon societal events and must develop insight into the role of science. It is a demanding task for a student to commence in all these expectations at the same time.

These challenges in engineering education have been introduced earlier in a complex system, as it is highlighted by Crawley, Malmqvist, Ostlund, Brodeur, & Edström (2014). Their approach to settling these conflicts is called Conceive-Design-Implement and Operate (CDIO). In order to facilitate the adoption of this approach in higher education, twelve effective practices were identified as standards which cover the engineering education life cycle and serve as universal guidelines, for instance, to education program reform and evaluation (Crawley et al., 2014, p.35). When evaluating and reforming an engineering program, the emerging field of engineering education research (EER) plays a vital role in achieving usefulness and scholarliness as it was outlined by Edström (2016). Thus, researches that merely focuses on basic science would be less applicable and appropriate to tackle a practical problem, while a specific problem-related study would also mean limitation for understanding a larger picture in which the education context primarily exists. Therefore, finding "*the balance and relationship between scholarliness and usefulness is both a philosophical and practical question*" (Edström, 2016, p.980). In the case of this study, the vision was to provide a practical and useful representation for colleagues and fellow researchers to map a design-implemented experience (Standard 5 in CDIO) principle that incorporates both scholarliness and usefulness. Furthermore, a practical adaptation of a sustainable change process based on Kotter's eight stages (Crawley et al., 2014, p.184) could be canvased.

Studies on the locus of control (LOC) started with Rother (1966), who introduced the theory and provided a scale to measure. It is accepted by now (e.g., Asante & Affum-Osei, 2019) that there are two main types of control perceptions an individual may possess. On the one hand, individuals with internal LOC believe that an outcome of an event is mainly influenced by their own action and behavior, therefore less likely that chance has to do anything with the outcome. On the other hand, individuals with external LOC rather believe that their life events and behavior are largely affected by external influences, and therefore, they lack control over their situations. These fundamental differences had been investigated in different areas, such as job attitude, job performance, and even in user experience design (e.g., Jang, Shin, Aum, Kim, & Kim, 2016). Studies on LOC and design decisions are scarce to find; the practical assumption here it, that design decisions require internal LOC, which is a resourceful move by the individual on a subjectively appraised objective possibility. Those who act on this opportunity may be more successful in the field of design than those who would not react. In terms of teaching design learners, our earlier investigation (Fischl, Granath, & Bremner, 2018) showed that one-quarter of the students would prefer group design exercises, which are less concrete/pre-described, hence be more open. Subsequently, education should progress to stimulate a gradual internalization of perceived LOC, in which professional skills may be fostered.

This study is a continuation of an earlier investigation (ibid.) about how undergraduate architecture-engineering students perceived control over their life situation and their problem-solving ability in group design exercises. The Department of Construction Engineering and Lighting Science at the School of Engineering, Jönköping University in Sweden, runs a program in Architectural Engineering and in Lighting design. Both educations are characterized by project works, which facilitate a comparison of the students' progression.

The lighting design education has recently been upgraded from a two-year-long undergraduate non-engineering education to a three-year bachelor program. Even though the lighting design education has been operating for 20 years, it is unique both nationally and internationally. The profession as a lighting designer is still in its early stage. Mostly practicing architects engaged themselves with daylighting and electrical engineers or electricians working with artificial lighting were interested in developing the field. As a consequence, it is shown that people seldom took responsibility for the field as a whole. Today, the profession is still somewhat divided between artistic and engineering approaches (Boyce, 2017, Cuttle, 2011). The lighting design students have not yet fallen into this professional trap as they usually come to the university directly from the upper secondary school. In the lighting design education, there are project courses in which the task always concerns a real building, often also with real stakeholders representing their demands and wishes. The students observe and analyze the environment; they make sketches, perform test lighting, visualize, and then orally present their work. Apart from lighting design, they also prepare light measurement, light calculations, cost estimates, and discuss environmental sustainability along with energy use. Human health and wellbeing are also a concern for the projects. This way, by showing skills on the wide spectrum of tasks, the students retain a great position in the market. During project courses, students are working in groups of three to four assigned by the teachers. They have inspirational lectures and seminars wherein the main part of the teaching is through supervision. Their group work is characterized by a rather open approach. Generally, every group receives the same task on the same site. Hence, they need to find their own ways to deal with uncertainty and defining the problems, formulate their ideas, to elaborate and present projects. The project-based courses are graded individually with a pass or fail. If a written exam is included in the course, the grades can be more differentiated in steps. However, oral feedback from the teacher is often just as valuable and motivated for learning as grades are.

In order to describe and characterize the lighting design education, the aim of this study was to map the Lighting design students' ability for problem-solving approach in relation to their control in group design exercises to create a strategy for sustainable change, if necessary.

METHOD

A mixed-method investigation was performed in this study, wherein lighting design students were involved in focus-group discussions and administered an internet-based questionnaire.

Participants

Altogether, 75 students were invited from a three-year lighting design program to respond to an internet-based questionnaire. Overall, 30 responses were collected, but due to a technical problem, only less than two-thirds of the responses were completed. Therefore, the response rate became 24% resulting in 18 participants (M_{age}=26.2; SD_{age}=4.65), out of which half of them were female. Due to the decreased number of valid responses in each schoolyear, the sampling was treated as one cohort instead.

The focus group interviews in total, included 13 students (M_{age}=26,8; SD_{age}=4.39) from which year one and three had four students each, while year two had five students. Convenience sampling was employed for finding participants through teachers' personal contacts within the academic courses. Additionally, all of the focus group students contributed to the online questionnaire, measuring locus of control, and were rewarded for their participation with a lunch.

Data Collection Instruments

A quantitative survey on an individual's locus of control (Nowicki-Strickland, 1973) was completed online, and it consisted of 40 forced-choice category level (Yes, No) standardized items that were computed to a single value. The lower value on LOC<=10 indicated a more external LOC, and a higher LOC indicated internally. In addition to this, demographic data (age, gender) and academic subject major were recorded together with a research consent for participation and publication of research results, ensuring an ethically conducted investigation.

The online survey also encountered experimental questions on how well-defined a recent experience group design exercise (APA_{rec}) was and what would be the preferred level (APA_{pref}) in the future. These ratings were indicated on a seven-point Likert-scale (1=More assignment oriented, 2=Assignment oriented, 3=Slightly assignment oriented, 4=Ambivalent, 5=Slightly problem-oriented, 6=Problem oriented, 7=More problem-oriented). The lowest value corresponds to a defined and assignment/task-based design exercise, which is characterized by tasks that are broken down in order to facilitate learning. Meanwhile, the highest value corresponds to an open and thus undefined design problem, which is not expressed in distinctive parts, but the aim is to develop and creative problem-solving approach without limiting self-reflection.

The focus group interviews were conducted using a protocol to ensure effective communication. The duration of each group interview was limited to 30 minutes. A semi-structured interview was applied, and the interview questions were organized according to Kolb's (1984) experiential learning styles. Questions targeted previous concrete learning experiences in group design exercises and perceived conflict and control during tasks; the questions on reflective observations entailed assignment- and problem-based exercises and issues of grading.

Procedure

Lighting design students in the bachelor program had responded to an email link for the Nowicki-Strickland (1973) questionnaire, including inquiries on demographic data and the research consent. This questionnaire was formed in Google Forms. After agreeing to the research consent, the participants could complete the entire questionnaire online. The three focus group interviews were conducted in a meeting room with four (and five) students and at least one researcher present at the time. The interviews were audio-recorded, then transcribed and analyzed following a content analysis technique on self-efficacy.

Data Analysis

The scoring procedure of the Nowicki-Strickland questionnaire (1973) provided interval data and could be treated parametrically. The information on gender was gathered as nominal data while age as ratio and school year as the interval. Statistical analysis in each school year could not be performed. Instead, a graphical analysis was prepared; consequently, gender and age differences were not explored in this limited dataset. The plot-diagram depicting LOC and APA_{rec} measures was divided into quadrants and described as follows:

1. *Comfortable:* students are receiving external demands and support for completing an assignment/task-based exercise.
2. *Performative:* students are more internally driven, routine-oriented, and familiar with the demands that may be represented in the assignment/task-based exercise.
3. *Being lost:* when high LOC is combined with a more openly defined project, the students experience being lost in the labyrinth of possible project solutions
4. *Creative*: this is the most preferable position; it is a combination of internal LOC and capability of solving problems that appear rather undefined. Self-reflection and performative practice with minimal tutoring may result in a unique solution.

Finally, a content analysis of the transcribed interviews was performed using a deductive technique. The interview data was structured in one main domain, self-efficacy.

RESULTS AND DISCUSSION

The aim of the study was to map the Lighting design students' ability for problem-solving approach in relation to their personal control in group design exercises for a sustainable change. The collected number of responses through the online questionnaire are summarized in Table 1. The LOC measures gradually decreased as the academic years progressed. This is a favorable trend when one of the purposes of the Lighting design education is to let the students take more control over their everyday activities and learning. In detail, students in the first two years find themselves more on the external LOC, while in the third year, they were more internally controlled. Regarding the assessment of the recent (APArec) and preferred (APApref) assignment-problem affinity measures, in each school year, the students would have liked a bit more defined projects than what they had experienced.

Table 1. Summary of results for the locus of control (LOC), the recent (APA_{rec}), and the preferred (APA_{pref}) assignment-problem affinity measures.

N	Year		LOC	APA_{rec}	APA_{pref}	Difference(APA_{pref}-APA_{rec})
4	1	Mean	11,75	4,75	4,00	-0,75
		SD	4,27	1,26	,82	
6	2	Mean	11,00	5,65	5,5	-0,15
		SD	2,89	,82	,54	
8	3	Mean	8,88	4,38	4,13	-0,25
		SD	3,91	1,51	1,26	
18	Total	Mean	10,22	4,89	4,55	-0,34
		SD	3,67	1,32	1,09	

Note: APA_{rec} and APA_{pref} were calculated on a 7-point Likert-scale (1=More assignment oriented, 2=Assignment oriented, 3=Slightly assignment oriented, 4=Ambivalent, 5=Slightly problem-oriented, 6=Problem oriented, 7=More problem-oriented)

The plot diagram shows all the students' responses (Figure 1) in each school year in terms of their LOC and APA_{rec} measures. The year clusters indicate that the development of the first two years is challenged by the third year's position. This can be explained by the fact that the Lighting design program was originally a two-year-long education, and the third year was added to complete the requirements for a Bachelor program. However, this program is portrayed as a creative one, and somehow it was only experienced by a few students according to this diagram. In terms of yearly development, the creativity quadrant is apparently lacking progression.

In contrast to this, the majority of respondents throughout the three years find themselves in a **being lost** position in which they would prefer more control/supervision/instruction when facing uncertainty in a problem-oriented project. It is an unfortunate combination in which individuals with external (high) LOC are not able to perform well.

The third quadrant (**performative**) is hardly visited by students. This quadrant should include students who gained enough knowledge and practical skills to execute larger projects alone or in groups. The internality in LOC refers to the ability of greater control, yet the assignment type of work would limit creativity. The lighting design program seems to avoid the performative quadrant for the second-year students.

Finally, the **comfortable** quadrant, which is described by external LOC (more teacher contacts and assignment type of problem-solving approach), is also barely activated. In this quadrant, only a third-year student went for the extreme, probably this student took a stand against the education progress after the first two years, namely, spending much time in the being lost zone.

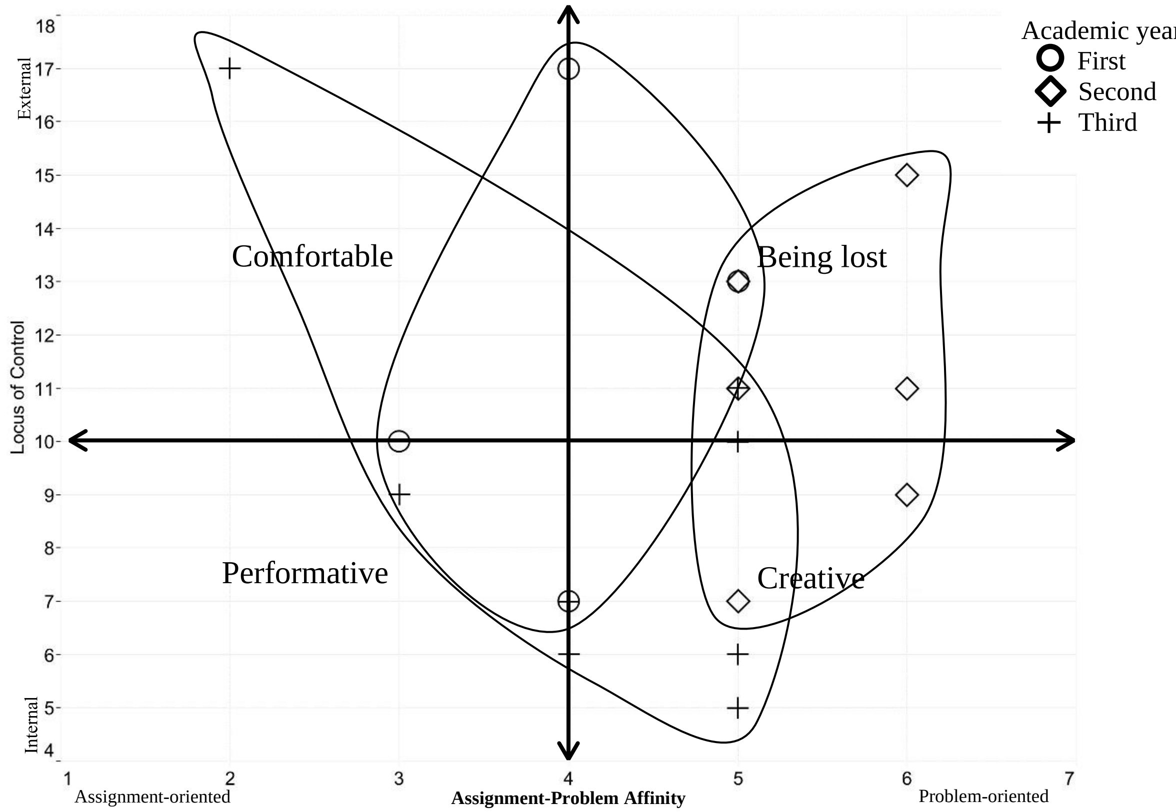

Figure 1. LOC positions with APA_{rec} for the corresponding student in different academic years

(N=18). Note: The LOC ambivalent position is located at the overall mean of LOC=10 (LOC<10 more internal, LOC>10 more external). The Assignment-Problem Affinity axis is on a neutral position due to its 7-point scale (1=More assignment oriented, 2=Assignment oriented, 3=Slightly assignment oriented, 4=Ambivalent, 5=Slightly problem-oriented, 6=Problem oriented, 7=More problem-oriented).

Focus Group Results

All groups answered in a similar way to the direct question if they preferred **open** or **closed** projects – they all prefer both, but they all also mentioned that the frames for the project must support them. On the follow-up questions for students who regard open projects as pleasant, - the first- and third-year students were positive; however, the former expressed concern about being too free, while the latter was concerned with the high energy (W) requirements in the project.

Regarding **control**, the first-year students wish that project courses are characterized by freedom, responsibility, and joy. In contrast, the second-year students with clear feedback, continuous supervision, clear and consequent instructions. The third-year students combine this by wishing a free task, but with clear instructions on what documents and specification they shall hand in. **Personality** also interferes with the results. One can have a controlling personality and being a perfectionist. Still, the same person can be very creative and free in their project design; how the student looked on the term "control" therefore varied.

There are several factors, except for those created by **teachers**, that impact if a project is experienced as open or closed. A project can be formulated as open, but the students may interpret this differently. For example, first-year students can feel it being too open because it requires knowledge they have not yet acquired. The second-year students can feel a project, meant as open, being closed because they have to design their lighting according to existing lighting standards and regulations. The third-year students who are accustomed to the regulations can work with the freedom within these frameworks. However, there are other causes that may interfere. One of them is the type of project. In this study, the second-year students stand out. They were overall more negative about their project experience. There might be different causes for this: the progression and maturity, the character of their recent project, or a lack of clear teacher **instructions**. Their recent experience was a realistic outdoor project, initiated as a sharp, almost real project with the local municipality as a client with their **demands**. The second-year students all agreed upon that the limits given by the municipality gave them too little freedom, and to this, they also needed to follow normal lighting regulations.

Regarding **realism in projects**, the first-year students say it makes them feel less free. The second-year students say that the client's expectations and the site conditions made it less open. The third-year students did not complain about the realism in the project and its conditions. Instead, they complain about inappropriate feedback and communication from teachers. A student from the third-year comments the realistic project's conditions and the client's expectations:

> "It felt hard to work with the wrong solution to the problem, because the problem was not bad lighting we should improve, by design. The problem was that we worked on a thing we knew wouldn't solve the problem fully."

The students from the third-year mention that if a project is open, the **project time** must be appropriate, open projects take more time. The second-year students, on the other hand, say that demands on students must be in relation to the **size of the project**.

From the quotations, there seems to be a clear progression, especially regarding **group dynamics** and how one relates to instructions and requirements. The students in the second year seem to wish for more **teacher control** than what the first-year students do and seem to have not as good of teaching experience as the others. This can depend on what kind of courses they recently have taken.

A student in the first year says:

> "But one must still know, what do you want to deliver? What do you wish to achieve? What do you want this to result in? Otherwise, it will be very hard to put something together."

A sign of the progression and how students mature is indicated in this quotation from a third-year student:

> "As you get further into the education, the more you start a project work with a plan."

The **power distribution** within a group can affect the perception of openness of a project. Especially in the first year, they talk a lot about the group constitution. It is natural since they do not know each other yet. Meanwhile, the third-year students focus their discussion on roles that are reflections of they know each other. There are also different culture and climate in each year. Some are more critical than others. Conflicts can ruin a project, but it can also make a project more open (said by a first-year student). The progression of **roles in a group** is especially interesting since this mirrors the overall progression. In the first-year student's focus at fellowship, they mimic each other's work, and they compete. The second-year students emphasize everyone's responsibility. They talk about themselves as a dynamic group. They also state that roles affect the control they have in the project. Students from the third-year express that they often fall into the same kind of role, nevertheless which project or group. They say that the group leader has a large impact on the groups' feelings of control. The number of group members also came up; three persons were regarded as ideal to really create dynamics.

A third-year student:

> "Group work has been easier the last years since you fall into it. You fall in a role, often the same. You know what you and others are good at…. If the roles shall be changed, someone needs to take the initiative to give up their "own" area."

Another third-year student:

> "I experience that I have become better on that I already was good at, but I have not improved that I was not good at from the start."

A quotation from a second-year student regards group leadership:

> "We need someone that just points with the whole hand when we can start producing."

A third-year student says:

> "That will say, you have more control over an undefined task if you have a clear leader who decides in what directions one should work."

When it comes to **instructions**, the first-year students say that if they are unclear, it limits freedom. The second-year students talk about the need for a clear aim and scope of the task. They wish that the teacher clarified what that is expected from them and what they shall deliver. The third-year students reflect upon the project that crashed because of unclear teacher feedback.

A student in the first year got the question of what is the worst thing with an open project. He answered:

> "The worst thing is probably that you may not always know what you should learn."

The **role of the teacher** is seen differently between the groups. The first-year students prioritize their support and say that students do not know what help they need. Conversely, the second year's students talk about a previous project failure by blaming the teacher's blurry instructions and inconsequent feedback. The third-year students point out that the teacher shall not be a sounding board, then it gets confusing. If the teachers give ideas, then the students think that must be correct. From this, we can see that students lack critical thinking from a constructive perspective. They are critical to the teachers, but they lack the ability to reflect on the situation from several viewpoints, like discussing their own role in this.

Regarding **feedback**, the first-years students wish for more teacher critique. The second-year group wishes for more consequent critique; the teacher shall not change what he/she says. Also, the third-year students say that teachers sometimes have given them critique they did not understand. There might be a discrepancy between what expectations students have on teacher feedback, respectively, what teachers think students will need and understand during different stages in their progression.

CONCLUSION

This study indicated that lighting design students' learning processes in group design exercises could be differentiated according to years of education. The analysis of each academic year revealed that the third-year education does not appear as a seamless development from the previous two years. Nevertheless, the third year's learning characteristics are preferable for an engineering education profile. This profile is described by creativity as a combination of internal control and problem-based approaches in group design exercises. Furthermore, the following themes should be addressed in the future for aligning the first two years for more organic development in group design exercises: *open/closed projects, control, the teacher's role, instructions, demands, realism in the projects, project size, project budget, project time, group dynamics, group size, group roles, leadership, personality, and conflicts.* Based on this investigation, and in order to successfully implement changes in an organization, Kotter's (1995), eight stages for change should be implemented. Due to the nature of the education, which consists of both artistic and engineering approaches, the sense of urgency can be established around a design process approach, which expresses the general participants' common interest, creating a common ground for shared understanding for a change. The second step is to form a powerful alignment across disciplines (design, engineering, lighting science) and create a vision for the new education, keeping in mind the deeper integration of the design process approach. By addressing the results of this study's qualitative investigations for the discrete organizational units, empowerment for the action of the vision can take place in which all participating organization unit can benefit. By introducing small rewards for teachers and students in the form of multidisciplinary design projects, all participants may benefit from the changes. These suggested design projects are positioned so that all should propagate internal control and enhancing self-efficacy within the problem-oriented design projects. Consequently, these small win-win design projects can reward everyone in the organization for continuing the change. When the pilot design projects are evaluated, and the credibility of the new approach is established within and outside of organization, the institution can articulate the connection between new behaviors and organizational success.

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LEARNING DESIGN AND THE TENSION BETWEEN STRATEGY AND DIDACTICS

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ABSTRACT

Enhancing courses with technology in a manner that supports students' learning, has clear underlying pedagogical values, and is aligned with a university strategy for course development is far from trivial. This paper describes and evaluates a Learning Design approach to such a process — a process that was initiated by a university's strategic goal of providing more and better use of technology for education. At the heart of the process is the Learning Design educational development methodology. The paper discusses the tensions between the goals of the process: learning activities supporting students' learning and the university's overall strategic goal regarding technology. We find that although tensions exist, they do not hinder the design of better teaching using technology, and we conclude that Learning Design is a useful methodology to address these tensions.

KEYWORDS

Learning Design, strategic goals, educational development, technology-enhanced learning, Standards 10

INTRODUCTION

Over recent decades, we have witnessed growing societal interest in the education system. According to Hargreaves (2003), this is linked to the idea of a knowledge society, which considers knowledge a fundamental resource for growth, development, welfare, and sustainability. This has led to increased participation rates in higher education (HE) and enhanced diversity in the student population, which challenges both the purpose of HE and its modes of delivery (Tang & Biggs, 2011, p. 3). Over the last 30–40 years, universities have changed from institutions for a small elite to institutions where a large percentage of a given youth cohort is educated (Hayhoe, Li, Lin, & Zha, 2011; Hussey & Smith, 2010). Therefore, university foci are broadening, and education is gaining a more central role in university responsibilities.

Furthermore, there is an increased focus on quality in teaching and learning. Quality assurance initiatives have taken various forms across different education systems (Alexander, 2000; Hopmann, 2007; Jongbloed, Enders, & Salerno, 2008; Labaree, 2012; Ozga, Dahler-Larsen, Segerholm, & Simola, 2011; Tang & Biggs, 2011). Academics are faced with unprecedented requirements in relation to documenting the quality of their teaching and justifying their didactic decisions. Another consequence of transcending local differences is an increased demand for teacher educator professionalism (Shulman, 1999; Trigwell, Martin, Benjamin, & Prosser, 2000). University teaching has become a 'scholarly enterprise,' formed by a scholarly approach not only to the disciplines but also to the profession of teaching (Boyer, 1990, p. 23). In a Danish context, political awareness of quality in HE can be seen in the new official job structure that has just passed in the Danish parliament (Retsinformation, 2020). It has been declared that all university faculty must teach, each faculty member must create a teaching portfolio, and there must be a competency development plan for each faculty member focusing on his/her teaching. This was based, among other things, on an extensive 2018 report addressing the cost and benefits of HE, as well as on a catalogue of 37 initiatives to raise the return on investment when improving the quality of teaching (Ministry of Research and Education, 2018).

One of the initiatives in the catalogue is an extended focus on using learning technology. This has led to universities having a strategic focus on educational technology. Most universities in Denmark have formulated a strategy for digitalisation that includes the use of digital learning. At Aarhus University, this came into play in 2015, when the university implemented a learning management system where all courses had a digital presence. In the newest contract with the ministry, one of the seven strategic goals is to "increase student learning outcomes," where one of the three indicators is the number of redesigned courses[1] with better and more substantial use of educational technology. This means that educational technology is singled out as a strategic goal and as a didactic means to enhance learning.

From the perspective of educational development, this raises the questions of whether and how this double understanding of educational technology is perceived and conceptualised by the academic staff, how it influences their approach to didactic redesign, and what educational development methodology is suitable to support this process.

RELATED WORK

In the CDIO framework, faculty teaching competences are addressed in standard 10:
A CDIO program provides support for faculty to improve their competence in integrated learning experiences (Standard 7), active and experiential learning (Standard 8), and assessing student learning (Standard 11). The nature and scope of faculty development practices will vary with programs and institutions. Examples of actions that enhance faculty competence include support for faculty participation in university and external faculty development programs, forums for sharing ideas and best practices, and emphasis in performance reviews and hiring on effective teaching methods. (Worldwide CDIO Initiative, 2020).

The critical reader of this standard could argue that it lacks a focus on educators as designers of teaching activities; the main focus is on the actual teaching, not the planning of it. This could be the reason why we have only been able to find one article from previous CDIO proceedings

[1] In the Danish context, a course is one subject/module (e.g., Calculus 1). Courses are in study programmes (e.g., Bachelor of Science in Maths).

describing the use of Learning Design as a tool for developing courses. In their article, Kozanitis et al. (2009) very briefly describe the use of Learning Design at Singapore Polytechnic.

LOCAL CONTEXT

Aarhus University is the second-largest university in Denmark. It was founded in 1937 and currently has five faculties: Arts, Health, Business and Social Sciences (BSS), Natural Sciences (NAT), and Technical Sciences (TECH). Prior to 2020, the university had only four faculties; NAT and TECH were one faculty called Science and Technology (ST). As this article was written just after the split of ST into two faculties, we still use the term Science and Technology.

All universities are state-financed in Denmark. The funding generally consists of two sources: money for research and money for education. The management model is—among other things—based on a strategic contract that the university negotiates with the ministry for a three-year period. The current contract was signed in 2018; as described previously, one of the strategic goals is that a number of courses must be redesigned using educational technology. No specific number of courses is mentioned; neither is a definition of what it means to be redesigned.

The faculty management at ST agreed that there should be support for the implementation or redesign. This support was placed at the faculty's teaching and learning centre called ST Learning Lab. The courses that shall be redesigned are all major bachelor courses—about 180 in total. The vice-dean of education invites the lecturers of the courses in question to start their redesign using a Learning Design workshop.

LEARNING DESIGN

The concept of Learning Design is ambiguous and is sometimes used to refer to a sharable representation of teaching practice that "*can serve as a model or template adaptable by a teacher to suit his/her context*" (Agostinho, 2006, p. 3) and sometimes to an educational development process and methodology of "*devising new practices, plans of activity, resources, and tools aimed at achieving educational aims*" (Mor & Craft, 2012, p. 86). Both Open University (2019) and Conole (2013) use the same definition. In the context of ST and this paper, we use both conceptualisations but refer to them differently. Learning Design (first letters capitalised) refers to the educational development process and methodology, whereas learning design (first letters in lowercase) refers to the representation of teaching practice.

In 2013 Learning Design was adopted by the Faculty of Science and Technology as an educational development methodology for integrating technology in teaching and learning in individual courses and as a compulsory component in the professional development of assistant professors (Godsk & Hansen, 2016). The aim was to provide a more systematic, effective, and efficient alternative to the previously prevailing ad hoc approaches to technology integration (Bates, 2005). Positive experiences and results from the professional and educational development initiatives led to further integration of Learning Design in 2018 in the faculty's strategy for course development for senior educators presented in this paper.

Learning Design for Course Development at Science and Technology, Aarhus University

According to Dohn, Godsk, and Buus (2019), a Learning Design practice is best described according to the six core characteristics of the methodology:

- the introduction of pedagogy-theory though practical models and tools;
- active involvement of educators as the designers;
- the aim of integrating technology for enhancing teaching and learning;
- a focus on students' learning;
- the use of aids, such as templates, IT tools and workshops, for developing, representing, articulating and sharing designs; and
- an ambition to establish a sustainable process of sharing and reusing designs.

In practice, this is actualised by means of design and implementation workshops, followed up by an individual, technical support. A design workshop is organised as follows:

- a face-to-face workshop with a three-hour compulsory part introducing the rationale behind the initiative and the Learning Design methodology;
- five local cases including details about their learning designs and underlying pedagogical ideas and models;
- discussing and sharing the educators' existing experiences with integrating technology in their courses; and
- an activity in which the educators in groups specify and discuss the purpose of the redesign, and clarify the educational priorities and qualities using a template with a so-called 'Quality Pyramid' and the OULDI curriculum feature cards.

Based on the prioritisations and presented cases, the educators describe their individual learning design and use of technology in general terms, together with a short action plan of when this will be implemented and whether or not technical support will be required (see Figure *6*).

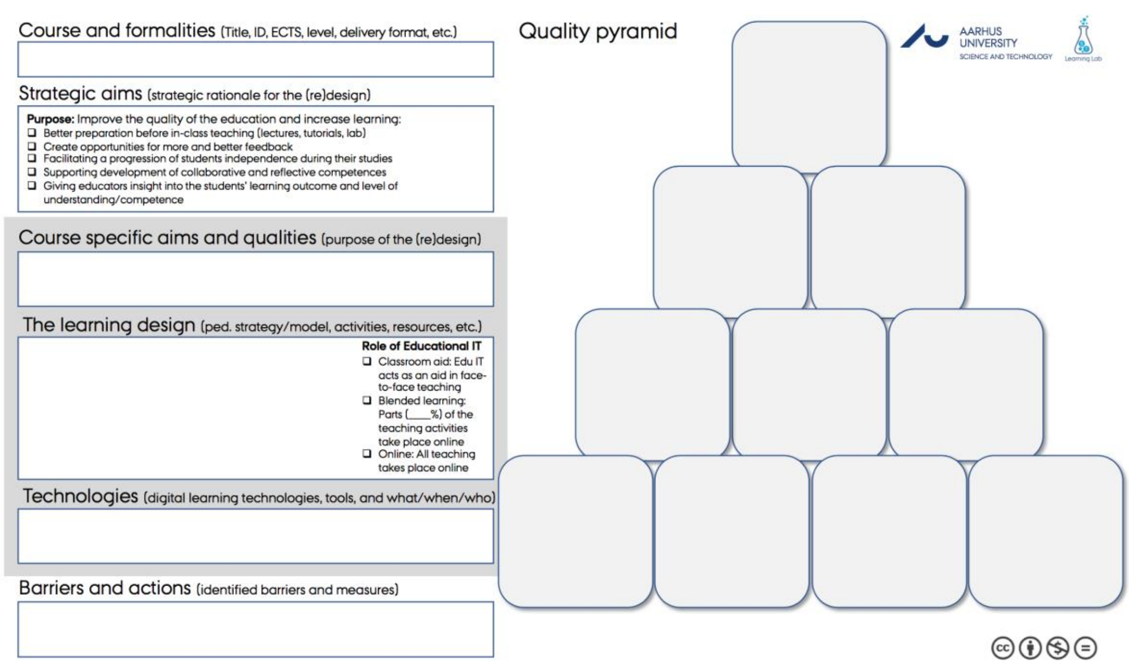

Figure 6: The Course Design Template, Including the 'Quality Pyramid'

The compulsory part of the design workshop is followed by an optional three-hour learning design development workshop. The educators are here invited to start developing their learning design in detail using a printed version of the LDTool (University of Wollongong, 2020) and share their design with their peers for feedback. The LDTool makes the students' learning process and activities the backbone of the learning design, rather than the content. This requires the educators to think about what the students are supposed to do, and this way qualify their use of technology, rather than developing technology and materials and then having to come up with a way of making this work in practice. Educational developers and learning technologists are present at the workshop to provide both pedagogical and technical support.

RESEARCH

In the following section, we elaborate on the research question.

Research Question

The aim of this study is to explore how educational technology is perceived and conceptualised by the academic staff in a design process characterised by a dual role of educational technology: as a strategic goal they must comply with and as a means to improve quality in teaching and learning.

Referring to Heimann (1962, p. 164), we might say that educational technology appears on two different levels in the didactic analysis. As a strategic goal, educational technology becomes an organising factor (factors that shape the educators' 'didactic game board'). As a didactic category (media), it must be aligned with the other categories in a didactic analysis: intention (objectives and learning outcomes), content, media or technologies, methods, students' prerequisites, and context (Figure 7). Similar categories are found in the broad concept of a curriculum (see Dillon, 2009).

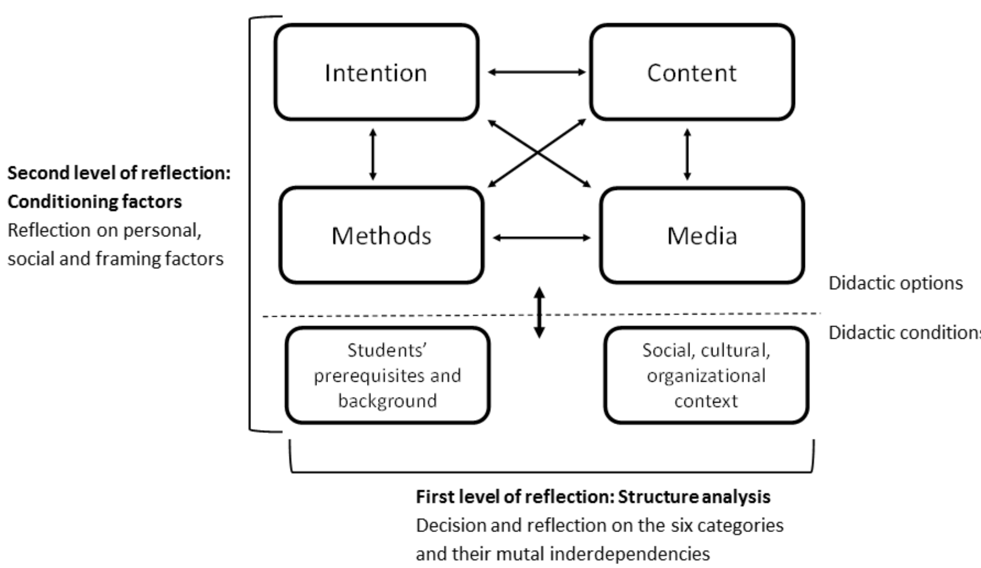

Figure 7: The Berliner Model: Levels and Topics in Didactic Reflection *(Keiding & Qvortrup, Higher education journals as didactic frameworks, 2018, p. 75)*

In this paper, we investigate how these often invisible and, to some extent, tacit organising factors become visible in a design workshop, as well as how potentially conflicting ideas and values are negotiated.

Methodology

The empirical approach combines participating observation, as described in Keiding (2010) and semi-structured interviews (Kvale & Brinkmann, 2014).

The design workshop was held three times in December 2019 and January 2020. The observed workshop was the final one, in which 10 associate professors from eight different departments participated. The participating observation focused on the dialogue between the participants in the design workshop using a single distinction: educational technology versus anything else. This means that only utterances and activities directly linked to educational technology were included in the analysis.

In the analysis of the data, the utterances were sorted into three categories:

Category	Example
Educational technology as a goal in itself	'We could do that, but I am not sure if it will improve my teaching.'
Educational technology as a means to improve learning	'Maybe the students would benefit from video tutorials before they go to the lab?'
Other aspects of educational technology	'I use [LMS] merely as a distribution platform.'

Based on the categorisation of the data from the observation, seven participants were invited to elaborate on their viewpoints in a semi-structured telephone interview. Five participants agreed to be interviewed. Each interview lasted for 15–20 minutes and was recorded.

ANALYSIS

The observations revealed two different ways of talking about educational technology. The following utterances are meaning condensed quotations from the discussions among the educators in the workshop:

1. "*But does this* [strategy driven redesign] *means that I have to give up my close direct interaction with the students in the lab and communicate digitally?*"
2. "*Maybe we could use educational technology to engage the students between the lectures*."
3. "*But what is a quality here? Do we know that students learn better if we use educational technology?*"
4. "*Educational technology should be used to engage students*."
5. "*Maybe it can support the lectures. For instance, use a quiz or show them something from a field trip*."
6. "*We have these two outcomes. Regarding the first, we actually do not know whether or not they learn it. The second is wrapped up on the blackboard. Could we use educational technology* [interrupted]."
7. "*We mostly use* [LMS] *as a distribution platform*."
8. "*There are so many tools. What is relevant to us?*"

9. "*I think we must be aware of not making things too complicated for the students; it might be hard to navigate many different tools*."

If we use the three categories to analyse the utterances, we see that utterance 1 and 3 questions whether it is at all meaningful to integrate educational technology. They appear to accept the fact that they must redesign their course towards increased use of educational technology, not because it is a vital didactical thing to do, but because it is a strategic goal forced on their course by management.

Other utterances (2, 5, and 6) address how and to some extent why educational technology might make relevant contributions to the courses, for example, by engaging students between lectures or for assessing learning. Here it is clear that educational technology is seen as what Heimann calls a didactic media. It is quite directly linked to the indicators for quality learning: time on task and formative assessment (Hattie, 2009).
Finally, we observe concerns regarding complexity for both students and lecturers (8 and 9).

The interviews support the overall findings of the observation: the educators see the tension between the strategic goals, but many of them do not care much about the strategic goal. However, all of them see the use of educational technology as a means to enhance the students' learning.

Educational Technology as a Goal in Itself

The workshop was framed by a person from faculty management. The participants felt that this showed commitment from management, but some of them found that management tried to neglect the importance of the strategic goal. As one put it: "*The manager told us that this does not matter a damn thing; it was only done as a way to make the ministry happy*."

When asked directly, several of the educators expressed that they did not care about whether educational technology was a strategic goal; they cared about the use of technology for enhancing teaching. As another put it: "*I don't care about it being a strategic goal. What I find important is that educational technology is used to make the students active.*"

Educational Technology as a Means to Improve Learning

In the interviews, we found two overarching uses of technology: to make course administration more manageable and to enhance learning.

Course Administration

One of the interviewed educators had already redesigned his course several times and had functionally integrated educational technology. His rationale for redesigning this time was to ensure that mandatory hand-ins were easier to submit using the LMS's assignment feature. However, one teacher had a different view: *"When you first hear about educational technology, it feels like everything is much easier, but after a while, you figure out that it is not easier, it can do something, and I can't do something else… it is not a silver bullet."*

Another educator had the view that it was challenging to imagine how educational technology could play a major role in his course (what he mistakenly felt was the goal of the workshop—"*to make your course a blended learning course*"). He taught a project course where the students worked in a studio. He did find that educational technology could be used to support the more formal parts of the course so that a focus on academic competences could be supported and documented.

Enhancing Learning

The interviews revealed different views on what educational technology is. Several of the interviewed educators talked about the purpose of technology. One expressed the view that it was mostly described as video lectures, something he found was not activating the students. For him, it was important that educational technology focused on activating the students: "*It is important that they do something instead of just observing something*."

Another focus point for one of the educators was the balance between the online and the physical 'space'—what should be done in the digital space and what should be done in the physical space. He found that the Learning Design method was an excellent tool to foster this discussion.

As described above, the participants constructed a Quality Pyramid during the workshop. The purpose of this activity was to foster a discussion on the teaching quality aspects of the design and thus see the use of technology as supporting learning, not as a goal in itself. Most of the educators found the Quality Pyramid helpful to focus on the teaching goals. However, one did not: "*I had difficulties understanding the idea of this* [activity]." The reason for this could be related to his participation and aim of redesigning a four-week project period and not an entire course.

DISCUSSION

Our results confirm our initial assumption that the educators' perceptions and conceptualisations of educational technology could point in two directions: as a strategic goal that must be met (disregarding didactic relevance), and as a media for enhancing learning. In addition, we confirmed that these perceptions have some level of influence on how the educators approach didactic design. However, several educators expressed that they did not care much about strategic goals. Instead, they cared about using technology for enhancing teaching.

One of the interesting and unexpected findings was that the perception of technology as a strategic goal shifted towards having educational potential after the part of the workshop where colleagues from different disciplines shared examples of how they had used educational technology to improve students' learning. This was despite the fact that in his introduction, the person from management presented several didactic arguments behind the strategy. Apparently, the educators' main take-home message from his introduction was that educational technology was a goal in itself.

In order to facilitate the process, Learning Design proved to be a useful educational development methodology. Its inherent characteristics of making educators conscious designers of technology-enhanced learning, its processes of articulating and sharing designs and practices, and the use of aids such as the Quality Pyramid stimulated important discussions among the educators about the purpose, role, and integration of technology in their courses. We see this as an important step in didactically qualified use of technology in HE, as well as a way to support a systematic, scalable, and potentially efficient introduction of educational technology.

FUTURE WORK

Future work includes further development of our Learning Design workshops to help educators realise the educational potential of technology, with less focus on educational technology as a goal in itself. Furthermore, more emphasis will be placed on how educators can design learning activities for students, including qualifying their designs based on relevant, underlying pedagogical ideas and models.

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LEARNING GAINS IN TRADITIONAL VERSUS CHALLENGE-BASED HIGHER ENGINEERING EDUCATION

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ABSTRACT

Engineering education at Eindhoven University of Technology (TU/e) is in the process of changing from instruction and teacher-based education to inquiry- and challenge-based education, where students are challenged to solve open-ended problems in collaboration with stakeholders in the field of science and technology (Eindhoven University of Technology, 2018) and hence the teacher's role becomes that of a coach. To determine students' learning gains in both traditional and innovative education (i.e., challenge-based learning) at TU/e, we formulated the following research question: *Which (kinds of) learning gains do engineering students perceive in challenge-based learning versus traditional learning?* To answer this question, we interviewed 13 students from "science" studies (e.g., Applied Mathematics), "core engineering" studies (e.g., Mechanical Engineering), and "social engineering" studies (e.g., Sustainable Innovation) about their perceived learning gains in traditional as compared to challenge-based courses. We used a new tool, "pie chart drawing," to elicit students' self-reported learning gains. Furthermore, we investigated students' reflections on the learning trajectory "Responsible innovation in a global context" to get deeper insights into learning gains in a challenge-based learning trajectory. The results showed that students perceived learning gains regarding their disciplinary conceptual and procedural knowledge, general cognitive learning, affect and thoughts related to learning, skills on teamwork and communication, and knowledge and skills about enterprise and business. Learning gains that were mostly obtained in traditional courses focused on disciplinary conceptual and procedural knowledge. Learning gains in challenge-based courses stimulated students' teamwork skills and collaboration with outside stakeholders (e.g., companies; institutes). General cognitive learning, communication with other students, and affect and thoughts related to learning were acquired in both traditional and challenge-based courses. The implications for CDIO related principles and engineering education, in general, will be discussed.

KEYWORDS

Innovative engineering education, Learning gains, Challenge-based learning, Standards 2, 3, 4, 5, 7, 8

INTRODUCTION

At Eindhoven University of Technology (TU/e) in the Netherlands, engineering education has been developing from instruction and teacher-based education into inquiry- and design-based learning in which students investigate and develop products as a solution to technical problems. In its strategy for 2030, TU/e further specifies the main educational approach as “challenge-based learning” (CBL) (Eindhoven University of Technology, 2018). Currently, there are pilots to develop CBL at TU/e.

The definition of CBL varies between different studies. In a study by O’Mahony et al. (2012), a challenge is, for example, formulated as a relatively closed problem. Other literature states that CBL refers to open-ended and authentic situations (e.g., Membrillo-Hernández et al., 2019; Rosén et al., 2018). An authentic problem is also part of design-based learning (DBL), which has already been implemented at TU/e. DBL consists of open-ended and authentic scenarios that students use to develop a product in multidisciplinary teams (Gomez, 2014). The difference with CBL is that students in CBL collaborate with industry, companies, and organizations (Eindhoven University of Technology, 2018) when working on open-ended and authentic problems. This is in line with literature that shows higher learning gains when challenges are formulated in collaboration with industry as compared to school-based challenges (Membrillo-Hernández et al., 2019).

Promising learning gains are claimed in the literature regarding CBL (e.g., O’Mahony et al., 2012; Martin et al., 2007). O’Mahony et al. (2012) found more interactions about knowledge in their challenge-based than in their lecture-based course. In addition, participants of the challenge-based course had a better understanding of the synthesis of concepts. In the study of Martin et al. (2007), students of a challenge- and inquiry-based course, and of a traditional course both gained knowledge about bio transport, but the students in the challenge and inquiry-based course gained more innovation skills. Moreover, when asked to rate how much they preferred challenge-driven education over traditional education, almost all students in the study of Rosén et al. (2018) provided high ratings for the project-based CBL setting.

At TU/e, students’ learning outcomes are measured in both instruction-based and challenge-based courses, but their gains in learning are often unclear. To measure students’ learning gains at university, Vermunt et al. developed a general learning gains framework (Vermunt, Ilie & Vignoles, 2018). However, a learning gains framework specifically for engineering education, was still lacking. Therefore, we decided to develop such a framework in a previous study (Van Uum & Pepin, 2019). Our framework is based on the CDIO framework for engineering education combined with the general learning gains framework of Vermunt et al. (2018) and inspired by a framework for mathematical proficiency (National Research Council, 2002). The developed framework consists of five categories: the disciplinary conceptual and procedural knowledge strand (e.g., understanding engineering concepts and procedures); the general cognitive learning strand (e.g., critical thinking, system thinking, and problem-solving); they affect, thought and learning strand (e.g., ethics and responsibilities of an engineer); the teamwork and communication strand (e.g., written and oral communication); and the entrepreneurial learning strand (e.g., enterprise and business context).

The learning gains framework for engineering education has been validated via interviews with students at TU/e. During these interviews, we became aware of possible differences between students’ perceived learning gains in CBL and in traditional teacher-based courses. Therefore, in the current study, we used our learning gains framework for engineering education to analyze students’ learning gains in both types of education. The research question of this study is: *Which (kinds of) learning gains do engineering students perceive in challenge-based learning versus traditional learning?*

METHOD

Participants

To investigate students' learning gains in CBL and traditional learning, we interviewed 13 students of TU/e, of which five were men and eight women. Eleven students followed a second-year Bachelor's degree program, and two students were further along with their studies. Nine students participated in the CBL learning trajectory "Responsible innovation in a global context." At a final event of this learning trajectory, at which the students presented their projects during an information market, 12 students were asked to participate in our study. Of these 12 students, nine were willing and available to be interviewed. As we wanted more input from "core engineering" students, we decided to approach students from a second CBL learning trajectory, "Engineering Design." Four additional students were willing to participate in our study. The 13 interviewed students consisted of four students from Sustainable Innovation and three students from Industrial Design. In the remainder of this paper, we will refer to these studies as "social engineering" studies. Applied Mathematics was studied by three students. We will refer to this as "science" studies. Finally, the term "core engineering" was used for the studies Mechanical Engineering (two students) and Computer Science and Engineering (one student).

In addition to the interviews with students, we analyzed reflections that were written by eight out of the nine participants who had followed the challenge-based learning trajectory, "Responsible innovation in a global context."

Instruments

To access students' perceived learning gains, we used semi-structured interviews. In each interview, students were asked to describe their perceived learning gains at the university, in which courses they had acquired these learning gains (to determine whether the learning gains were acquired in traditional or challenge-based courses), and why these learning gains were important to them. After students had mentioned all their perceived learning gains, they were asked to visualize the size of their learning gains via the strategy "pie chart drawing." For that, they divided a circle into different parts, with each part representing a particular learning gain. In addition, they wrote a short explanation about each learning gain and in which courses they perceived the learning gains. This provided us with an overview of students' learning gains that we could connect to their explanations in the interviews.

To determine students' perceptions of the challenge-based learning trajectory "Responsible innovation in a global context," they were asked to write (at least) one page of reflections on perceived learning gains in this learning trajectory.

Procedure

Students who had worked on the same project were interviewed together when possible. Due to different schedules, three students were interviewed alone, and ten students were interviewed in pairs. The semi-structured interviews were recorded on a voice-recorder and transcribed by a student assistant.

To acquire more information about students' learning gains during challenge-based learning, the learning trajectory "Responsible innovation in a global context" was investigated. The overall goals of this learning trajectory were: to understand the relevance of responsible innovation in a global context and how these innovations work in practice, to analyze and design responsible innovations, to reflect on analyses and designs, and to communicate ideas about responsible innovation in a global context to stakeholders (source: Osiris, TU/e). To reach these goals, students worked together in multidisciplinary/transdisciplinary groups on real-life projects supervised by engineers from companies/industry and the course teacher. In the first quartile, students learned about the context of responsible innovations. In the second quartile, they started to make design decisions to develop a product. In the third quartile, they thought about how to implement the product and how the product could have an impact. At the end of the learning trajectory, "Responsible innovation in a global context," students were asked to write down their perceived learning gains. The learning gains of eight students (who were interviewed as well in the first part of our study) were analyzed.

Data Analyses

For each learning gain that students mentioned in the interview, they explained in which course or courses they had acquired this learning gain. Via the course descriptions and information that the students provided on these courses, we determined whether the course was a "traditional" or "challenge-based" course. Although our definition of challenge-based learning, provided in the introduction section of this paper, includes interaction with clients from industry, we decided to include results on design-based learning as well, as these courses were clearly different from instruction-based education. During design-based learning, students at TU/e worked together and designed a product as a solution to a problem that could be formulated by the teacher or the students without contact with clients from the industry.

The "pie chart drawings" of the students were analyzed using the Grounded Theory approach of Glaser and Strauss (1967). First, we grouped similar learning gains together and labeled these with the same category name. For example, learning gains as "basic knowledge," "theoretical knowledge," and "pure theory" were grouped into the category "theoretical knowledge." For each category, we differentiated between "traditional" and "challenge-based" learning gains depending on the courses that students mentioned when referring to their learning gains. Subsequently, each category was connected to one of the "strands" of our framework on learning gains for engineering education. In the results section, for each strand, the different categories are presented, and for each category, it is clarified whether the learning gains were, according to the students, (mostly) acquired in traditional or challenge-based courses. Students' explanations from their interviews are added to clarify their learning gains.

The reflections of eight students who had followed the learning trajectory "Responsible innovation in a global context" were analyzed using our learning gains framework for engineering education. First, we divided the reflections into fragments, each representing a different unit of analysis. Subsequently, each unit of analysis was labeled with a category from the learning gains framework.

RESULTS

For each strand, the results on the "pie chart drawings" and interviews are presented in a table. Following each table, the written reflections on the challenge-based learning trajectory "Responsible innovation in a global context" are described.

The Disciplinary Conceptual and Procedural Knowledge Strand

This strand refers to knowledge of mathematics and sciences, fundamental knowledge regarding engineering, (engineering) subject matter knowledge, and disciplinary procedural knowledge. Table 1 shows that the interviewed students described learning gains that could be categorized as theoretical knowledge and applying theory in models/graphs/programs. Most students mentioned learning gains acquired in traditional courses.

Table 1. Results on Disciplinary Conceptual and Procedural Knowledge

Traditional/ CBL	**Category**	**Example quote**
Traditional	Theoretical knowledge	Steven (Mechanical Engineering) about the need for knowledge acquired in a traditional course to do a DBL project: "You really have to understand thermodynamics to calculate with heath."
	Applying theory in models/ graphs/ programs	Peter (Applied Mathematics) about a traditional course with application elements: "You use data to make graphs and to interpret it."

In the written reflections of the CBL learning trajectory, "Responsible innovation in a global context," just a few students mentioned learning gains regarding the disciplinary conceptual and procedural knowledge strand. They referred to (engineering) subject matter knowledge, such as knowledge on responsible innovations.

The General Cognitive Learning Strand

This strand consists of cognitive learning, such as analytical reasoning, problem-solving, system thinking, critical thinking, and research and design. Table 2 shows that the interviewed students perceived learning gains in both traditional and CBL courses.

Table 2. Results on General Cognitive Learning

Traditional/ CBL	**Category**	**Example quote**
Traditional/ CBL	Critical thinking	Kim (Applied Mathematics) about a traditional course: "I noticed (…), you learn a way of thinking and proving things. You learn not to accept everything. In high school, it was like: ok, differentiate this. But now you think: what does that mean? Are you allowed to do that?"
		Mandy (Industrial Design) about a DBL course: "When we design something, that you think: is this really a good idea or should it be different? (…) That you really think about…, whether you made the right decision."
CBL	Research	Rachel (Industrial Design): At [a DBL course], there we have to do pilots too and do research with participants.
	Design (Scrum)	Walter (Computer Science and Engineering): "I was made to be the Scrum master. So, I went to the training and learned about Scrum, and I did the training again, because this quartile, I am a tutor for that course."

Students' written reflections regarding the CBL learning trajectory "Responsible innovation in a global context" revealed additional learning gains in cognitive learning, such as analytical reasoning, system thinking, and CDIO (with a focus on design).

The Affect, Thought, and Learning Strand

This strand refers to attitudes and thoughts about learning, such as taking the initiative, perseverance, and lifelong learning. In addition, it includes ethics, responsibilities of an engineer, and taking into account the external, societal, and environmental context. Table 3 shows that the interviewed students mentioned learning gains regarding ethics, taking into account the social context, and planning and responsibilities.

Table 3. Results on effect, Thought, and Learning

Traditional/ CBL	Category	Example quote
Traditional	Ethics	Irene (Sustainable Innovation): "That you know how to look at ethical problems. (…) You are really busy with: there has to be a result, and your technology or innovation has to work. But why ethics is important is that you think more about what you are doing and why."
Traditional/ CBL	Taking into account the social context	Ann (Sustainable Innovation): [Taking into account the social context is part of] "all the courses, for Sustainable Innovation, that I have to take."
CBL	Planning and taking responsibility	Mike (Mechanical Engineering): "I also learned a lot during the DBL projects that we do at the Mechanical Engineering Faculty. (…) But also taking responsibility for a specific part. You are responsible for finishing that."

The written reflections of the CBL learning trajectory "Responsible innovation in a global context" revealed comments on (a positive) attitude, reflection, and taking into account the social, political, economic and/or ecological context.

The Teamwork and Communication Strand

This strand focuses on teamwork, communications (e.g., written, oral), and communication in foreign languages. In the interviews (see Table 4), soft skills, such as presenting and academic writing, were acquired in traditional and CBL courses, and teamwork skills were acquired during CBL.

Table 4. Results on Teamwork and Communication

Traditional/ CBL	Category	Example quote
Traditional/ CBL	Presentation and communication skills	Steven (Mechanical Engineering) about DBL projects: “You also learn to present. You learn soft skills with these projects because you have to present quite a bit.” Ann (Sustainable Innovation): “We have these skills [classes, such as presenting] that we have to pass.”
CBL	Teamwork	Flora (Sustainable Innovation): “One of the biggest challenges for me was the intra-team collaboration. I had never worked so closely together with two people on a project for this long. We had a very different point of view on our project, resulting in discussions every now and then. The differences between us, however, have also strengthened our group work. I have learned from both [name student] as well as [name other student], and the collaboration within our group.”

Regarding the CBL learning trajectory, “Responsible innovation in a global context,” students mentioned communication with team members as learning gains in their written reflections.

The Entrepreneurial Learning Strand

The entrepreneurial learning strand addresses the enterprise and business context, leading engineering endeavors, and entrepreneurship. In the interviews (see Table 5), students mentioned learning gains regarding collaboration and communication with companies during CBL.

Table 5. Results on Entrepreneurial Learning

Traditional/ CBL	Category	Example quote
CBL	Collaboration/ communication with companies	Charlotte (Applied Mathematics): “The most interesting, I thought, was getting experience with how to deal with companies and what they expect of you. (…) At a certain moment, you have the CEO of the company, who says: ‘I can help you.’ That is really nice. But you also have another company that did not reply at all. And then you have to think about a solution for that.”

Similarly, in the written reflections on the CBL learning trajectory, “Responsible innovation in a global context,” the students mentioned learning gains regarding collaboration and communication with outside stakeholders.

CONCLUSION AND DISCUSSION

In order to answer this study’s research question *Which (kinds of), learning gains do engineering students perceive in challenge-based learning versus traditional learning*, we interviewed 13 students about their learning gains at the university. In the data analyses, we differentiated between learning gains related to a) traditional and b) challenge-based courses (including DBL). In addition, we analyzed reflections that eight students wrote about the challenge-based learning trajectory “Responsible innovation in a global context.” In Table 6, students’ self-reported learning gains in CBL and traditional learning are presented.

Table 6. Students’ Self-reported Learning Gains in CBL versus Traditional Learning

Framework strand	**Challenge-based learning**	**Traditional learning**
Disciplinary conceptual and procedural knowledge	(Engineering) subject matter knowledge	Theoretical knowledge Application of theory in models, graphs and programs
General cognitive learning	Analytical reasoning System thinking Conceiving, designing, implementing, operating Critical thinking Research/design	Critical thinking
Affect, thought, and learning	Self-direction and responsibilities Taking into account the social context Attitude Reflection	Ethics Taking into account the social context
Teamwork and communication	Teamwork Communication	Communication
Entrepreneurial learning	Communication and collaboration with stakeholders	-

The results from the interviews and “pie chart drawings,” and the written reflections on the challenge-based learning trajectory “Responsible innovation in a global context” have similarities: for example, the fact that learning gains regarding the disciplinary conceptual and procedural knowledge strand were mostly acquired in traditional courses and were mentioned the least of all five strands in the written reflections on the challenge-based learning trajectory. This result connects to the study of Malmqvist et al. (2015) who compared different CBL courses and found that students in the Challenge Lab course were, amongst others, positive about the contact with stakeholders, but did not experience enhancement in specialized knowledge. In another article (most of) the same authors did find positive values for acquiring specialized knowledge, but students differed in their opinion: there were also students who were not positive about their knowledge enhancement (Rådberg et al., 2020). Therefore, attention to disciplinary conceptual and procedural knowledge is important when developing and implementing a CBL course or learning trajectory.

Another similarity between the interviews (including the “pie chart drawings”) and the written reflections on the challenge-based learning trajectory was the learning gains related to the entrepreneurial learning strand (communication and collaboration with stakeholders). The importance of involving stakeholders is addressed by other researchers as well (Membrillo-Hernández et al., 2019), as this contributes to the formulation of realistic and complex challenges.

In summary, first, it seems advisable to further increase challenge-based learning at TU/e, as students value collaboration with companies on a real-life project. Second, it can be concluded that CBL courses did not seem to fulfil all learning gains intended in the curriculum and that a mixture of CBL and (parts of) traditional courses appear to be beneficial for engineering students throughout their Bachelor years.

Limitations and Recommendations

Although we were able to investigate the learning gains of 13 students in-depth, we recommend investigating a larger number of students to acquire more information on students' learning gains in traditional versus challenge-based courses.

During our interviews, we asked students about their learning gains at the university. In our data analysis, we differentiated between traditional and challenge-based courses. As the reflections of the students on the learning trajectory "Responsible innovation in a global context" provided detailed information about their learning gains, a recommendation for future research is to investigate several challenge-based courses in-depth and to determine students' learning gains in these courses.

In addition, most of our participants were second-year Bachelor students. For future research, we recommend including students that are further along in their studies and have more experience with both traditional and challenge-based courses.

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BIOGRAPHICAL INFORMATION

Martina van Uum is a postdoc researcher and teacher at the Eindhoven School of Education of the Eindhoven University of Technology in the Netherlands. Her current research focus is on students' learning gains in (innovative) engineering higher education with a special interest in challenge-based learning. Together with Birgit Pepin, she developed and validated a learning gains framework for engineering education based on the CDIO framework and inspired by other frameworks.

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PREREQUISITES FOR INTERDISCIPLINARY LEARNING: ORGANISATION AND STAFF

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ABSTRACT

Today, most universities are organized in disciplinary departments where discipline based programme coordinators design curricula and learning is mainly based on disciplinary approaches. The emerging view is that to solve the more complex societal problems, more interdisciplinary approaches are required. In our study at the Delft University of Technology (TU Delft), we investigated what the prerequisites are for the design and delivery of interdisciplinary courses in a discipline-based university. We have interviewed 18 staff members involved in interdisciplinary courses and analyzed their experiences, thoughts, and needs in interdisciplinary course design and delivery. Results indicate that several competencies and experiences for staff members are necessary, such as open-mindedness, stepping out of the spotlight, and having worked in the industry. Furthermore, the disciplinary structure at TU Delft is currently felt to hamper interfaculty collaboration.

KEYWORDS

Interdisciplinary, requirements, learning, course development, Standards 9, 10

INTRODUCTION

Currently, most learning at universities is based on disciplinary learning approaches, although a shift to more interdisciplinary education has taken place over the years. Disciplinary education, however, is not sufficient anymore to solve the more complex societal problems of today (Holzer, Gillet, Laperrouze, Maitre, & Tormey, 2018). Complex problems need multiple perspectives and integrated approaches to be taken into account to broaden the problem-solution space and to realize new innovative solutions (Thomson Klein, et al., 2014). To meet these requirements, universities strive to strengthen their educational programs with interdisciplinary courses and programs. (Holzer, Gillet, Laperrouze, Maitre, & Tormey, 2018). Kans analyzed the meaning of interdisciplinary in the CDIO context, which varied between different actors (Kans & Gustafsson, 2016). We define interdisciplinary courses as those that enable students to define problem statements, translate and synthesize theories, methods of at least two different disciplines to come to an integrated result, and innovative solution.

Like most universities, TU Delft is a typical example of a Dutch technical university organized along disciplinary boundaries, wherein disciplinary departments, scientific staff work with their own epistemologies, methodologies, vocabulary, and curricula, which are designed by discipline-based program coordinators. Staff members are usually dedicated to and appraised on the education programs and courses within their own disciplines and are rarely involved in interdisciplinary education. Equally, individuals are judged on their disciplinary research standards, and contributions to collaborative research are less valued.

At the same time, according to its vision, TU Delft "*stimulates diversification of the portfolio by strengthening educational programs with interdisciplinary courses and programs*" (Mulder, Baller, & Kos, 2017). Indeed, TU Delft is providing interdisciplinary courses to its Bachelor and Master students.

The disciplinary foundations of universities make working interdisciplinary and collaborating across disciplines a real challenge across the academic system (Thompson Klein & Falk-Krzesinski, 2017). Disciplinarity poses organizational, structural, and pedagogical challenges to the interdisciplinary design of education (Holley, 2009) (Gantogtokh, Kathleen, & Quinlan, 2017).

Facilitation of interdisciplinarity consists of elements like infrastructure and institutional support such as instruction rooms, incentives, professional development of teachers, allocated time and budget for curriculum or course development, the involvement of departments (Larsen, et al., 2011). Although most of these support elements do exist in disciplinary institutes, they may not per se stimulate the interdisciplinary course endeavors, as they do not necessarily break down the disciplinary boundaries or sustain interactions across disciplines amongst Staff (Carr, Loucks, & Blöschl, 2018), limiting the development and execution of interdisciplinary learning programs (Thompson Klein & Falk-Krzesinski, 2017), (Lattuca, Knight, Kyoung, & Novoselich, 2017) (Frodeman & Mitcham, 2007).

In a previous quantitative study, we have investigated the perception of interdisciplinarity by program and course responsible coordinators. To investigate the perception, we have used the framework for interdisciplinary engineering education developed by the 4TU Centre for Engineering Education (Klaassen R. G., 2018). The framework focuses on the constructive alignment of the courses: the alignment between the educational vision, turning this into pedagogical approaches, and facilitated by support structures.

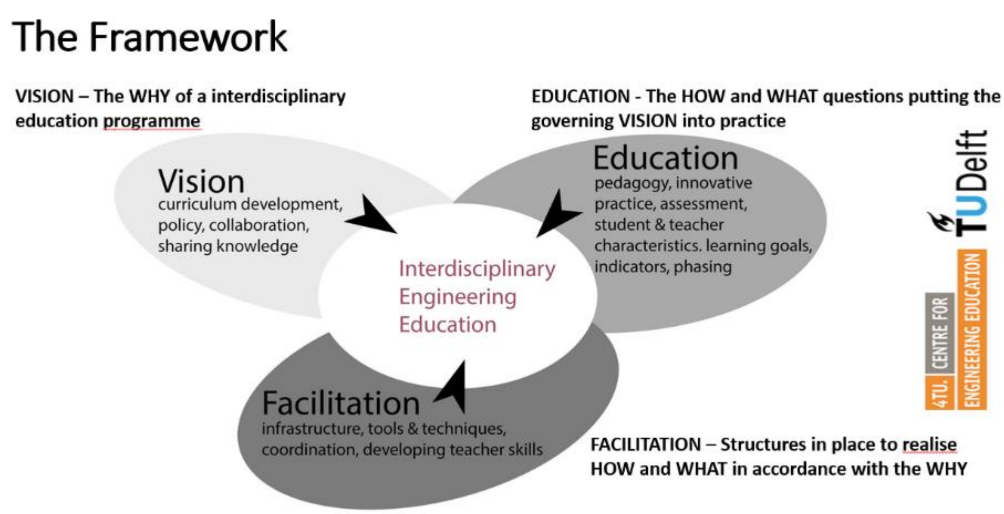

Figure 1. Framework for Interdisciplinary Engineering Education (4TU Centre for Engineering Education).

In this paper, we looked specifically at perceptions of the facilitation component as a follow-up study to the perceptions of visions, skills knowledge, and assessment of interdisciplinary learning (Klaassen, De Fouw, Van der Tang, & Rooij, 2019). The facilitation of interdisciplinary education is defined as the facilitation needed to realize interdisciplinary education. The aim of this study is to establish what we can learn from the interdisciplinary practices at TU Delft to make interdisciplinarity work. The key research question is: “What support (staff/organization) do the program and course responsible coordinators and teachers need in order to design and deliver interdisciplinary courses and brake down the disciplinary barriers?”

METHODS

A total of 18 individuals from TU Delft (14 course responsible coordinators and four educational directors of seven of the eight TU Delft faculties; all coordinators were also teachers) were interviewed about their experiences and perceptions with their interdisciplinary minor and master programmes[1]. This group was chosen since they determine the requirements of a program. As it was not always clear from the course descriptions whether the courses were indeed interdisciplinary, a snowball technique was used to find our respondents.

The conducted qualitative interviews were semi-structured, using a predetermined set of open questions in line with the 4TU Framework, but diversions and new ideas or thoughts of the interviewee were also allowed. All interviews were audio-recorded and transcribed and analyzed according to a three-step analysis process of data reduction of excerpts into predetermined content codes, data display in thematic subcategories of indicators, and data interpretation. The interview transcripts were divided into excerpts, each of which was coded by three raters independently. All interviews were coded based on 11 indicators, which were established on the basis of the aforementioned study (Klaassen R. G., 2018). The excerpts that were coded with the indicator 'Prerequisites of Staff and Organisation' are analyzed and discussed in this article.

In order to determine the reliability of this coding method, the inter-rater reliability was calculated, which is the degree of agreement among a number of raters. The Fleiss' kappa (κ) was used as a measure of reliability; this is often used for analyses with three or more raters. The higher the Fleiss' kappa, the higher the agreement among raters, and therefore, the higher the reliability (Fleiss, 1971). The average Fleiss' kappa for the indicator 'Prerequisites of Staff and Organisation' over the 18 interviews were found to be 0.720, which means that there is a substantial agreement of the three raters (Landis & Koch, 1977). In those 18 interviews, the indicator 'Prerequisites Staff and Organisation' was applied 635 times.

RESULTS

The results section focusses first on requirements for staff, then on Organisation (Figure 2).

Staff

What is done on the level of staffing to realize the interdisciplinary content/coordination of the different courses and or programs?

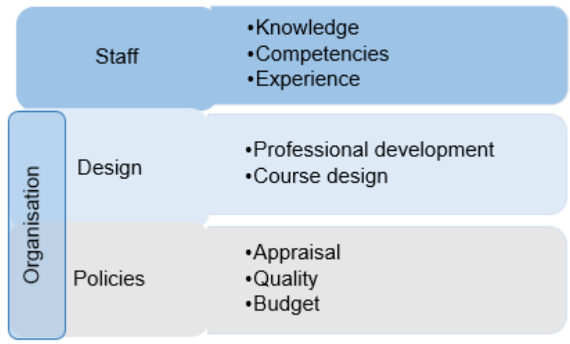

Figure 2. Structure of results section.

Knowledge

According to our interviewees, those individuals involved in interdisciplinary course design and delivery should at least have a profound knowledge in one specific discipline or domain. In addition, most of them suggest that it is best if they are so-called “T-shaped,” having in-depth knowledge of their own discipline and having many “hooks” to communicate about and integrate knowledge from other disciplines (Gero, 2014) (Brown, 2005) (Frank, 2000). Some of the interviewees refer to this as being system integrators. These should see the link between the different disciplines.

> *“You need several persons who have this vertical expertise pole. But at the same time, they should also have many hooks on their wide horizontal pole in order to communicate with the outside world.”*
> *“First of all, you should have content knowledge of the case study at hand. You do not need to know all ins and outs of it, because then you are an expert. You should be a system integrator. You should know where the disciplines come from and what is more or less going on in that area of expertise.”*

There is one interviewee who specified in more detail the required knowledge of coaches, who facilitate the interdisciplinary teams. They should be process-focused, not content-focused- stating:

> *“The coaches have completed the course xxx. That does not mean that they have the knowledge of the technology they are coaching. I have come to realize that I do not mind they do not know anything about the technology. I really want them to only play the role of coach. The students should do the content. That is what I call guiding the process. They should make sure that the student can perform optimally. We teach the coaches how to do this. “*

The interviewees indicated that those involved should have a common understanding of the jargon used and a common frame of reference towards the problem solutions. They should see the bigger picture and be able to apply their knowledge in other domains. If the teachers are too focused on their own discipline, they tend to forget the other disciplines, to work together, and to integrate knowledge were possible.

Competences

Many different competencies (attitude, skills, and experience) were mentioned by the interviewees necessary for working interdisciplinary. An overview of these is shown in Table 1.

They should be enthusiastic, have an open mind to societal context, have wider interests than only technology, should not mind stepping out of the spotlight, share responsibility, and credits. They need to be able to take a step back. They should not pose their own discipline at the foreground and be interested in and trust other disciplines (rely on their input). They should be convinced that their work is for the total sector and not only their own domain.

> *"We (ref: teacher) also have the same constraints in that we have our own disciplinary backgrounds. We see things and talk about things in our own languages. But I think we have been successful at stepping back, stepping out of the spotlight and letting the students debate about how to proceed forward in their multidisciplinary interfaculty groups."*

Their mentality should be open: openness to other disciplines and to mentally learn and grow. They should not be afraid to talk to and work with other disciplines and other teachers. A networking attitude is important to link with colleagues from other disciplines.

Table 1. Attitude, Skills and Experience overview

Attitude	**Skills**	**Experience**
Enthusiastic, open to learn	Awareness of disciplinary boundaries	In industry/business
Open-minded towards societal context and other disciplines	Networking skills	Prior experience with multi/interdisciplinary group work.
Share responsibility and credits	Approach student at the appropriate level of knowledge	University Teaching Qualification
Stepping out of the spotlight	Strong communicators/collaborators	In one specific discipline
Interests wider than technology only	Facilitation skills	T-shaped
Rely on upon and trust other disciplinary input	Team dynamics	Dealing with different opinions

For optimal interaction with the students and to facilitate integration, they should be able to relate to the students' knowledge level and approach them at the required level. They should be able to teach students from different backgrounds, ways of thinking, and levels of knowledge. They should be strong communicators in order to do so.

> *"I think it has to be someone who's very conscious of the student background. Because often, if you've come through a certain education path, you know a bachelor standard is this, a master standard is this, and a Ph.D. standard is this…. But of course, they know almost nothing about certain subjects."*

> *"So it has to be someone who realizes what is taught where and to quite carefully introduce things….., you can go quite fast through a lot of things. They're relatively mature students. But you have to go back to the beginning of a lot of things. And I think if it's given to anyone who doesn't have a kind of skill in that, then it's very difficult. Students get lost quite quickly".*

They should be able to facilitate multidisciplinary teams, know when to steer and when to let loose, and also know about team dynamics.

".. and our students have not yet worked in teams. Therefore there is also an aspect of teamwork. Therefore we also need to show them what it is to work in a team. They will do a teamwork game like Belbin role play".

Experience

In order to appreciate the challenges in interdisciplinarity, most interviewees find it important that the staff has worked in or has experience with the industry /business, providing an interdisciplinary background. The lecturer should have dealt with multidisciplinary groups, have experience in working with other disciplines, and in dealing with different opinions.

"It should be someone who has a good connection with the business. Who knows many people in the industry because otherwise you cannot get all project up and running. But one also needs to have a feeling for how one works at a company. We have, for instance, started up two new companies from our own department. You should know what is going on in a company."

"I think it is obvious (to have business experience), but I have worked half of my career in the business. Then you look at it differently. But, you do have individuals here with only a full academic career, and they may not have that skill available."

Organization

What is done at the level of the organization to realize the interdisciplinary content/ coordination of the different courses and or programs? Firstly, requirements for the design and subsequently for policies are provided.

Design: Professional development of teachers: training, informal learning and learning on the job

According to the interviewees, the teaching staff should have the University Teaching Qualification, which is obligatory for all teaching staff at TU Delft (Vereniging van Universiteiten, 2018)**.** Interviewees also suggest that teachers need to be trained in interdisciplinarity, as most of them do not know how to design/deliver interdisciplinary education. No such formal training exists at TU Delft. Some teachers train themselves (informal learning), by talking to experienced interdisciplinary teachers and read students' end-reports to get familiar with the integration of knowledge and ways of working.

"I think it is not that easy to do this kind of course. I think that the teachers, too, need to be trained in how to teach a very mixed group and in how to content-wise combine knowledge from different disciplines."

"It should be taught to people how to integrate and how to approach this. That should be handled in a more structural way at a university. However, the university is disciplinarily focussed, so who will take the lead and who will pay? "

Others use training on the job. Some interviewees experiment with different educational approaches and learn during their own course how to integrate and deal with complexity. Over time they become more secure in dealing with interdisciplinarity, and they tend to see better the importance of having a wider picture.

The interviewees suggested sharing the learnings and experiences amongst interdisciplinary teachers and novices, to improve the overall knowledge level. Suggested topics for development were: difficulties encountered and solved, jargon and language issues, dealing with complexity and integration.

Design: Course design

Most interviewees said that improved interdisciplinary courses/curricula would be delivered when teachers with different disciplinary backgrounds design them together. This ensures alignment in program, vocabulary, methods, and approaches, minimize overlap, and increases the coherence of the program. The way they work together could also be improved. Co-teaching, for instance, would help teachers to get more insight into the other disciplines and get vocabulary usage aligned.

> *" .. We should define much more together what kind of students we want to educate and deliver. We need to exchange much more information between different courses in order to get a shared view on what courses we deliver as well. I think that if we do this much more frequently, that the meaning of interdisciplinarity will become clearer, also for new teachers."*

For the design of an interdisciplinary course, the commitment of important, impactful professors across disciplines is key. They should also be fully aligned with their interdisciplinary views. If these views differ, it is difficult to design such a course.

The alignment of interdisciplinary views is also an issue in graduation committees in an interdisciplinary program; in addition to the chair being a professor, there are two supervisors from two different disciplines. The student needs to satisfy them all.

Equally, some interdisciplinary programs/courses have some mono-disciplinary courses included. When their content is changed due to, e.g., curriculum redesign, the interdisciplinary course is also affected and needs to be realigned with the mono-disciplinary course, which usually causes lots of problems.

Policies: appraisal

The appraisal system in TU Delft is linked to the staffs' contribution to research, not to education. Their main priority is, therefore, their research.

Teachers are not motivated per se in joining an interdisciplinary course as there is no direct incentive, such as a link with their own disciplinary research. It is time-consuming, and there is no reward because the results cannot be used for their own research and articles. Papers based on interdisciplinary topics prove to be more difficult to publish.

Furthermore, course codes are frequently not linked to their own faculty, so it is unclear what they actually contribute to their faculty. A teacher of an interdisciplinary minor course states:

> *"… So there is really no reward for you?*
> *No nothing, no, no reward, no appreciation, really totally nothing".*

So what is in it for them?

Policies: Quality through availability of teachers and budget

A common issue for all interviewees is the availability of teachers for interdisciplinary courses for different reasons. As interdisciplinarity is not in the veins of a disciplinary institute such as

TU Delft, tutors who would like to get involved are absorbed by their own departmental obligations and have no time. Also, little budget is available for interdisciplinary work, and sometimes teachers leave the university without replacement. Searching for an alternative teacher from a different faculty and discipline is difficult and takes time. He/she may have different views on the course and the integration of disciplines. This may result in a drop in the quality of the course.

> *".. because we needed to continuously chase people and once in a while a teacher does not want to continue, and then you need to find an alternative. And at a certain point in time, it becomes a kind of a mess, a kind of collection of certain courses, with little connection and integration".*

What could help to attract teachers is when the organizational structure is clear and visible. They feel more rewarded when their contribution is visible to others. An interviewee suggested that only well-established research groups should deliver teachers. In these groups, more individuals are available to teach, there is a shared vision on education, and thereby the availability of a teacher and continuity of the course is ensured.

Usually, new lecturers are appointed through departments. They are appointed for educational tasks within the departmental, disciplinary programs and not for interdisciplinary programs. This is seen as a missed chance to improve the number and quality of lecturers who have experience in interdisciplinarity.

> *"Well, that is a bit tricky in my role as education director. I do not appoint people. That runs through the departments or institutes. We have an open vacancy for a tenure track, and someone will be recruited who can teach within the programs our department provides. But, as education director, I am not involved in what we actually need for our programs". So there is a mismatch."*

There is a tendency to allocate more budget to research than to education, which hinders the development of improved educational, interdisciplinary programs.

> *" …. And, by the way, education dangles a bit. Despite the fact that they all say that education is also important. But meanwhile, the most budget goes to the research-driven faculties."*

Besides this, more students are admitted to the university, but no more budget is provided for course design, improvement, and facilitation.

Policies: Quality through team-teaching, planning, and evaluation

It is important to have an educational expert in the team, focusing on course design. Correct learning objectives will be delivered, the course is constructively aligned, and integration takes place.

> *"And then ask lots of questions about the more education part. So what the learning objectives were and how things fitted with the learning objectives. And I think having someone asking those questions helps. Because everyone who works at the university understands those things, and that helps translate a lot of the jargon and the specifics to a course to say the slightly more abstract learning objectives."*

A few interviewees specifically mentioned that in the team, one person was responsible for project management without any contribution to the content, guaranteeing, in combination with an educational expert, a well-designed course delivered on time.

As different faculties take part in course design, all stakeholders should be involved for input and commitment. Therefore a steering group was appointed with relevant representatives from the disciplines/faculties having a say in the course design. A curriculum committee specifically looked at the integration of the different disciplines in the course.

At the moment, at TU Delft, there is only a small “timeslot” in which interdisciplinary master courses can run across all faculties, which limits the delivery of the interdisciplinary course. It is recommended to reserve a specific timeslot in the masters’ program, equal across all faculties, enabling easier logistics and stimulating students to select the interdisciplinary course. This would allow one overarching course code and one administrative point, centrally organized allocating ECTS, time, and budget fairly across different faculties. Interviewees equally recommend a centrally directed course evaluation system. Currently, course evaluations are still organized per faculty, evaluating their own courses. Evaluation of interdisciplinary courses is, therefore, more difficult.

DISCUSSION

In this paper, we have looked **at** “What support (staff/organization) do the program and course responsible coordinators and teachers need to design and deliver interdisciplinary courses and brake down the disciplinary barriers?”

With respect to staffing, we have been able to derive a clear profile of the potential interdisciplinary teacher and his/her professional competencies. Most interviewees would appreciate stimulation of staff professionalization for interdisciplinary teaching, for interdisciplinary course development and delivery. One methodology already used is working in interdisciplinary teacher teams consisting of content experts, educational experts, and representatives from different faculties. Ideally, these should be valued in the appraisal system and in budget allocations to these courses. With respect to the particular additional disciplinary knowledge required for a particular teacher in an interdisciplinary environment, our results show that a T-shaped teacher is recommended.

With respect to the organisation, we argue that the current disciplinary structure of TU Delft is felt to hamper interfaculty collaboration in terms of budget, appraisal, quality assurance, and evaluation. Alignment of the different faculty defined systems and processes is one of the first steps to remove some hurdles to interdisciplinarity at TU Delft. Interviewees also felt that the organization of interdisciplinarity at TU Delft would benefit from a more centralized, less departmental approach. Working in interdisciplinary teams should be more valued by the organization in terms of appraisal, allotted time, and budgets. Non-departmental budgets should be available for these interdisciplinary programs and courses. Overall, our findings are in line with earlier studies reported in this area (Gero, 2014) (Brown, 2005) (Frank, 2000) (Kans, Haralanova, & Khoshaba, 2014).

The development of one TU Delft shared vision on interdisciplinary education is recommended since this will lead to a clear organization and course structures. This is in alignment with our earlier research in which it became apparent (Klaassen, De Fouw, Van der Tang, & Rooij, 2019) that these visions vary amongst teachers and faculties, also within one course, which hinders constructively aligned program development.

Thus, alignment of the different faculty defined systems and processes is one of the first steps to improve interdisciplinarity at TU Delft.

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BIOGRAPHICAL INFORMATION

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Youandi van der Tang is a Master student in Aerospace Engineering, with a specialization in Spaceflight, Space Exploration. Currently, he is organizing the Massive Open Online Course: "Hyperloop: The Future of Transportation." As a Teaching Assistant, he works as a data analyst in research into interdisciplinarity of university programs, under the supervision of R. Klaassen. He has vast experience in working interdisciplinary as he was a member of the interdisciplinary development team "Hyperloop Pod Competition" 2019.

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INVESTIGATING REPEATABLE NUDGE EFFECTS WITH SPACED REPETITION IN USING MCQs

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ABSTRACT

The contemporary learner's learning habit is very different now due to their exposure to new technology at a young age. They have a lot on their proverbial plates; by having too many things on one's mind made them easily distracted and unable to retain the information. This led to "binge and purge" learning, a common practice whereby learners cram for an assessment by consuming subject matter in a large lump (binge) and then spitting it back in the assessment (purge). Due to their proverbial plates being full, this led to learners favoring "binge and purge" learning to achieve academic results, but not the knowledge and skills needed for the future. A constant nudging to learners to revise and test their knowledge throughout lessons could be more appropriate in evaluating these contemporary learner's academic achievement. In this paper, an initial study was carried out with weekly e-quizzes to "nudge" learners to study, and to find the optimal number of questions to be repeated from their previous lesson. The intention of these spaced repetition learning was to enhance learners' knowledge retention of key concepts. The optimal number of questions, as defined in our study, was the number of cumulative repeated questions that would help learners to retain key concepts but would not overwhelm learners with too many questions. A subsequent study was then conducted to validate the findings and its scalability with different groups of learners learning different aspects of networking concepts. The paper ends with a discussion on the effect of spaced repetition on learners' motivation and performance in learning data communication and networking by using the data gathered from the MUSIC Model of Motivation survey and learners' average scores in e-quizzes respectively.

KEYWORDS

Nudge Theory, Pedagogy for Modern Learners, Spaced Repetition, Sustainable Development, E-learning, Assessment of Learning, Standards 8

INTRODUCTION

It had been observed that more and more contemporary learners have cultivated "binge and purge" learning. These learners usually use their short-term memory to consume subject matter in a large lump (binge) and reproduced them in the assessment (purge). This memory work would not last, and the assessment credentials would be at stake. The ability of a learner to remember key concepts is vital for Engineering learners; learners are required to remember key concepts for them to innovate and apply to real-world situations. Remembering is different from memorizing. Memorizing tends to be based on short term memory, whereas remembering is not just the process of committing information to memory but also the process of understanding, retaining, and recalling the information. The process of remembering requires the learner to understand a concept, retain it over a time period, and then recall the concept when it is needed. The weekly E-Quizzes would nudge learners to revise what they were taught for the week. The incorporation of spaced repetition learning with spaced presentation should enhance the process for learners in remembering the key concepts for all the taught topics. The "nudging effect" is expected to change learners' behavior and motivate learners to learn; and, in the long run, cultivate their interest in engineering when they see an improvement and ability to perform.

Literature Review

Nudge theory is about positive reinforcement and indirect suggestions as ways to influence the behavior and decision making of a human being. Nudging could be vital in influencing learners' behavioral and psychological factors when they made education decisions (Jabbar, 2011 and Koch et al., 2015). During learning, there were evidence that interventions with nudging as a factor could address a set of specific learning behavioral challenges (Lavecchia et al., 2016). Empirical evidence simplifying the transition to higher education is present. (French & Oreopoulos, 2017). These interventions were using new education technology and could influence one's behavior (Escueta et al., 2017). Recent empirical work from a social welfare perspective suggested too much nudging could sometimes backfire (Carroll et al., 2009; Handel, 2013; Damgaard & Gravert, 2018). Thus, it would be useful to quantify the result for the circumstances under which nudging may or may not be successful. Empirical studies had also revealed that nudges might have very heterogeneous effects (Allcott, 2011), and as a result, it may be desirable to use targeted nudges rather than universal nudges. Furthermore, behavioral interventions may be particularly relevant and effective when individuals face economic or social scarcity because it occupied the attention and potentially impedes good decision making (Mullainathan & Shafir, 2013). A reasonable degree of "nudging" depending on individual learning ability and circumstance is deemed appropriate to each individual and would influence one's behavior, thus motivating learners to learn.

Spaced repetition was well researched and had shown promising results. Spaced repetition was first introduced in Iowa (Spitzer, 1939), and research had shown manipulation of repetition space could improve recall (Melton, 1970 and Landauer & Bjork, 1978). Recent research had also shown positive results with spaced repetition (Kang, 2016 and Kelley & Whatson, 2013). According to the principle of "spaced repetition," instead of massed learning, remembering and the practice of skills were more efficient if each item's practices were spread out over time (Bloom & Shuell, 1981). Concepts that are difficult should appear more often and materials that are easy, less often, with difficulty defined according to ease with which the user could remember the material. Incorporation of interleaving between different topics was ideal as it has the potential to stretch learners beyond information retrieval to making sense of newly taught concepts (Brown et al., 2014). The difference between consistent and expanding duration between spacing had found to produce insignificant improvement in retrieval, while more repetitions were found to be more important in producing improvement in retention (Thalheimer, 2006). Spaced learning also had the potential to impact policy and curriculum planning since it could produce improved learning outcomes and higher learning per hour compared to conventional teaching methods, backed by evidence from neuroscience on rapid memory processes in humans (Kelley & Whatson, 2013). The basis that the ability of the brain to retain memory decreases overtime is based on the forgetting curve of Ebbinghaus, as shown in Figure 1. It is a theory that humans start losing the memory of learned knowledge over time, in a matter of days or weeks, unless the learned knowledge is consciously reviewed at constant time intervals. After each revision, repetition space could be spaced apart long before the retention rate drops to 80%. If knowledge is consciously reviewed at constant time intervals, the knowledge will eventually be remembered.

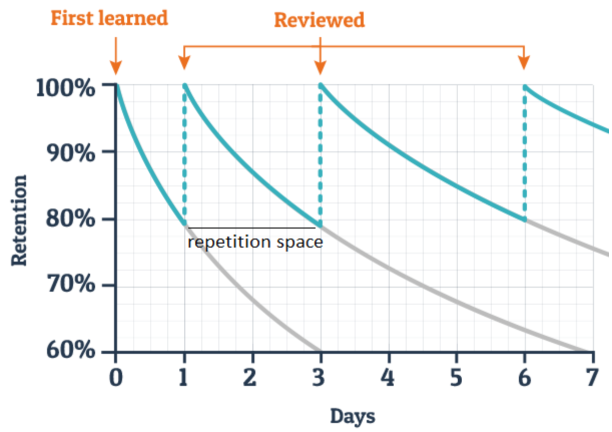

Figure 1. Typical Forgetting Curve for Newly Learned Information (Schneider, 2014)

The MUSIC model of academic motivation (Jones, 2009) is a framework used to measure and engage learners in learning. It consists of five categories of teaching strategies derived from research and theory that were critical to learners' engagement in academic settings: eMpowerment, Usefulness, Success, Interest, and Caring (MUSIC is an acronym).

Usefulness and Success relate to how learners believe the topics are relevant and important in helping them succeed, respectively. Interest indicates the level where learners like and are curious about the topic.

Evidence suggests that lecturers who address the MUSIC components were more likely to be successful at motivating their learners to engage in learning (Jones, 2013, 2015). We adopted the three categories of the MUSIC model (Usefulness, Success, and Interest) to evaluate learners' academic motivation in our investigation. We aim to gain insights into the impact of spaced repetition on learners' motivation.

METHODOLOGY

By deploying spaced repetition in the Data Communication and Networking module, we seek to investigate whether such teaching methodology help learners to better remember the technical terms and concepts to improve their academic performances in the module. Our study focus is to determine the "nudging effect" and to find the optimal number of questions to repeat in networking topics and the effect of the number of allowed attempts. The methodology is shown in Table 1.

"Nudging" in our context is to conduct weekly E-Quizzes on the topics they have learned for the week. The idea is to keep the revision materials on a weekly basis, bit-size, and manageable to revise. In having weekly E-Quizzes, the learners would be tested on their knowledge on the current material before new material is taught in the coming week's lesson. Several past E-Quizzes questions would be added in a cumulative manner to the current material, thereby nudging them to revise on a constant basis. The assessment will contribute 20% to their total grading. The effect of the "nudging effect" would be measured in terms of their motivation.

Cohen's d is an effect size used to indicate the standardized difference between two means. It is widely used in meta-analysis. Cohen's d is an appropriate effect size for the comparison between two means.

In our case, we used Cohen's d to determine the effect size for the comparison between the mean of learners' performance in the E-Quizzes of the Experimental Control Group (EG) in the initial study and each of the experimental group's means. Cohen's d suggested that d=0.2 be considered a 'small' effect size, 0.5 represents a 'medium' effect size and 0.8 a 'large' effect size (Cohen, 1988, 1992). The rational in designing the experiment was to have the Experimental Control Group (EG) to serve as a baseline, Experimental Group 1 (E1) was to investigate the effect of having two repeat questions, Experimental Group 2 (E2) was to investigate the effect of having three repeat questions and Experimental Group 3 (E3) was to investigate the effect of the number of tries.

Table 1. Methodology for initial study

G	SS	Methodology
G	39	A weekly E-Quizzes based on the lesson conducted for the week. The E-Quiz consists of 10 multiple-choice questions (MCQs) with unlimited tries.
E1	58	Same assessment method, as stated in the control group but two questions from the previous weeks added to subsequent weeks in a cumulative manner.
E2	106	Same assessment method, as stated in the control group but three questions from the previous weeks added to subsequent weeks in a cumulative manner.
E3	98	Same assessment method, as stated in experimental group 2, but the number of tries is restricted to 3.

Legends: Group (G), Sample Size (SS), Experimental Control Group (EG), Experimental Group 1 (E1), Experimental Group 2 (E2), Experimental Group 3 (E3). Remarks: This experiment was conducted with first-year learners doing Data Communication and Network module in a networking diploma

MUSIC survey was conducted at the end of the last E-Quiz for all the experimental groups. The MUSIC survey questions were shown in Table 2.

Table 2. MUSIC Survey Questions

Q	C	Question
1	U	The repeated questions in the after-lab e-quiz was beneficial to me as I could better recall the concepts taught in class.
2	U	In general, the after-lab e-quiz was useful to me as it summarized important concepts taught in class.
3	U	I found the after-lab e-quiz to be useful for other modules in DMIT.
4	U	I will be able to use the knowledge I gained in this module.
5	U	The knowledge I gained in this module is important for my future.
6	S	I was confident that I could succeed in the after-lab e-quiz.
7	S	Throughout the module, I felt that I could be successful on the after-lab e-quiz.
8	S	I felt I could be successful in meeting the academic challenges in this module.
9	S	I am capable of getting a high grade in this module.
10	I	The after-lab quiz held my attention.
11	I	The after-lab e-quiz was interesting to me.
12	I	The instructional methods used in this module help my attention.
13	I	I enjoyed the instructional methods used in this module.
14	I	The instructional methods engaged me in the module.
15	I	I enjoyed completing the after-lab e-quiz.

Legends: Q: Question Number, C: Components, U: Usefulness, S: Success, I: Interest

RESULTS

An improvement in learners' performance in terms of average marks is observed in the experimental groups using spaced repetition learning with unlimited attempts (E1 and E2) and with limited three attempts (E3) in the initial study, as observed in Figure 2.

In the study, the result tends to contrast to the findings in literature studies that learning is improved through spaced repetition, the results from Figure 3, the study showed that there was no significant difference in the quiz scores between learners in EG and E1 (d = 0.29). The reason for the small effect size could be that only two questions per topic were repeated. Thus, the effort required by learners to recall previously taught topics was negligible and resulted in insignificant improvement in learners' academic performance. In comparing EG and E2, the repeated questions were increased from 2 questions to 3 questions. The effect size was medium (d = 0.32), an improvement over the effect size between EG and E1. This suggested that increasing the additional weekly questions from previous topics alone does not significantly contribute to a significant improvement in learner's academic performance. In order not to overwhelm learners with too many questions, the assessment method in E3 is identicial with E2 but the number of tries was limited to 3 instead of unlimited. The effect size had increased to large (d = 0.67). This suggests that restricting the maximum number of attempts for the quizzes together with a suitable number of additional questions from previous topics had a moderate impact on learners' academic performance. E3 methodology was deemed as appropriate for validation study to determine if this methodology was suitable for different levels of learners in learning key concepts in networking topics.

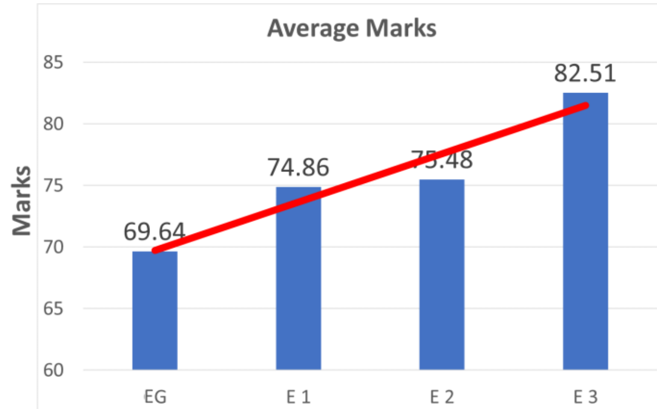

Figure 2. Average marks for all the experimental groups. The linear trendline is indicated as the red line.

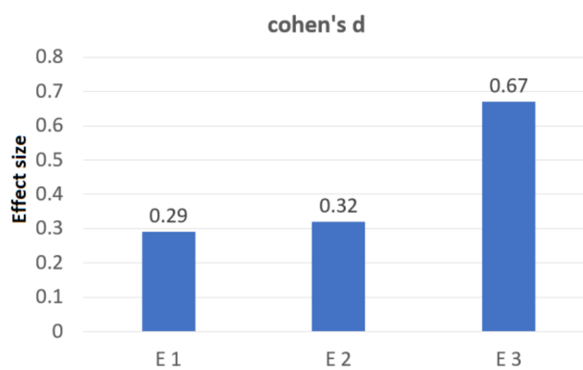

Figure 3. Cohen's d effect size for all experimental groups with respect to the control group

The performance of academically stronger learners (GPA≥3.0) in each of the experimental groups and the control group was further analyzed. The result was shown in Figure 4. Interestingly, we found that the effect size across the experimental group and the control group had significantly increased. This suggested that spaced repetition methodology had a greater influence on the academically stronger learners.

Interestingly the results show that with the same assessment methodology used, the average marks and the Cohen's effect size show the same outcome. This suggested the result could be repeated across learners studying networking modules.

Learners in the experimental groups responded positively to the spaced repetition methodology, as shown in Table 3. EG did not take the MUSIC survey as we are not making a comparison with the experimental group. The MUSIC survey is to determine if nudging will motivate our learners. They generally agreed that the after-lab e-quiz was useful, helpful, and interesting, and it helped to improve their learning. Learners remained interested in the module content, and instructional activities led them to believe they can succeed if they put forth the effort required. The increase in difficulty for the weekly e-quiz (from unlimited attempts to maximum three attempts) did not create any significant impact on learners' motivation.

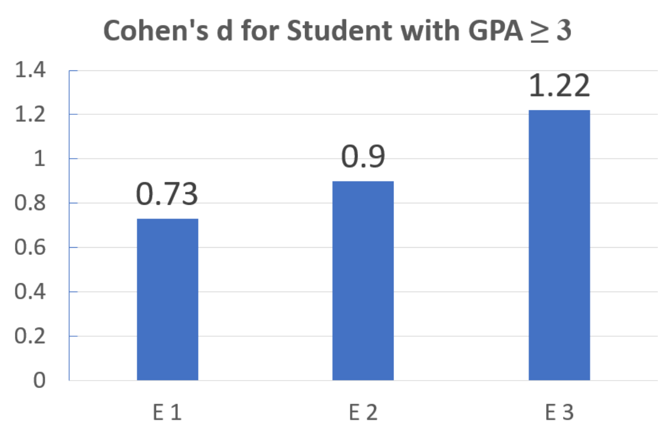

Figure 4. Cohen's d effect size for academic stronger learners (GPA≥3)

Table 3. MUSIC Survey result, taken from each experimental group at the end of the experiment

Component	Average MUSIC Score#		
	E1	E2	E3
Usefulness	5.24	5.25	4.52
Success	5.17	5.18	4.51
Interest	5.34	5.22	4.63

Likert-type scales: Strongly Agree (Score = 6), Strongly Disagree (Score = 1)

DISCUSSION

The results proved the effectiveness of using spaced repetition learning in improving learners' performance. This is in-line with other studies in virtually every standard experimental learning paradigm, with various traditional research material (Dempster, 1987a; Hintzman, 1974; Melton, 1970). However, it was interesting to see that spaced repetition was much more effective on learners who are academically stronger. Although this could be attributed to space effect, where two spaced presentations were about twice as effective as two massed presentations (Hintzman, 1974; Melton, 1970), and the difference between them increases as the frequency of repetition increases (Underwood, 1970). In this investigation, spaced presentations were employed, but the repetition frequency was the same for all learners and, therefore, may not have the same influence on the academically weaker learners as compared to the academically stronger learners. Learners who have a longer knowledge retention period generally performed better academically. This could suggest that some of the academically weaker learners could have forgotten before the questions were repeated and reviewed; therefore, the spaced repetition impact on academically weaker learners was limited.

An interesting finding was that learners responded positively, showing an improved motivation for them to learn the concepts in networking despite the increased workload required from them. The "nudging effect" in urging learners to revise on a weekly basis had influenced their behavior and motivated them to work.

CONCLUSION

There is a need to prevent "binge and purge" learning, which will not equip learners with the knowledge and skill for the real world. The learner with "binge and purge" learning may get a good grade, but they will not gain the knowledge. Continuous assessment at a bite-size level in "nudging" our learners to study on a regular basis could be the way forward for the learner to retain the knowledge as they progress. Based on our studies, the "nudging effect" of having weekly E-Quizzes in evaluating our learners' academic achievement could be more appropriate for learners to remember the key concepts for their future work. Incorporating spaced repetition learning into the weekly E-Quizzes showed great potential in improving learners' academic performance among the academically stronger learners. The hypothesis we have drawn is that the academically weaker students could have forgotten before the revision. Every learner has different knowledge retention periods, and it is logical to assume academically stronger learners have a longer knowledge retention period as compared with academically weaker learners. Further research will be necessary to understand the impact of the repetition frequency on the academically weaker learners for a holistic, practical learning system. In addition, further work to apply this study with other modules on upper-level learners would be carried out to validate the findings.

Learners generally perceive this methodology to be useful, interesting, and it helps them to improve their learning. Their motivation was also not affected by the additional effort that they must put in to remember the technical terms. In addition, learners' performances in the repetition tests provide useful feedback to learners learning progress and facilitate the lecturers to intervene and provide help to learners in a timely manner.

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INSTRUCTOR-STUDENT DYNAMICS MAPPING PROTOCOL DESIGN FOR A GEOMATICS ENGINEERING CLASSROOM

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ABSTRACT

The discipline of Geomatics Engineering evolved from Survey Engineering in response to the rapid development of technologies. Two University of Calgary courses, ENGO 343: Fundamentals of Surveying and ENGO 363: Estimation and Statistical Testing, are core courses taken by second-year Geomatics Engineering students, where they often have trouble grasping the content. Instructors restructured the courses to transition from a traditional lecture-centric classroom into an active learning environment. A longitudinal study was designed to map instructor-student dynamic in a classroom, using classroom behaviour to assess student learning. An independent third-party observed a given lecture by recording the actions of the instructor and students. The pilot was successful, and the study moved forward to Phase 2 in Winter 2019 using a revised observation protocol based on the Interactive-Constructive-Active-Passive (ICAP) Framework. lectures in ENGO 343 and ENGO 363, as well as lectures, labs, and tutorials for ENGG 407: Numerical Methods in Engineering were observed, where student and instructor actions at every 2-minute intervals were recorded using a list of pre-determined action codes. Different teaching styles inform the distribution of observed codes. Instructor must facilitate more active learning events, specifically Constructive and Interactive learning opportunities, to retain student engagement. The current protocol is revised to capture the complex student-student dynamics in a non-instructor-led classroom setting.

KEYWORDS

Geomatics Engineering, Classroom Mapping, Class Observation, ICAP Framework, Engineering Education, Active Learning, Standards 8, 11

INTRODUCTION

Geomatics engineering is the discipline specializing in the acquisition, modelling, analysis, and management of spatial data (*Geomatics Engineering*, n.d.). The discipline evolved from Survey Engineering as a response to the rapid advancements in engineering technology. As an accredited engineering program in Canada, all Geomatics engineering students must be able to demonstrate technical proficiency in the subject. Fundamental courses taught in second and third years ensure a strong technical and mathematical foundation for students, allowing them to explore advanced technical topics of their interest. Two of these second-year core courses are ENGO 343: Fundamentals of Surveying and ENGO 363: Estimation and

Statistical Testing. An additional mandatory mathematical course, ENGG 407: Numerical Methods in Engineering, while offered as a common core course by the school of engineering, is nonetheless taught by Geomatics professors.

These courses followed a traditional teaching approach for many years, where students copy notes as the lecturer presents, and the knowledge is cemented through fieldwork and programming-based lab assignments (Rangelova & Cao, 2019). In this learning framework, students' cognitive engagement is lower due to the limited opportunities for problem solving and discussions on open-ended questions. Also, students can struggle with the retention of fundamental engineering concepts as they move further into their studies (Rangelova et al., 2018).

The overall goal of this research is to assess student learning in the aforementioned courses, aligning with CDIO Standard 11: Learning Assessment. The research goal during phase 1 of the study was to determine the threshold concepts in the core geomatics engineering courses of ENGO 343 and ENGO 363. A threshold concept bottlenecks student learning, where a reconfiguration of the learning process is necessary to eliminate the bottleneck (Meyer & Land, 2003)(Meyer & Land, 2005). Examples of threshold concepts include random and systematic errors in data, univariate and multivariate data propagation, etc. Therefore, the main goal of phase 1 of the study was to identify these areas of troublesome knowledge (Rangelova et al., 2018). Phase 1 concluded that student cognitive engagement was higher when more problem solving and active learning were incorporated.

Following the conclusion of phase 1, instructors began incorporating more active learning into their lectures. Phase 2 was situated in the Interactive-Constructive-Active-Passive (ICAP) framework (Chi, 2009)(Chi & Wylie, 2014), as it provides the necessary contextualization for active learning in engineering (Streveler & Menekse, 2017). A new hybrid observation protocol, based on the ICAP framework, was used to assess both teaching and learning environment together with active learning (Rangelova & Cao, 2019). The goal of phase 2 is to determine how much classroom activities facilitate student's cognitive engagement at different levels of active learning.

BACKGROUND

As CDIO Standard 8, active learning is an instructional method that engages students in the learning process, requiring students to do meaningful activities and problem-solving while actively thinking about them (Prince, 2004)(*CDIO Standards 2.0*, n.d.). This contrasts with traditional lectures, where students passively receive information from the instruction. Active learning is characterized by student activity and engagement in the learning process. The benefits of active learning are evident from literature such as where students will remember more content if brief activities are introduced to the lecture, and that courses should promote collaborative and cooperative environments (Prince, 2004). Also, Freeman et al. (2014) show that active learning can increase student examination performance by half a letter grade on average and demonstrates a 35% decrease in failure rate compared to traditional learning methods.

The ICAP framework further contextualize students' cognitive engagement behaviours into four modes: Interactive, Constructive, Active, and Passive (Chi, 2009). In the Passive mode, students store information but make no effort to participate, and learning contains no active engagement with course material. Examples of Passive learning includes listening to instructor or talking to a peer during instructor explanation. The Active mode involves students integrating new information by connecting it to their prior knowledge. Examples of Active learning for students include taking notes or asking the instructor a question. Through reflection, re-evaluation of their knowledge connection, contrasting ideas and solutions, and inducing information, students can achieve the Constructive learning mode. Constructive learning includes suggesting a solution or discussing the outcome. Finally, the Interactive mode is achieved when students collaborate on a learning task while transitioning through the previous modes with their peers. Interactive learning examples include explaining their solution or presenting (Rangelova & Cao, 2019).

Context

The classroom observations took place in the winter term of 2019 for the two geomatics engineering courses (ENGO 343 and ENGO 363) and the spring intersession for one common core engineering course (ENGG 407) offered to students in most engineering programs. In 2018-2019, there were 154 undergraduate students enrolled in the geomatics engineering program. During the phase 2 of the observation period, 52 students were enrolled in ENGO 343, 54 were enrolled in ENGO 363, and 65 were enrolled in ENGG 407. Out of all students enrolled in ENGG 407, 13 students were in geomatics engineering.

METHODOLOGY

Classroom mapping was performed by a third-party observer, working independently of the instructor and students. The third-party observer is a recent Geomatics engineering graduate with background knowledge in the course content and an MSc student in engineering. Before the observations, the course instructor provided the observer with some basic information about the lecture, including the topic, learning goals, and criteria for success. The observer made notes of the classroom dynamics using the classroom observation protocol, initially adapted from the works by Arshavsky et al. (2012). The protocol began with lecture description, student attendance, start time, end time, and occurrences of lecture interruptions. To assess the learning environment, four categories were observed on a 4-point scale. These categories include geomatics engineering content, instruction and feedback, student cognitive engagement, and student behavioural engagement.

The core observation protocol was modified for phase 2 of the study, by adopting the ICAP framework for categorizing classroom behaviour. A list of teacher and student activities were introduced, alongside a list of matching 2-4 letter codes. Student activities were broken down into Passive, Active, Constructive, and Interactive categories. For example, teacher activity codes include TEX – explains a concept, TAQ – answers a question, etc. Student activities can include SL – listen to instructor's explanation (Passive), STN – take notes (Active), SSS – suggest a solution (Constructive), and SES – explain a solution (Interactive). The observation sheet includes the following fields:

- Time interval: duration of each observation, in minutes
- Codes: three observed action codes
- Task: the classroom activity during each observation
- % Class Engaged: the percentage of students that appeared to be cognitively engaged by the lecture

See Appendix A for the full observation protocol used.

Before the start of the lecture, the observer completed the metadata for the class observation, including the fields of:

- Course name
- Instructor name
- Observer name
- Date observed
- Location of lecture / lab / tutorial
- Number of students in attendance (The observer may update this field if students enter the class after observation starts)
- Observation start time / end time
- Was lecture / lab/tutorial interrupted?

The observer also made note of the lecture topic, learning goals, and criteria success.

The class observation began when the lecture starts. For every two-minute interval, three action codes are observed, the task was noted, and the percentage of class engaged was recorded. The three action codes note the most significant learning events from both teacher and students during the observation period, even if more than three action codes could have occurred. Periodically, the observer records comments of classroom activities, whether to generalize interesting classroom dynamics or to note the effectiveness and drawbacks of the observed teaching method.

The observation data is tabulated in spreadsheets for visualization and analysis using custom Python code. The following analysis was performed on each set of observed data from each course:

- Teaching and ICAP distribution of observed student codes
- Student engagement during class
- Time spent on each Teaching and ICAP categories
- Time spent on each student code observed

In addition to the observations, students completed two sets of self-assessments: a conceptual checklist of current chapter topics and an end-of-unit survey.

RESULTS AND FINDINGS

Three sets of classroom observations were made for each class of ENGO 343, ENGO 363, and ENGO 407, generalized in Table 1.

A comparative analysis of ENGO 343 and ENGO 363 will be performed, to evaluate the differences in the teaching approach between two instructors to the same group of second-year geomatics engineering students. ENGG 407 will be analysed separately to determine the difference in student cognitive engagement between lecture, lab assignment, and group quiz.

Table 1. Metadata of Observed Courses

Course	Date Observed	Learning Activity	Observation Duration (min)	Student Attendance
ENGO 343	March 18, 2019	Lecture	50	22
	March 20, 2019	Lecture	50	26
	March 25, 2019	Lecture	52	23
ENGO 363	March 20, 2019	Lecture	50	16
	March 25, 2019	Lecture	52	18
	March 27, 2019	Lecture	52	16
ENGG 407	May 15, 2019	Lecture	66	62
	May 16, 2019	Computer Lab Assignment	50	39
	May 22, 2019	Group Quiz	22	64

ENGO 343 and ENGO 363

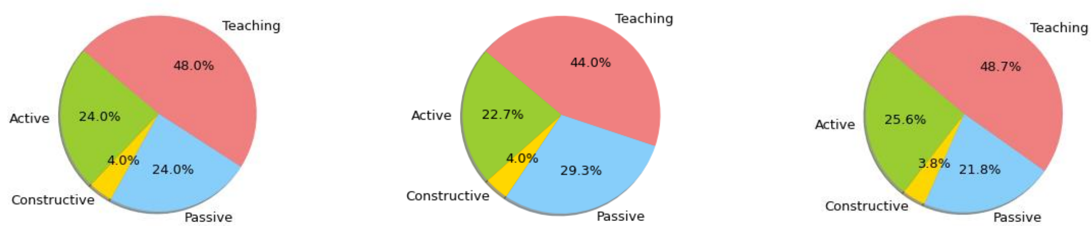

Figure 1. Teaching and ICAP distribution of ENGO 343 on March 18th (left), 20th (middle), 22nd (right)

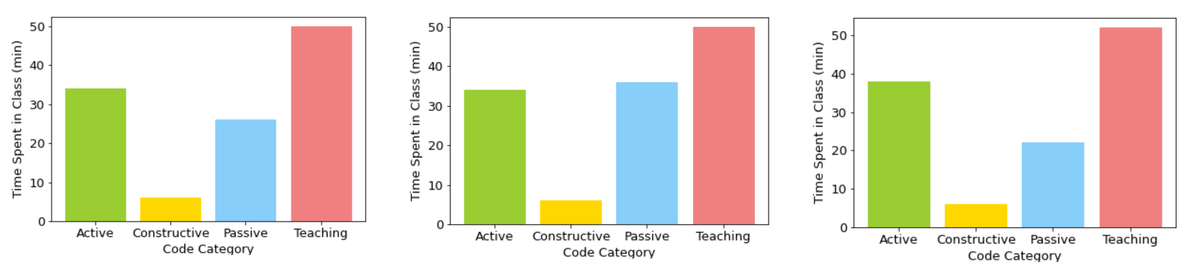

Figure 2. Time spent on Teaching and ICAP categories in ENGO 343 on March 18th (left), 20th (middle), 22nd (right)

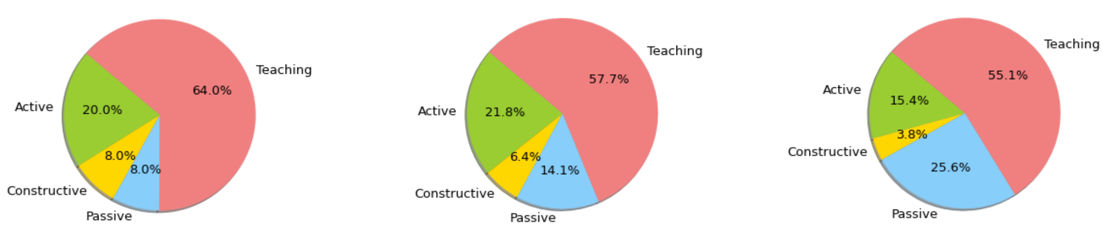

Figure 3. Teaching and ICAP distribution of ENGO 363 on March 20th (left), 25th (middle), 27th (right)

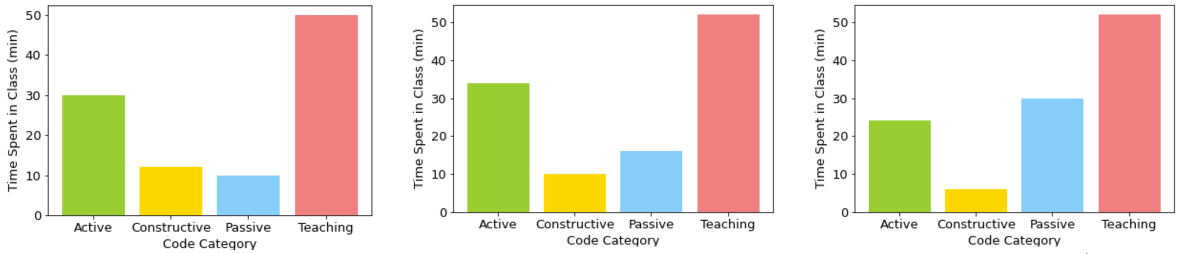

Figure 4. Time spent on Teaching and ICAP categories in ENGO 363 on March 20th (left), 25th (middle), 27th (right)

The distribution of Teaching and ICAP categories remains consistent across the three observed sessions in ENGO 343 (Figure 1). This figure compares the percentage of actions by the instructor (Teaching), and actions by the students (Passive, Active, and Constructive). Teaching occupied less than half of the observed codes, indicating that there were an equal amount of significant teaching events and student cognitive engagement events observed. On average, there is a similar amount of Active and Passive codes observed, but very little Constructive events occurred. Figure 2 quantizes these observed distributions into the number of minutes. Teaching occupied all 50 minutes of the lecture, which was the duration of the class itself. Active learning events were observed among some of the students for 30-40 minutes of the class. At the same time, Passive learning events were also observed for 80% to 90% of the students, for 20-30 minutes in the March 18th and 22nd lectures or for 30-40 minutes in the March 20 lecture. Constructive events were observed for less than 10 minutes in each lecture. The lectures in ENGO 343 offered a balance between teaching and student learning, but the learning still contained significant passive events. All three lectures covered 4 lessons in the topic of Route Surveying.

Compared to ENGO 343, the teaching events in ENGO 363 occupied more than half of all observed codes. In these lectures, the instructor was performing multiple significant events in many observations, and students demonstrated less cognitive engagement in comparison (Figure 3, 4). Students in ENGO 363 demonstrated slightly less Active learning, and slightly more Constructive learning in the March 20th and 25th lectures. However, the March 27th lecture yielded around 30 minutes of Passive events, significantly longer than the previous two lectures. The March 27th lecture was on the topic of Parametric Least Squares, where the instructor worked on an example by hand for the entire class duration. Observer comments noted that the lecture “pacing was slower than Monday’s [March 25th] lecture” and that “less student interaction than observed in prev. lectures”. Lectures on March 20th and 25th introduced and enforced a variety of topics in each lesson.

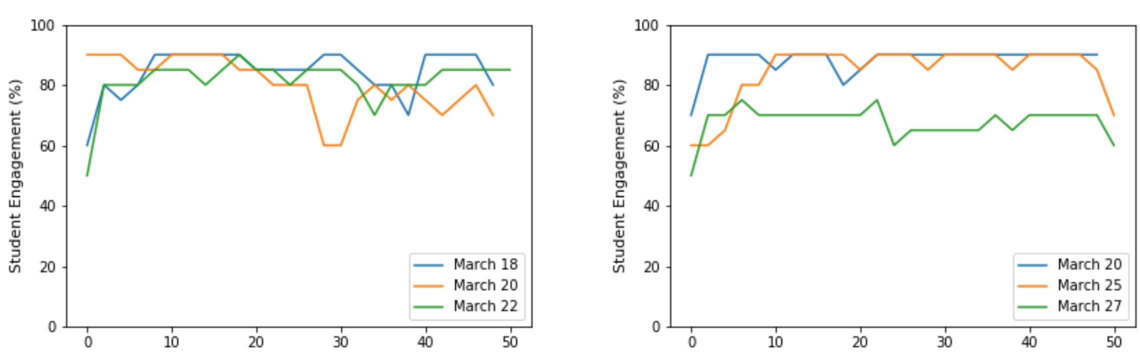

Figure 5. Student engagement in ENGO 343 (left) and ENGO 363 (right)

Seen in Figure 5, no lectures in both ENGO 343 and ENGO 363 managed to engage 100% of the students, as at least one student is always occupied with a non-related activity. In ENGO 343, student engagement falters immediately when the instructor is not directly engaging them with course material. Significant drops in attention occurs when the instructor is performing administrative work (making announcements and distributing documents), and when the students were asked to perform self-reflection on the topics covered in the previous lesson. It was observed that “student attention waivers when explaining long slides”. Comparatively, student attention remained consistent in the ENGO 363 lectures, as the instructor did not implement any student self-reflection. The March 27th lecture, as also noted earlier, had significantly lower engagement.

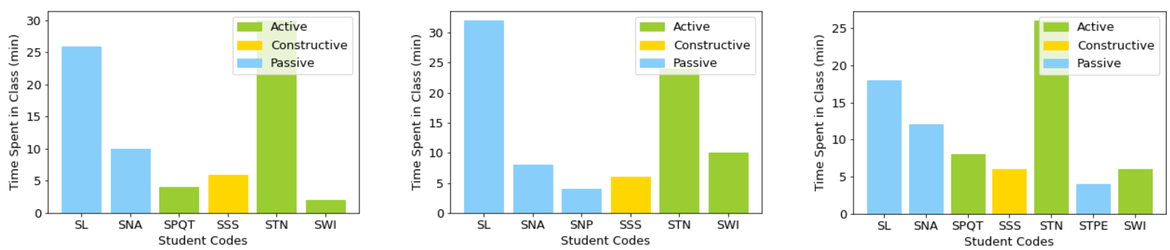

Figure 6. Time distribution of codes observed in students in ENGO 343 on March 18th (left), 20th (middle), 22nd (right)

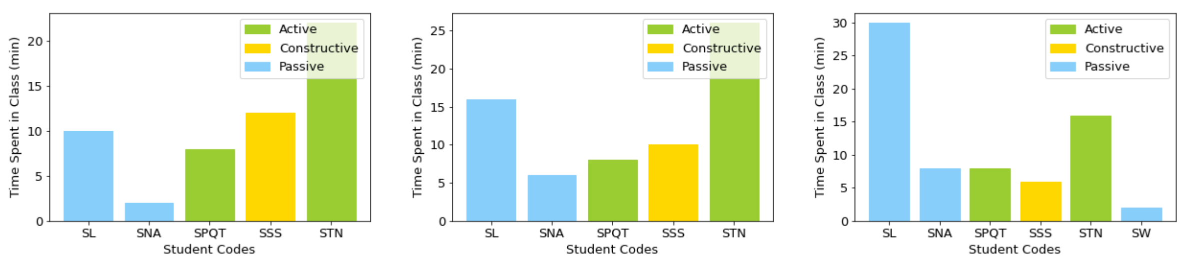

Figure 7. Time distribution of codes observed in students in ENGO 363 on March 20th (left), 25th (middle), 27th (right)

Figures 6 and 7 above break down the time-based distributions of each code observed for the student engagement, where:

- SL: listen to the instructor’s explanation (Passive)
- SW: idle / wait for the instructor (Passive)
- SNA: occupied with non-related activities (Passive)
- STPE: talk to a peer during explanation (Passive)
- SPQT: poses a question to the teacher (Active)
- STN: take notes (Active)
- SWI: work individually / reflect (Active)
- SSS: suggest a solution (Constructive)

In all lectures, the most predominant student activity observed were students taking notes (Active) and students listening to the instructor’s explanation (Passive). The only Constructive code observed was a student suggesting a solution when prompted by an instructor’s question. It should be noted that no Interactive codes were observed during both ENGO 343 and ENGO 363.

ENGG 407

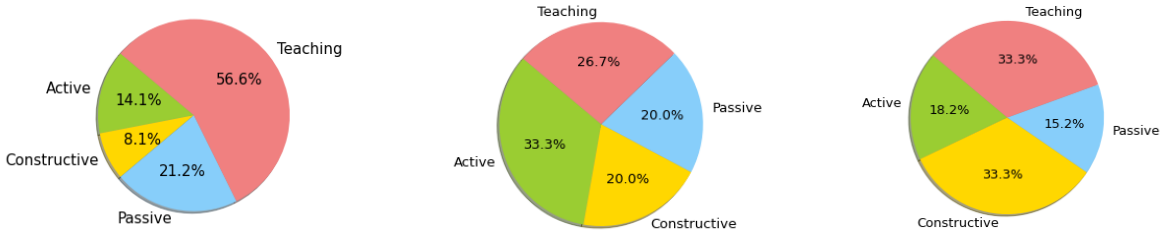

Figure 8. Teaching and ICAP distribution of ENGG 407 on May 15th lecture (left), 16th lab (middle), 22nd group quiz (right)

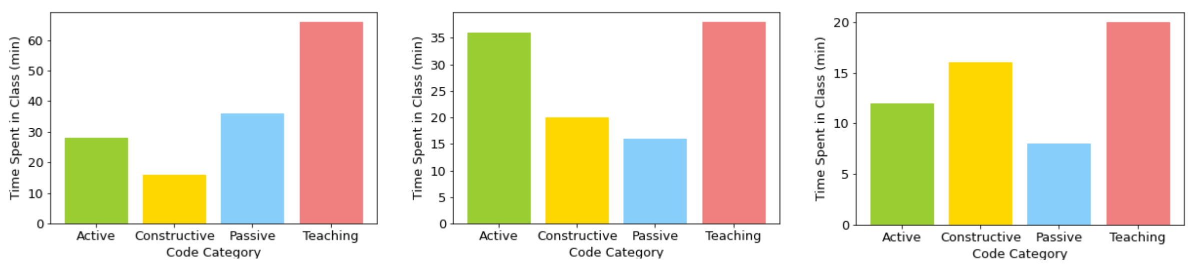

Figure 9. Time spent on Teaching and ICAP categories in ENGG 407 on May 15th lecture (left), 16th lab (middle), 22nd group quiz (right)

ENGG 407, taught by the same instructor as ENGO 363, saw a similar distribution of codes in the only lecture observed on May 15th (Figure 8). This reflects on the instructor's teaching style of performing more than one significant event for some observations. Both the lab assignment and the group quiz saw less teaching events, as the primary goal of the activities were to encourage collaborative problem solving. The time-wise distribution for the lecture (Figure 9) was comparable with observations in ENGO 363. Despite the larger percentage, Constructive learning occurred for a longer duration in the lab assignment as opposed to the group quiz.

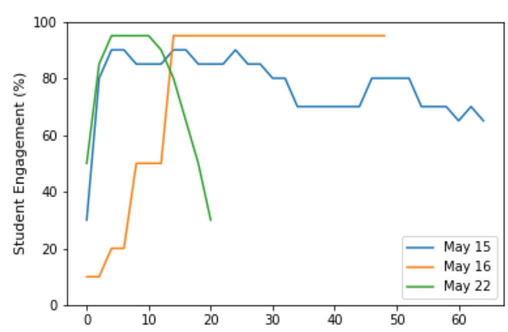

Figure 10. Student engagement in ENGG 407

Student engagement in the May 15th lecture saw a decline in cognitive engagement around 30 minutes into the lecture, following a period of high engagement. The decline corresponded to the beginning of an instructor-led coding tutorial, with observer comments being "not a lot of note-taking during tutorial". Comparatively, the lab session on May 16th reached a peak in the cognitive engagement as soon as the instructor concluded their explanation of the lab assignment. The group quiz on May 22nd showed a sharp decline in engagement as students finished their quiz.

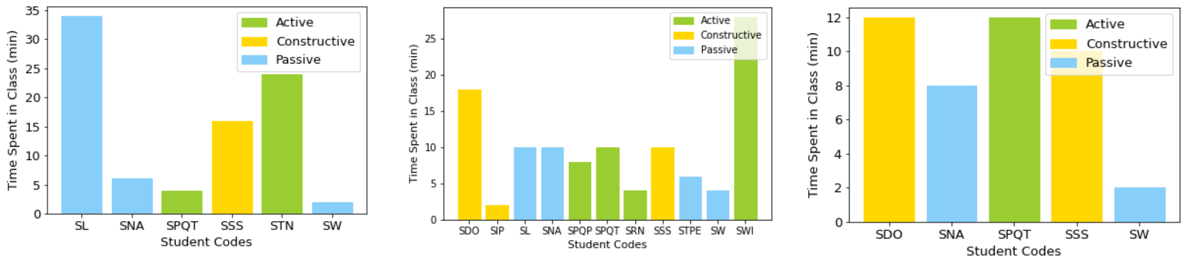

Figure 11. Time spent on each student code in ENGG 407 on May 15th lecture (left), 16th lab (middle), 22nd group quiz (right)

As per Figure 11, no additional codes were observed during the lecture, compared to ENGO 343 and ENGO 363. The primary Active learning activity during the lab session was students working individually on the assignment (SWI). The major Constructive code observed was student discussing outcomes amongst themselves (SDO). While a lot of codes were present, student activity observed was mainly focused on working individually, and using discussions with other students to support their learning. Additional codes observed during this session include:

- SPQP: pose a question to a peer (Active)
- SRN: read notes (Active)
- SDO: discuss outcome (Constructive)
- SIP: iterate a process/procedure (Constructive)

The group quiz observed mostly students discussing the quiz answers and asking the instructor for clarification on the questions. Just like ENGO 343 and ENGO 363, no Interactive activities were observed in ENGG 407.

RECOMMENDED CHANGES

Addendums and changes are recommended to the list of codes and observation protocol to:

1. Capture more complex student-to-student interactions during non-lecture class activities; and
2. Ease of recording for the observer.

The current observation protocol works well to capture the instructor-student dynamic in a lecture setting but fails to reflect the complexity of student-student interactions when they are working together on assignments and quizzes. The following codes are suggested to better understand student dynamic, especially for non-instructor-led activities:

- SNC: occupied with non-related coursework (Passive)
- SRA: research for an answer (Active)
- SPCT: pose a clarifying question/request to the teacher (Active)
- SIS: implementing a solution (Constructive)
- SBS: brainstorm solution (Constructive)
- SCP: collaborate to create a prototype (Interactive)

An additional “student disengaged” code is proposed to include where students are not learning, such as sleeping or leaving early. The observation data-sheet is modified to separate the codes between the teacher and student, as well as starting to track the number of students engaged, rather than tracking the percentage. The Table 2 below illustrates the new observation data sheet header:

Table 2. Proposed Update to Observation Data Sheet

Observation Interval: (min)		Observation Codes				Number of students present	Number or % students engaged
Obs. No.	Observed Task	Teacher		Students			

Additionally, the student self-assessment is recommended to move to a mobile-friendly online survey form, to encourage anonymity and increase the response rate.

These changes will be implemented during phase 3 of the study, for ENGO 343 and ENGO 363 in the Winter 2020 semester.

CONCLUSION

This research performs a longitudinal study on second- and third-year geomatics engineering students by assessing their learning (CDIO Standard 11) in an active learning environment (CDIO Standard 8). Based on the feedback from its first iteration, geomatics engineering and core math classes were observed using action codes based on the ICAP framework. The instructor teaching style informs the distribution of codes, observing either an even split between Teaching and Student, as well as Active and Passive (ENGO 343), or more Teaching than Student events (ENGO 363 and ENGG 407). Decrease in student engagement corresponds to an increase in observed Passive actions, as well as when the instructor is not directly engaging them with course content. Classroom content must incorporate more active learning activities and consequently provide more Constructive and Interactive learning opportunities for students. The current protocol is not equipped to capture the complex student-student dynamic in non-lecture-based class activities, so therefore new codes and protocol is proposed for phase 3 of the study in Winter 2020.

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BIOGRAPHICAL INFORMATION

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APPENDIX A

Classroom Observation Protocol

Section 1: Meta Data

Course: Instructor: Observer: Date:

Lecture:	Lab:	Tutorial:
Class arrangement:		
Number of students in attendance:		
Start time:	End time:	
Was lecture/lab/tutorial interrupted?		

Topic:

Learning goals:

Criteria for success:

Most time spent on: (check on of the following objectives)

Conceptual knowledge	Introduced	Developed	Applied
Procedural knowledge	Introduced	Developed	Applied
Problem solving	Introduced	Developed	Applied
Inquiry learning	Introduced	Developed	Applied
Engineering Design	Introduced	Developed	Applied

Section 2: Codes

What the teachers does

TEX	explains a concept
TAQ	answers a question
TPQ	poses a question
TWB	writes on the board
TW	waits for students to finish
TMO	moves through the class and observes students
TDG	discusses with a group of students
TDC	discusses with the class
TC	draw a conclusion
TGA	assignes a group activity
TCA	assignes a class activity
TF	provides feedback to the class
TAD	performs administration work
TI1S	inreacts with one student

What students do

SL	listen to instructor's explanation	Passive
SW	idle/wait for the instructor	
STPE	talk to a peer during explanation	
SNP	do not participate in a group/class activity	
SNA	occupied with non-related activities	

STN	take notes	Active
SPQT	pose a question to the teacher	
SPQP	pose a question to a peer	
SWI	work individually/reflect	
SRN	read notes	

SDG	Draw a graph	Constructive
SSS	Suggest a solution	
SDP	Design a procedure	
SPE	Provide evidence	
SDO	Discuss outcome	
SCA	Choose alternative	
SIP	Iterate a process/procedure	
SR	Reflect on learning	

SEC	Explain a concept	Interactive
SES	Explain a solution	
SEP	Explain a procedure	
SPS	Provide a summary	
SRF	Respond to feedback	
SD	Debate	
SP	Present	

Section 3: Observation Data

TIME INTERVAL (min)		CODE	CODE	CODE	TASK	% Class Engaged
0	2					
2	4					
4	6					
6	8					
8	10					
10	12					
12	14					
14	16					
16	18					
18	20					
20	22					
22	24					
24	26					
26	28					
28	30					
30	32					
32	34					
34	36					
36	38					
38	40					
40	42					
42	44					
44	46					
46	48					
48	50					

COGNITIVE, SOCIAL AND EMOTIONAL ASPECTS OF INTERDISCIPLINARY LEARNING

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ABSTRACT

The aim of the Joint Interdisciplinary Project (JiP) is to prepare Master students for their entry into the workforce after their study. In JiP they will contribute to solving impactful, real-life technological challenges provided and supervised by renowned companies. Interdisciplinary student teams are guided by a company coach and are offered academic and industry expertise. These projects not only demand good engineering working knowledge but also a solid grounding in interdisciplinary and systems thinking, and both knowledge and mindsets of innovation and entrepreneurial behaviour. The curriculum of Jip was designed to deliver this. The current study aims to evaluate the curriculum design with a pre and post-test survey amongst students about their, cognitive, social and emotional expectations and challenges in interdisciplinary working and the highlights of the learning process during the programme.

KEYWORDS

Interdisciplinary Learning, Learning dimensions, Engineering Higher Education, Learning Approaches in an Engineering Context, Curriculum Design, Standards 8,11,12

INTRODUCTION

Kamp (2019) in his work, has already shown that many industry experts and leaders in innovation found the knowledge and skills of most graduates are not broad enough and not adapted to the digital transformation taking place. "*Many young graduates who enter our workforce after their study at a university have a good theoretical understanding of the fundamentals, but little idea how business works and what engineering practice is about".* The primary value and function of an engineering professional are to go beyond the acquisition of knowledge towards the application of knowledge (Miller, 2018).

The ultimate purpose of the Joint interdisciplinary Project for students is to come up with an innovative design /research with a sustainable impact on society and added value for the company within a period of 10 weeks. The brief with the problem is related to minimally 2 of the sustainable development goals (SDG) and solved in an interdisciplinary team of engineers, designers and scientists. The company aims to find new commercial applications and business models inspired by advanced technologies. Each project uses the same common aspects of innovative engineering and technology in an interdisciplinary mindset, in a proper balance with non-engineering aspects such as societal relevance and impact, and 'out-of-the-box' business 'in the niche' development. The project outcomes are actionable.

The projects are a unique opportunity for cross-disciplinary and holistic work, beyond "engineering bricks", in which students discover that interdisciplinary problems are often so complicated that it is impossible to know everything one needs to know to fully understand them (Kamp, 2019). These wicked problems are complex in nature, open, interdependent and a moving target (Dorst, 2017). They require an open mindset and interdisciplinary thinking skills to be able to solve these complex problems (Spelt 2017, Boon, 2018, McLeod, 2018).

This Joint Interdisciplinary project welcomes the students as equal participants in problem analysis, problem-solving and knowledge construction. Students are based in the company part of the time and become acquainted with many CEO/Head R&D and other key persons in the company, as well as academic experts. During the course there is a kick-off, focusing on getting the team started on their project work and includes workshops on team building, project management and company content information, such as value-based design, design integration, etc. and 3 major reviews for the assessment of the work. The project work is guided by the company coach, academic staff and the JiP team support staff and is finalised with a public-defence. This course has currently run for the 2nd year with 50 students and 11 companies like Airbus, Royal Haskoning DHV, Huisman, Axxiflex, Arcadis, Feadship, FreshTec, LEAN and WE-P. Next year it is expected to scale up towards 200 students.

As the Joint Interdisciplinary Project is still somewhat in a design prototyping phase we wanted to know with which Interdisciplinary skills master students who are entering the learning environment came in. Do they have an open and interdisciplinary mindset, supposedly necessary for this type of work? We framed this mindset as expectations. Are students aware of these Interdisciplinary skills and do they expect to acquire these skills in JiP? Equally, we wanted to know which of these skills are developed within the JiP course. Spelt (2017), has successfully measured the interdisciplinary mindset of Engineering students in a (Research) University, along the learning dimensions of Iliris (2002). These learning dimensions included a **cognitive learning dimension** (learning to use the content of different disciplines to solve problems), a **social learning dimension** focused on different communications and interactions (e.g. socially engaging with peers and stakeholder to recognise similarities in perceptions and experiences) and **emotional learning dimensions** focusing on well-being and confidence of the students (incentives, challenges, feelings when dealing with interdisciplinary learning).

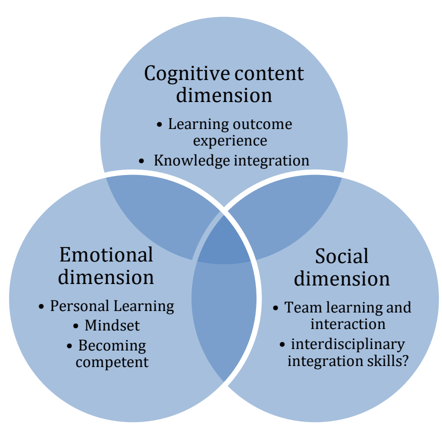

Figure 1. Three learning dimensions and survey structure

Main Research Questions

- What expectations (cognitive, social and emotional) do students have at the beginning of the course? (pre-course survey- students)
- What is the perceived realisation of the learning process in this course? (Post-course survey students)

METHODS: *SURVEY QUESTIONS*

Student pre-survey consisted of 50 questions, measured on a 5 point Likert scale strongly disagree to strongly agree, focused on motivation to participate in JiP and questions about cognitive, emotional and social development. The post-survey consisted of 43 questions, measured on a 5 point Likert scale, one rank-order question and 2 open questions. The questions were partly practical, evaluating elements of the course, and partly repeated questions on the cognitive, emotional and social development. The post-survey specifically explores more practical issues on whether students felt if certain components in the course contributed or hampered their learning. We expect this will strengthen the insight into the course. We rounded off the post-course survey with 3 qualitative questions, what did you lack in the course, three tops and tips of the students for this course and general remarks if there were any.

The Survey questions of the cognitive, emotional and social development in this study have partly been adapted from the three- dimensional model of Spelt et. al. (2018) on Interdisciplinary learning and were calibrated against interview results of Spelt (2018) on these learning dimensions. Survey questions have also been calibrated on Repko(2017) work, who in his work proposes several skills necessary to work in interdisciplinary teams and fitting the cognitive and social dimensions. These are included in a broad model rubric for assessment (p.377) and a service-learning rubric (p.365) to evaluate the interdisciplinary skills of students. The survey consisted of a pre-and post-survey questions amongst students and felt as valid questions to establish the level of expectations and interdisciplinary learning in this course. Similarities and differences are expected to be found between the expectations Pre- survey (zero measurements in week 1) and the experiences post-survey (t 1= week 10 measurement). The hypothesis is that the higher the score on the pre-test, the more an "interdisciplinary mindset" is already present. The lower the score on the pre-test the more steep the learning curve in interdisciplinary learning. In this paper, we will present the findings of the pre-post survey amongst student participants for the cognitive, social and emotional aspects before and after the course.

Method of Data Analysis

Both the pre and post questionnaire reliability was tested with Cronbach's alpha and were respectively .88 and .86, showing a high overall consistency of the items about what we wanted to measure. The pre-survey response rate was almost 95%, in absolute numbers N= 47 out of 50. The post-survey response rate was 50%, in absolute number 26 out of 50. It means we need to keep into account that the overall numbers are small.

Clustering of the sub-scales on the cognitive- social and emotional aspect was done based on the pre-survey item with a Pearson correlation between different items. Items between 0.30 - .80, which are moderate to fair correlations, were paired into sub-clusters. The post-survey items, when similar to the pre-survey questions were added to the subscales. As the number of respondents was rather small we have not gone beyond reporting descriptive percentages (frequencies)and average means (standard deviations) of the results. Since the overall consistency (Cronbach's alpha) was rather high we feel we can safely continue with descriptive analysis and expect to be giving a fair and relatively representative view of what happened in this course concerning the 3 measured learning dimensions.

RESULTS

This section describes the different components stated in fig.1 of the cognitive content dimension, the social and emotional dimension of learning in an interdisciplinary environment. The similarities and differences are interpreted as expectations prior to the course and having learned something as opposed to not having learned something after the course. In each dimension heading we will repeat the definition of the dimensions, cognitive, social and emotional growth expectations in italics to make reading easier. Each table is a combined description of pre and post-survey results. The pre-test results will be discussed prior to a table, the post test results at the bottom of a table, the conclusion at the end of the dimensions paragraph.

Cognitive Learning Dimension

Cognitive and or content learning dimensions deal with learning how to use the content of different disciplines to solve problems. This also includes activities that provide access to this content.

Learning Outcomes

In table 1 the aggregate findings are presented on the learning outcome component of the cognitive learning dimension. In the pre-test the questions related to the expected learning outcomes are related to being able to apply theoretical concepts to real-life problems (Question 12 pre, Mean 3.8), built a network (Question 36- pre, M=3.8), to revise a viewpoint based on logic and reasoning (Q15 pre, M= 4.1), and gain experience in an innovative professional environment (Q 38- pre - M=4.4.).

Table 1. Learning outcomes experience

	Learning outcomes experience alpha .84 for pre-survey	*Strongly/ disagree*	*Agree nor disagree*	*Strongly/ agree*	*Mean (SD)*
12pre	to understand how to apply theoretical models or concepts to real-life situations	13%	19%	68%	3.8 (.97)
17post	**I have learned to apply theoretical models or concepts to real-life complex problems**	**12%**	**12%**	**76%**	**4.0 (.98)**
36pre	To build a network within my branch of interest	17%	17%	64%	3.8 (1.1)
25post	**I have built a network of contacts within the industry/academia**	**12%**	**24%**	**64%**	**3.6 (1.1)**
38 pre	To gain experience in an innovative professional environment	4%	6%	87%	4.4 (.97)
24 post	**the company gave a lot of opportunities to see its operations**	**40%**	**24%**	**36%**	**3.1 (1.3)**

15	to revise a viewpoint using logic and facts as a basis for reasoning	2%	25%	72%	4.1 (.88)

Results indicate that students perceived their expectations with respect to applying theoretical models to real-life were exceeded and they did learn to do apply theory in practice. Expectations for building a network in academia and industry have been met. Those who did not expect it (the difference between strongly disagree/disagree is 7%) have moved into the area where they might be open to it (agree nor disagree). Concerning gaining experience in a professional environment, it is noted that a lot of students, did not get the opportunity to see the company in operation, or possibly did not have a company visit. Seeing the company in operation strongly depends on the company policies, accessibility and practical limitations of place and distance.

Knowledge Integration

Table 2. Knowledge Integration

Questions nr.	*Knowledge integration pre-survey alpha .77*	*Strongly/ disagree*	*Agree nor disagree*	*Strongly/ agree*	*Mean (SD)*
	I recognize one needs				
14 pre	to zoom in and out of disciplinary focus at different levels of abstraction	2%	15%	81%	4.3 (.82)
19post	**I manage to zoom in and out of disciplinary focus at different levels of abstraction**	**4%**	**12%**	**84%**	**4.2 (.83)**
8pre	to recognise that answers can be based upon various uses of disciplinary knowledge	-	15 %	85%	4.2 (.70)
14post	**To recognise that answers can be based upon various uses of disciplinary knowledge was an eye opener for me**	**16%**	**36%**	**44%**	**3.6 (1.1)**
18 pre	to design an integrated solution to solve the problem defined by the team	4%	4%	90%	4.4. (.79)
32post	**We were able to design an integrated interdisciplinary solution to solve the problem defined by the team**	**4%**	**8 %**	**88%**	**4.4 (.81)**

Table 3 is about knowledge integration and shows the extent to which students were expecting to be able to deal with using disciplinary knowledge to create an integrated design solution. If we look at the pre-test students were rather confident about zooming in at different levels of abstraction Q14 -pre (M =4.3), recognising and using disciplinary knowledge Q8 pre (M = 4.2), and design integration of the solutions Q18 pre (M= 4.4.).

In practice zooming in and out at different levels of abstraction seems to be easily achieved Q19 post (M= 4.2) and it was not a surprise that different uses of disciplinary knowledge could be used Q14 post (M = 3.6). Note that Q14 post? the answer is a negative question, which means that if one strongly disagreed it was not an eye-opener, they were able to recognise easily to use different disciplinary knowledge 16%, 36% unsure and 44% was confronted with an eye-opener at this point. Meaning they had anticipated it but the reality was possibly harder than expected.

Students expectancies with respect to learning content and integrating different types of disciplinary knowledge were largely met in the course. They were specifically disappointed in getting too little information on the company in operation.

Social Learning Dimension

The social learning dimension focuses on communication and interactions with peers and stakeholders, including the skills that are required to realise the interdisciplinary interaction. The dimension is measured by team learning and interaction and interdisciplinary integration skills.

Team learning and interaction

Table 3. Team learning and Interaction

	team learning and interaction - alpha.70	*SD/D*	*DnorA*	*SA/A*	*Mean (SD)*
4pre	To learn from peer perceptions and experiences		4%	93%	4.5(.62)
4post	**I have learned a lot about other disciplines, new topics, experiences from our JiP Team Peers**		**8%**	**92%**	**4.5 (. 65)**
2pre	To recognise similarities in perceptions and experiences, when I engage with peers within the JIP team and context	6%	26%	66%	3.8 (.85)
7post	**I have learned to switch easily between the various viewpoints of others in order to check my own viewpoints**	**4%**	**16%**	**80%**	**4.1 (.81)**
3pre	To be able to engage and share the taken approach, arguments, and decisions within the JIP team and context	2%	4%	92%	4.1 (.85)
8post	**Our team was in it together and shared responsibilities for the team's success or failure**		**8%**	**88%**	**4.8 (.66)**
6pre	To be able to contribute to the learning of the team-partners	2%	15%	81%	4.2 (.80)
5post	**I have been able to contribute to the learning of the team- partners**			**100%**	**4.6 (.51)**

Table 3 particularly dealt with team interaction and peer learning. Results on the pre-course questions show that expectancies about the team interaction and learning thereof either by Q3-pre -sharing perspectives (M= 4.1), Q4 pre-learning from team experiences and peers (M= 4.5), or Q6- pre - contributing themselves to the team learning (M = 4.2) is very high.

In practice (on the post-test) these expectancies were confirmed. Q3 pre was rephrased to Q 8 post sharing responsibilities, the score soared to M = 4.8. Q4 post learning from other disciplines team experience was largely fulfilled score remaining M=4.5 and team contribution Q5- post went up to M= 4.6 and was a 100% positive on team learning!! The students' equally felt they were able to switch between various viewpoints more easily after having finished JiP up from Q2 pre – M= 3.8 to Q7 Post to M = 4.1.

Interdisciplinary integration skills

In table four skills acquiring a helicopter view, switching from viewpoints to benchmark one's viewpoint and justification of decisions based on solid arguments are questioned. Most students expected these skills to be developed Q 9 pre (M= 4.1) , Q11 pre (M = 4.2), Q13/28 pre (both M = 4.1).

Table 4. Interdisciplinary skills integration

	Cognition/ interdisciplinary integration skills - alpha = . 66	*Strongly/ disagree*	*Agree nor disagree*	*Strongly/ agree*	*Mean (SD)*
9pre	To adopt a helicopter view of the interdisciplinary research and the disciplinary contributions	4 %	19%	75%	4.1 (.88)
15post	**I have developed a helicopter view across different fields of knowledge**	**4%**	**4%**	**80%**	**4.0 (.76)**
11pre	To learn to switch easily between the various viewpoints of others in order to check my own viewpoints	4%	17%	76%	4.2 (.90)
7post	**I have learned to switch easily between the various viewpoints of others in order to check my own viewpoints**	**4%**	**16%**	**80%**	**4.1 (.81)**
13pre	to justify decisions made and to compare the issues and arguments raised	4%	11%	85%	4.1 (.73)
28pre	justify decisions made to solve the problems discussed	-	17%	79 %	4.1 (.75)
18post	**I have learned to support arguments to justify decisions made on the topic of study**		**12%**	**88%**	**4.3 (.70)**

In the post-test, this was confirmed and better than expected Q15 post (M= 4.0) with 80% agreeing to strongly agreeing, Q 7 post – (M = 4.1) again with 80% agreeing to strongly agreeing. Q18 post – (M = 4.3) with 88% agreeing to strongly agree. The average not necessarily being higher but more people convinced of their learning or being able to apply this skill. NB that Question 13 and 28 are integrated into the post-test.

On the "social learning dimension," students felt they learned more than expected from other disciplines and were able to contribute to the team learning. They acquired skills such as using a helicopter view, switching from viewpoint and justifications of arguments. This supported their interaction with different disciplines and stakeholders.

Emotional Personal Learning Dimension

The emotional learning focusing on well-being and confidence of the students (incentives, challenges, feelings when dealing with interdisciplinary learning) while interacting with different aspects of interdisciplinary working, such as being on top of the content and social engagement with different peers/stakeholders as well as reflection, critical assessment and self-directedness. The dimension is captured under the heading and tables personal learning, mindset and becoming competent.
Personal learning

Table 5 looks at personal learning increasing personal understanding (q5 pre – M = 4.5), becoming confident (Q26 pre – M = 4.2), noticing a problem has various solutions (Q33 pre – M = 4.4) and making connections more easily across different disciplines (Q 34 pre – M = 4.6).

Table 5. Personal Learning

	personal learning I expect to learn alpha .78	*Strongly/ disagree*	*Agree nor disagree*	*Strongly/ agree*	*Mean (SD)*
5 pre	I expect to increase my personal understanding while reflecting on other disciplinary viewpoints		6%	93%	4.5 (.62)
6post	**I have been able to increase my personal understanding of the world while reflecting on other disciplinary viewpoints**		**16%**	**84%**	**4.2 (.71)**
26 pre	Feeling competent is important		9%	81%	4.2 (1.3)
44post	**I feel more competent and confident after having completed JiP**	**4%**	**16%**	**80%**	**4.1 (1.1)**
33pre	To discuss different solutions scenario's for the topic of study		9%	89%	4.4 (.68)
21 post	**I have come to realise a problem can have many solutions**	**8%**	**8%**	**84%**	**4.2 (.93)**
34pre	To connect more easily with people in different disciplines for the purpose of solving particular problems	2%	4%	92%	4.6 (.71)
16post	**I have learned to connect more easily with people in different disciplines for the purpose of solving particular problems**		**4%**	**88%**	**4.6 (.71)**

The expectations were largely confirmed yet had slightly lower averages and levels of the agreement except for making connections, which was at the same level. Personal understanding (Q6 post – M = 4.2), feeling confident (Q44 post – M = 4.1) , various solutions (Q21post – M = 4.2) and making connections (Q16 post – M = 4.6) . The real world was possibly more complicated than expected and experiencing complexity goes both ways. Being able to deal with complexity gives a boost, but also becoming aware of the vastness of the complexity is a little frightening, showing how little we know to make oneself possibly less confident.

Mindset

Table 6 shows Q24 pre and Q23 post students expected and have acquired new professional skills.

In the majority of the cases, the students were driven to realise personal growth (Q25 pre) and were able to realise this through the personal InterVision and personal reflection that have been part of the course structure. (Questions 28a, 39 post). Fortunately, students felt even more prepared for the industry than expected (Q22 post). The interdisciplinary interrelationships were a little less strongly present than anticipated at the beginning (Q7 pre and 13 Post).

Table 6. Mindset

	mindset alpha = .65	Strongly/ disagree	Agree nor disagree	Strongly/ agree	Mean (SD)
24pre	I easily acquire new knowledge	4%	19%	77%	4.0 (.85)
23 post	**I have acquired (new) professional skills**		**12%**	**88%**	**4.3 (.68)**
25pre	I'm seeking personal growth	2 %	2%	92%	4.7 (.70)
28a. 4.post	**The personal intervision supported my personal growth process**	**8%**	**8%**	**80%**	**4.1 (1.0)**
39post	**Personal reflections allowed to monitor my personal development**	**8%**	**20%**	**72%**	**3.9 (.89)**
22 post	**I feel more prepared for a future in industry**	**8%**	**16%**	**76%**	**4.0 (1.0)**
21 pre	I am interested in different topics that contribute to solving societal challenges				4.6 (.69)
7pre	To design conceptual models representing disciplinary interrelationships	8.5 %	28%	61%	3.6 (1.1)
13post	**We have designed conceptual models representing disciplinary interrelationships**	**24%**	**16%**	**56%**	**3.9 (1.3)**

Becoming Competent

Table 7 becoming competent shows that students seem to have a fairly realistic perception of how they address complex problems (Q19 pre-M = 2.7). They didn't expect it to be difficult to use disciplinary knowledge to solve complex problems and Q33 post (M = 3.1) shows that 40% felt it was as difficult as they thought it would be. However, 36% felt it was a rather difficult task as opposed to 15% in the Q19.

Table 7. Becoming Competent

	alpha .56 becoming competent	SD/D	AnorD	A/SA	Mean (SD)
19 pre	I find it difficult to match and select disciplinary knowledge to address complex problems	51%	32%	15%	2.7 (1.0)
33post	**The tasks to solve the case were very different from what we imagined and seem very difficult to accomplish**	**40%**	**20%**	**36%**	**3.1 (1.2)**
20pre	I feel uncertain when having to frame a complex problem	45%	30%	23%	2.8 (1.1)
41post	**I feel better able to frame a complex problem after JIP**		**8%**	**84%**	**4.3 (1.1)**
10 pre	To create multiple answers by integrating disciplinary knowledge in various ways	11%	17%	78%	4.1 (1.1)
14post	**To recognise that answers can be based upon various uses of disciplinary knowledge was an eye opener for me**	**16%**	**36%**	**44%**	**3.6 (1.1)**
39pre	To be coached by and learn from professionals		6%	92%	4.6 (.64)
26 post	**The Company coach has given us constructive and relevant feedback**	**4%**	**28%**	**68%**	**4.0 (.88)**
27post	**The Experts (company professionals) have given us constructive and relevant feedback**		**20%**	**80%**	**4.1 (7.3)**
28 post	**The Experts (academic staff) have given us constructive and relevant feedback**	**4 %**	**28%**	**68%**	**4.0 (.89)**

In Q20 pre and Q41 is shown that around 40% feels more confident after Jip framing a complex problem. Learning from professionals 39 pre and Q26/Q27 post it was shown that students expected a lot from the professional (company coach). In the majority of cases, students were still very satisfied, yet it was possibly sobering to experience the professional is only human, like anyone else.

The emotional learning dimension shows that students particularly felt they have acquired new skills, feel better able to frame complex problems and feel more competent to work in the industry after having completed the Joint interdisciplinary Project.

Tops

We finalise with the aspects of learning which are particularly appreciated in the course:

- **Working in an interdisciplinary team:** (with different disciplinary, cultural and educational backgrounds), especially the management site, the inspiration, the great teammates, the different mindsets, becoming more assertive as a person, working 9-5 in a team and learning different skills from team members. (N= 17)
- **Working on a company assignment:** Bringing (your) skills into play on a practical assignment related to our study and contributing to the company product. Getting exposure to working environments in industry and obtaining real insights into how companies and client organisations work in the Netherlands
- **Expanding the Network:** Great networking experience with the reception of valuable feedback with both academic staff, company representatives, professors and professionals from other branches.

DISCUSSIONS & CONCLUSIONS

We have started this paper with the question “What expectations (cognitive, social and emotional) do students have at the beginning of the course?” (pre-survey), “What is the perceived realisation of the learning process in this course? (post-survey students)”. Additionally, we had two hypotheses, if there was a high score on the pre-test students might be more interdisciplinary-minded and possibly learned less during the course. If there was a low score they are likely to have learned more.

When studying the results we notice that expectancies at the beginning of the course were rather high on the entire survey. It seems the expectations levels matched what students knew about interdisciplinary learning and the information given before the course has been sufficiently informative. As the post-survey outcomes were equally high we presume that students have been able to apply their interdisciplinary skills in this course or have learned to apply them in this course. The experiences in the “tops- section” confirm that students have learned the interdisciplinary thinking skills set out in the learning dimensions.

We may conclude that an open learning format, where interdisciplinary students teams are in the lead of their learning process, offer a unique opportunity to acquire interdisciplinary thinking skills. Dealing with peers, a variety of different stakeholders in academia and industry allows for a “good” preparation for real-life complex problem-solving. Yet the interaction with industry remains a precarious point as not all companies can provide access to their organisations.
Despite the final remark, it should be noted that expectation management, promising students insight into a company organisation, is a weak point. An alternative way to get a better insight

into the company organisations is to make site visits to an array of companies in a domain of the case studies addressed. It may help to offer engineering students a better perspective on a professional career in Engineering and offer more strategically relevant innovations.

We would like to finish with the general remark of two of our students which nicely summarises the learning curve the students have gone through.

"I found the JIP an enjoyable and very well organized experience. I could only wish that my master program was organized so well. Also, the JIP gave me more insight in how companies work, what their struggles are and how you as a student can still add value even though a company may be very well established with thousands of employees and years of successful operation"

"A great experience with amazing people!"

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BIOGRAPHICAL INFORMATION

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Birgit de Bruin is Managing strategic interdisciplinary engineering & educational projects, enhancing strategic liaisons between education and business and has been one of the initiators of the Joint Interdisciplinary Project. Other projects involve Business (context) development, interdisciplinary strategic projects for education, curriculum development, liaisons management, bridging the gap between young talent and their future professional environment in engineering.

Nanneke de Fouw is currently a senior researcher for 4TU-CEE at TU Delft. She holds a PhD in Medical Biology (University of Utrecht). She has more than 25 years' experience in leading and facilitating multidisciplinary teams at major multinational FMCG companies, in product innovation and learning. She holds certifications in Belbin, MBTI and Prince 2, and is a certified IAF facilitator. Her interests are in the development of young professionals in their interdisciplinary environment.

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Hans Hellendoorn is Director of Education and of the graduate school at the faculty of Mechanical, Maritime and Materials Engineering. The faculty counts over 4.700 student and 300 PhD. More than 20 years of industrial R&D and innovation experience gave him insight into the relevance of industrial involvement in the master education for future engineers. In 2018 he became Chair of the Cognitive Robotics Department
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DEVELOPING ENGINEERING GROWTH MINDSET THROUGH CDIO OUTREACH ACTIVITIES

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ABSTRACT

CDIO based learning is established around student-centred pedagogy where active learning method is incorporated, and project-based hands-on skill is fostered with academic facilitation. To support the development of the new School of Engineering, Technology and Design, the academic team of Canterbury Christ Church University has been promoting engineering courses through creative project-based activities at High Schools as a part of the university's outreach. These sessions were aimed to help students realizing how complex, industry-standard engineering product can be designed from a simple idea. At the beginning of each activity, students' response was usually very low as only a few students were genuinely interested in pursuing an engineering career. However, the confidence level of the students had been boosted through CDIO activities where they conceived an engineering problem, therefore designed and developed feasible engineering solutions of it. Feedback from students revealed a list of socio-economic barriers that were preventing students from considering engineering, such as; fear of mathematics; not having enough practical knowledge; hands-on skills. Students also perceived that they should be extra-ordinary or super-intelligent to pursue an engineering course. According to a recent UCAS survey, the number of students admitted to the graduate degree course (especially engineering) is decreasing. Even after enrolling into a graduate programme, the student retention ratio is very low, either they left the course or choose another career option. In this paper, we have identified the areas for improvement in the outreach activities to support the growth mindset of students, myth-busting who can be engineering professionals and develop student confidence in their ability to be a future engineer. Once they recognize their strength, they will be driven by their passion rather than pressure. This paper also highlights the advantage of utilizing CDIO activities in the outreach to change student's mindset, successfully promote engineering.

KEYWORDS

Outreach, CDIO, project-based learning, growth mindset, STEM

INTRODUCTION

This paper aims to show how the student's perspective can be changed following the CDIO activity at schools and colleges. Most of the universities in the UK take part in outreach activities for promoting career in STEM subjects (Millar, et al. (2019)). Canterbury Christ Church University has been working in collaboration with local schools and BTEC colleges in the south-east region of UK for nurturing future aspirants in engineering and medicine. So far, we had an opportunity to engage with seven high schools and one BTEC college. After delivering these outreach activities, we have identified the key issues that constrain student's mindset to pursue an engineering career. After a thorough analysis, we believe CDIO based activity is one of the best solutions to overcome these issues.

Before starting the CDIO session, a small survey was usually conducted among the students to know their mind-set about pursuing their career in engineering in future. It was quite surprising to see that most of the students were reluctant to see themselves as a future engineer. Out of those students, only 10% were interested because of their family history, either their ancestors were engineer or they were influenced by their family members or relatives. Only 5% of the students were genuinely interested to pursue engineering course. After further analysis of student feedback, there were several misconceptions about engineering courses. Most of the students thought engineering was difficult and strenuous to undertake, because it is all about mathematics, engineering courses required investment, time and hard work which may lead to failure. This could lead to students dropping out of their studies mid-way incurring financial debt, in turn, deprive them of having high-quality employment and life. Also, they used to consider engineering as one of the monotonous subjects which may hinder their personal and social life.

Our observations are consistent with Hochanadel & Finamore (2015) who reported that the most common underlying reasons why the majority of students were not confident enough to pursue engineering was their fear of mathematics, possibly because of their prior experience and mindset. Students were under impression that they need to be super intelligent to pursue an engineering career and they believed that intelligence is something come with birth and they cannot do much to change that.

All these socio-economic problems suppress the interest of engineering in most of the students. In the present scenario, the number of students admitting into degree course is reducing. Courses related to the STEM subjects are affecting the most, therefore the numbers of future engineers and technicians all around the UK is decreasing day by day. Following a recent UCAS survey (HESA, 2018), it was found out that the number of students admitted in a graduate degree course (especially engineering) is decreasing. One of the present statistics (Dusty Baxter-Wright, 2018) shows that even after enrolling into graduate programme, students leave the course in mid-way or chose another career.

Several researches have been trying to enhance the engineering pedagogy and learning experience, through project-based learning (Petersen & Nassaji, 2016), problem-based learning (Savery, 2006), CDIO (conceive-design-implement-operate) based approach (Ye & Lu, 2011), experimental learning (McDonald & Spence, 2015) and so on. In project-based learning, students are actively engaged in real-world projects during the course. At the end of the course, they can demonstrate their knowledge by giving a presentation. Students can develop critical thinking about the real-world problem, collaboration with fellow friends, team-work with a meaningful discussion and deliver an idea with proper implementation. In problem-based learning, students are focused to learn subjects through the experience of solving open-ended problems. This type of learning process encourages students to acquire new knowledge with group work and critical appraisal through literature retrieval. CDIO based learning is also one kind of project-based learning, where modules are developed around a CDIO based project. This type of project helps them to conceive an idea, design a solution to implement that idea and operate the solution to verify its working principle for further modification and improvement of the project. Experimental learning is another form of learning where students learn through the reflection of previous experience. It also promotes hands-on skills and supports the students process their learning each quadrant of Kolb's learning model (Konak, Clark, & Nasereddin, 2014). The main theme of all these learning approaches is based on student-centred pedagogy where project-based learning implementation.

Out of all these methods, CDIO was found to be quite helpful to motivate the students in outreach in terms encouraging them to pursue their career in STEM subjects because we believe it would combine the rest of the other methods under a single platform. CDIO is a four-stage engineering project framework. In the first stage, conceive helps students to develop new ideas to solve a problem assigned to them, do background research, come up with a feasible solution. In the next stage, students plan the design and develop the solutions. Students would fabricate or manufacture the design and implement the solution in the implementation stage. In the final stage, students will evaluate the challenges and issues of the developed solution and provide critical in-depth reflection for further improvement. Using CDIO based activity, students would be benefitted from every aspect of several learning approaches such as project-based learning, problem-based learning and experimental learning. For an example conceive and design stage of CDIO reflects the problem-based learning whereas implementation stage of a design idea shapes the project after several iterations- which is nothing but project-based learning, and experiment learning is all about operating it to identify the areas of improvement through future modifications.

METHOD OF OUTREACH ACTIVITY

The outreach activity was organised in four segments (). In the first segment, recent innovations in science, engineering and technology were shown to students, made them familiar with the real-world engineering problems and its probable solutions. Students are usually fascinated by these amazing innovations and ideas. In the next segment, few PowerPoint slides were presented consisting of some industrial standard products followed by a couple of hobby projects, sharing the similar engineering concept.

In the next segment, the fundamental conceptual link between those complex engineering products and hobby projects was explained among the students, also described how those hobby projects can be transformed into complex, industry-standard and commercialized products with appropriate technical expertise and hands-on skill. In the third segment, few CDIO activities were carried out to enhance their interest level through active participation in designing and developing a project. For example, a simple project that needs to be designed by students within a time limit or they need to program line tracking LEGO robots. This type of project helps them to conceive an idea, design a solution to implement that idea and operate the solution to verify its working principle. In the last segment, feedbacks from students and teachers were collected to evaluate the potential of the CDIO activity and recommendations were taken on board for making it more effective.

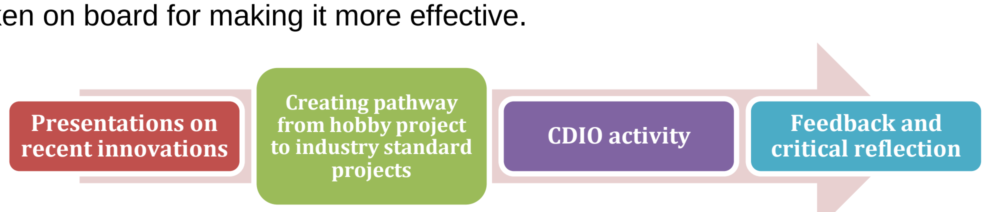


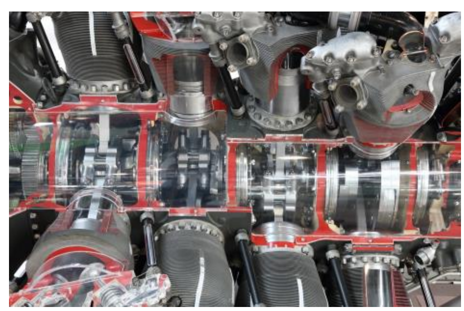
Figure 8. Four segments of outreach activity

Presentation on Recent Innovations

This segment was aimed to show students the conventional as well as the cutting-edge research projects in engineering and technology all around the world. Sometimes, students are unaware of current innovations, therefore this approach would make them familiar with those innovative projects and increase their interest level in STEM subjects. Also, it showed the transition of the scientific world from earlier days to the modern era where students can contribute and become a part of it. Those projects were divided into two categories (Figure 9); one is the conventional industry set-up that has been running for the last two decades and other is the emerging cutting-edge technology that has been implemented to solve specific problems. First two examples were conventional car manufacturing industry and four-stroke engine. In-car manufacturing industry, conventional serial robots perform most of the functions and the four-stroke engine is a conventional engineering product, one of the finest examples of mechanism and design.

Next two examples fall into the category of cutting-edge research such as exoskeleton and drone-based car. Exoskeleton or wearable skeleton is normally people-oriented robots designed to be worn for training and assistance. These robots are designed based on the function and shape of the human body so that users can control intuitively. Exoskeletons can assist in walking, running, jumping or even lifting objects one would normally not be able to. Drone is one of the most trending topics in the current scenario, there are several applications of it; staring from medical purpose to use it as an aerial ambulance or to transfer medical equipment like blood quickly. It could be used as public transport to avoid heavy traffic. Also, there is plenty of applications for surveillance and military operation in the defence sector.

a. Car manufacturing industry



b. Four/stroke engine

c. exoskeleton

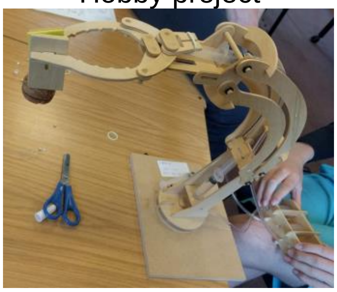
d. Drone based car (Fildes & Yang, 2019)

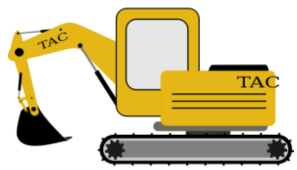
Figure 9. Innovative products (conventional and cutting-edge technology) (all the pictures are licenced for reuse)

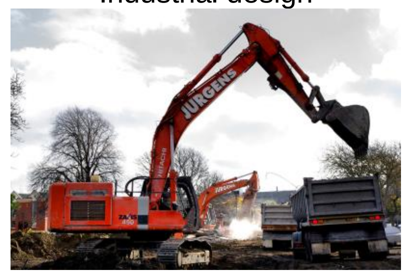
Creating the Pathway from a Hobby Project to Industry-Standard Project

This segment is the most important and was designed to enhance the confidence level of students. We have chosen three different types of projects for the students.

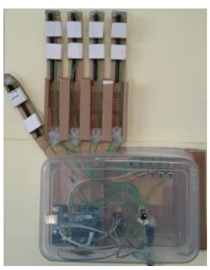
Hobby project Simplified design Industrial design

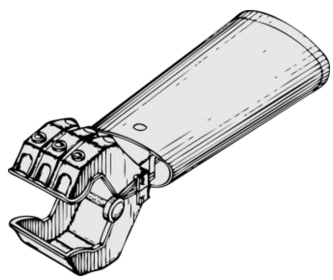




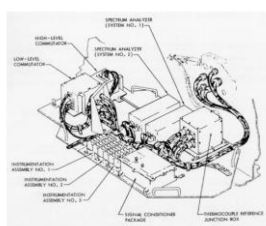


Hydraulic digger project





Bionic hand project



LEGO-based unmanned vehicle project

In each project, the left-most picture shows a basic hobby project which is comparatively easy to design for school students. The middle picture shows the engineering concept behind all those projects. The right-most picture shows the advanced commercial products which share similar engineering principle with the hobby one. In the first project, a hydraulic digger made from plywood was shown to students, which is the basic design of an industrial digger. Therefore, students will be familiar with the conceptual design framework of an industrial digger. The next project was about a paper-based artificial robotic hand which is a simplified version of a bionic hand and the third project showed a LEGO robot which could be transformed into an unmanned ground vehicle. In all cases, the basic designs were shown to students in the beginning. After that, the advanced designs were displayed along with the engineering principle to make them realised the link between those basic and advanced designs. This whole segment would create a pathway that guides students to reach from a basic idea to an advanced design model.

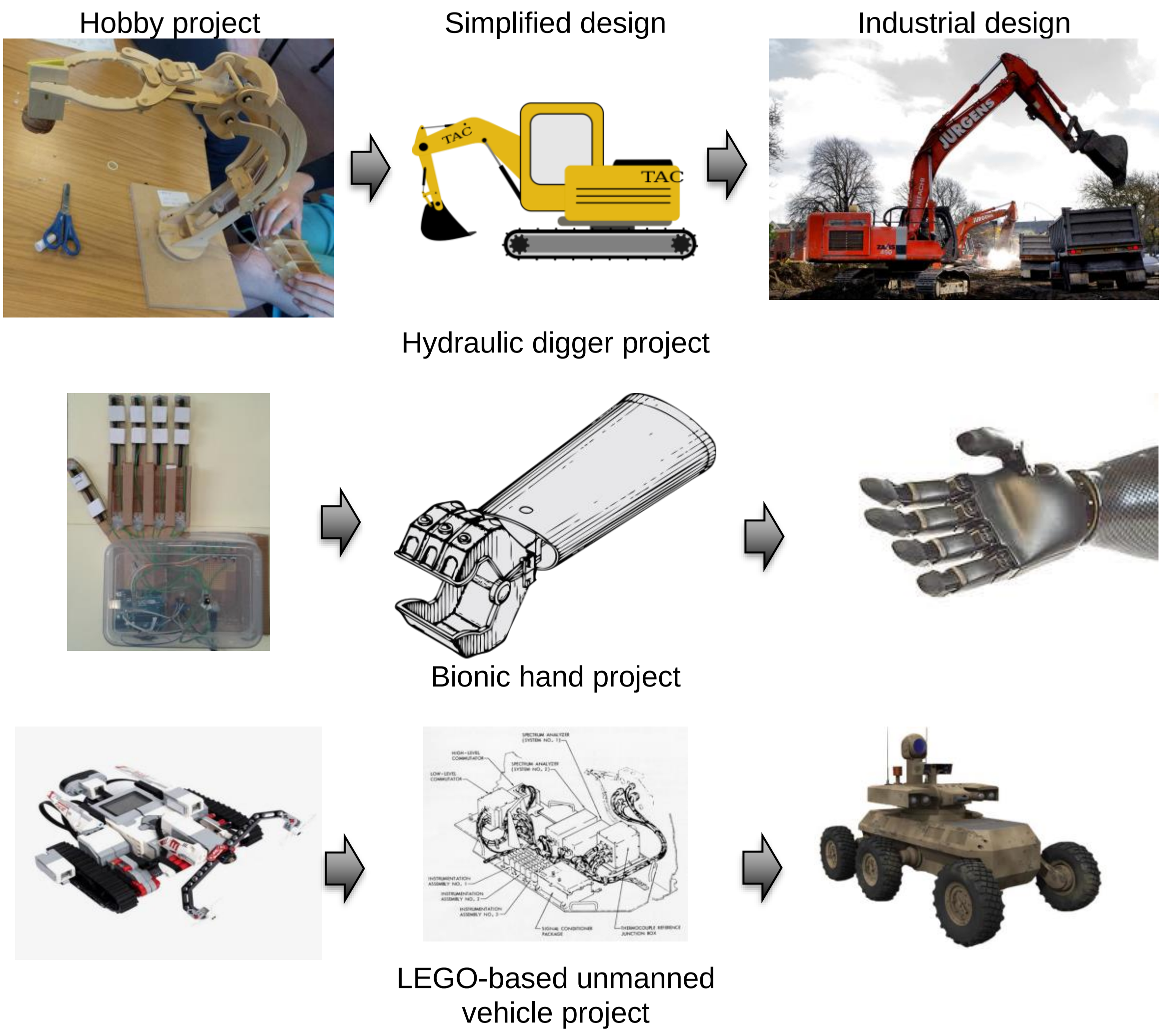


Figure 10. The pathway from hobby to industry-standard project (all the pictures are licenced for reuse otherwise taken from CDIO sessions run by CCCU)

CDIO Activity

Following the previous segments, three CDIO projects were configured (Figure 4) where several technical and professional skills (Table 1) were nurtured among the students. The first project was the design and development of a hydraulic digger where students were supposed to construct it from hard plywood and screws. For implementing hydraulic actuation system, small syringe had been used with water. This project was designed to show the basics of hydraulic actuation and holding mechanism in the simplest way; therefore, students can easily conceptualise its underpinning engineering ideas.

The other project was making of an artificial robotic hand from generic items such as hard paper, paper straw and cotton string. The project was given to students to put them in a real-life scenario, for example, if they need to make an artificial hand for amputees, what would be their approach? how they would design it so that the functionality of artificial hand will be the same as a real human hand? Students worked in a team to complete the task. The Lego Mindstorms robot was also included as a CDIO activity. Since those robots are easy to construct and program, those activities are suitable for school students. Students were supposed to program it in a way so that it would follow a certain track avoiding all obstacles. This project was interesting for students because they need to calculate the speed, power, rotation, direction angle to decide the trajectory of LEGO robots.

Hydraulic digger   Articicl robotic hand   LEGO Mindstorm robots

Figure 11. CDIO activities
(all the pictures are taken from CDIO sessions run by CCCU)

Table 1. Three CDIO activities

Type of activity	**Description**	**Technical skill involved**	**Professional skill involved**
Artificial robotic hand	Introduction to the design and development of an artificial robotic hand. This workshop will provide a great opportunity for students to learn about different engineering aspects such as mechanical design, actuation system and controlling circuit.	Mechanical design, analytical skill, actuation system, electronics	Teamwork, time management, collaborative work, critical reflection
Lego Mindstorm robot	To improve critical thinking, problem-solving and collaboration skills, an engaging and inspiring STEM activity is designed based on Lego Robotics technology. Students will be introduced to the programming concept and path planning skills of the robots. In the end, Students will work in a team and they will be provided with the Robots, iPads and short training to complete a Robotic race.	LEGO robots, basics of programming, simple mathematics, computer apps	Teamwork, time management, collaborative work, critical reflection
Hydraulic digger	Introduction to the design and development of a hydraulic digger. Students also will gain knowledge of 3D modelling using CAD software. In the end, they will get the opportunity to build their hydraulic arm using the provided hydraulic kit.	Mechanical design, CAD design, mechanism, hydraulic actuation	Teamwork, time management, collaborative work, critical reflection

All these CDIO workshops provided a great opportunity for students to learn about different engineering aspects such as mechanical design, actuation system and controlling circuit for obtaining a technical solution to a genuine engineering problem. They were also able to analyse the core engineering principle behind the project and their hands-on skill was enhanced through the engaging activity. Also, they got the opportunity to understand the advantage of teamwork because an ultimate engineering product requires multidisciplinary engineering knowledge starting from electronics, mechanical, computing, electrical and design. Students can develop their engineering competency through producing and implementing innovative and creative ideas.

These outreach activities were usually organised in career fair weeks where students came to know more about engineering, its curriculum and future aspects. Table 2 gives the statistics of the total students who participated in these outreach activities.

Most of the students were from year 12 as they were on the verge of choosing their career. Whereas, we also had students from year 7, 8, 9 and 13. From the statistics shown in Table 2, it was very inspiring to see the female to male ratio, it showed that a significant number of girls students participated in those outreach activities which proves that girls are equally interested in pursuing an engineering career.

A typical outreach activity was carried out on average from 50 mins to 1.5 hours depends on the type of activity, year group of students and number of students. Out of the total time spent, CDIO activity was typically carried out on average from 40 mins to 1 hour.

Table 2. Statistics of outreach activities run by us from May 2019 to December 2019

Date	**School name**	**No of students**	**Female: Male ratio**	**Year**	**Total time for outreach**	**CDIO activity Time**
03/05/19	Skinner Academy	26	11:1	12	1:5 hours	1 hour
18/06/19	Folkestone School for Girls	15	All girls	7 & 8	1.2 hours	1 hour
18/06/19	Ursuline College	15	All girls	7	1.2 hours	1 hour
18/06/19	Spires Academy	15	13:2	9	1.2 hours	1 hour
16/07/19	Dover Grammar School for Girls	14	All girls	8	50 mins	40 mins
		74	All girls	9	50 mins	40 mins
		62	8:3	12	50 mins	40 mins
19/07/19	Sandwich Technology School	10	All boys	12	1 hour	45 mins
04/11/19	Leigh UTC College	35	2:3	12	1 hour	45 mins
		35	2:3	13	1 hour	45 mins

Feedback and Critical Reflections

To enhance the involvement level of students and to know their present career perceptions, few questions were raised such as what they know about engineering, how many of them would like to pursue engineering as a career? Few questions are listed below in Figure 12. The advantages and constraints of pursuing engineering and technology as a career were also explained to them so that they would be clear about their choice. Few technical questions were also asked to students to see their confidence level in dealing with an engineering project. In the end, several enquires were raised from students as well as teacher, few of those queries were listed in Figure 12. Most of the queries from students were all about engineering and its prospects whereas teachers mainly asked about the infrastructure and facilities available in the School of Engineering, Technology and Design at CCCU.

Questions asked by instructor from CCCU
What do you like to be in future or what type of career you want to choose in future and why?
What do you think about engineering?
How many of you are interested to pursue engineering as a career?
How many of you are confident enough to make this type of project? (pre and post CDIO activity)

Questions asked by students and teachers
How math is involved in engineering?
What are the career options available after pursuing engineering?
What are the facilities available at CCCU?
And, several questions about the School of Engineering at Canterbury Christ church university

Figure 12. Questions raised during outreach activities

We realised that students always want to see some innovative engineering projects instead of complex mathematical equations and calculation. Due to our prior experience, most of the sessions had been planned on hands-on skill where students were supposed to do some activity by developing some projects. Feedbacks were taken from students after each segment to understand their mindset.

For instance, after showing those recent innovations, we wanted to see the attitude of students towards solving a problem, so we inquired how many of them were confident to make those kinds of product if they get an opportunity provided with enough resources and technical expertise, only 25% of the interested students showed a positive response. Their opinions about engineering were taken into consideration and appreciated positively. However, the student's response has been increased drastically (up to 75%) after executing these CDIO projects. It was found that the engagement ratio of students in outreach was also increased by 91% after doing the CDIO activities (Figure 13). Also, the number of raised questions from students was increased by 64% post activity, as shown in Figure 13. At the end of the session, a greater number of students became interested to pursue an engineering career.

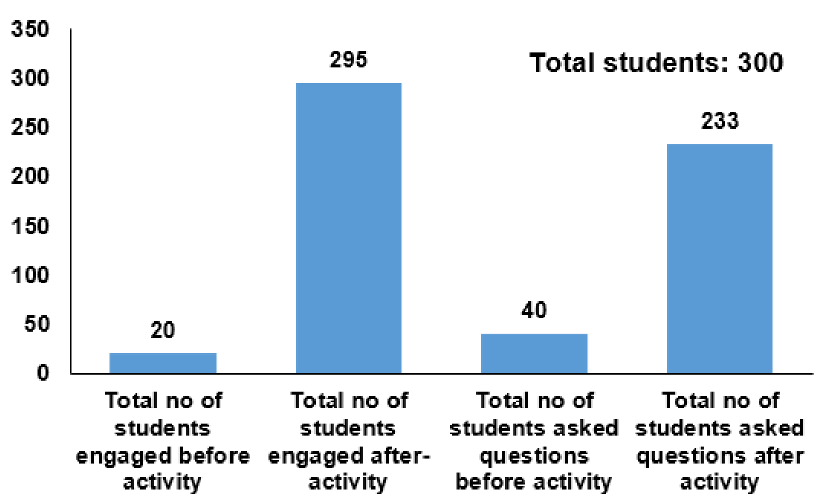


Figure 13. Engagement of students in pre and post CDIO activity

Few positive feedbacks from coordinators of those schools are listed below as an example to showcase the efficacy of implementing CDIO activity in outreach. The feedback has been anonymised to ensure the anonymity of the students and good ethical research practice.

Example 1

"*Thank you from xxx Grammar School*
Teacher A
XX/XX/2019

Can I just say a huge "Thank you" to you for your wonderful support of our students at our recent and inaugural XXX Careers Fair.

The feedback we have had from students has been universally positive and I hope that you also enjoyed interacting with our young people. Such events only work when people such as you give so generously of your valuable time and we are hugely appreciative of the efforts you have gone to on our behalf…."

Example 2

"*Thank you from xxx Tech School*
Teacher B
XX/XX/2019

I just wanted to send a thank you for coming in to speak with our students. These opportunities are always valuable and so insightful for our Year 12 students as they enter year 13 and consider their next options. I have received great feedback from the students…"

Example 3

"*Thank you from xxx College*
Teacher C
XX/XX/2020

Just wanted to take this opportunity to thank you for an amazing day. The year 12 and 13 students were captivated by your workshop today. All the teachers that attended gave me glowing reviews of your sessions and the students walked out of the lecture theatre motivated and inspired…."

CONCLUSION

"Student should be encouraged to think, to doubt, to communicate, to question, to learn from their mistakes, and most importantly have fun in their learning" (Richard Feynman)
Following these outreach activities, it has been proved that implementing CDIO activities in outreach could potentially change a student's mindset towards engineering courses. We have received several positive feedbacks from students as well as teacher about these CDIO activities. Responses from students demonstrate that their confidence level was enhanced and their attitude towards solving a technical problem has been changed. All those activities aimed to make them realised that studying engineering is all about to conceive those innovative ideas blending with subject knowledge to achieve the proficiency level. These CDIO activities influenced most of the students and engaged them in the engineering theme. The strategy consisting of four segments starting from introducing innovative engineering project to

designing the project could be a game-changer for bringing back students to the STEM subjects. The experiences gained through these CDIO activities can even improve the learning strategy and could be implemented in the engineering curriculum.

Engineering subjects are typically underpinned by their prior concept of physics and mathematics where students might struggle. However, students should have a chance to cultivate their hands-on skill as well, which would help them to have a better understanding of STEM subjects. The learning environment should be enhanced to change the mindset of students to boost their confidence and motivate them to undertake engineering career.

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